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Oncoplastic Surgery

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Plastic and Reconstructive Surgery

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Foreword I

Jointly started and organized by Prof. Wang Wei from the Ninth People's Hospital affiliated to Shanghai Jiaotong University School of Medicine and the Zhejiang Science and Technology Press, *Encyclopedia of Plastic and Cosmetic Surgery*, with its huge capacity of more than 20 volumes, covers the latest developments in the plastic and cosmetic surgery and the reparative and reconstructive surgery in the twenty-first century in China and the world. This is a monumental project both in the medical field and the publishing world. Professors such as Wang Wei and Zhang Zhiyuan serve as general editors in chief of the *Encyclopedia*, of which Profs. Zhou Xiao et al. serve as the editors in chief of *Oncoplastic Surgery*, one of the first series of the *Encyclopedia.*

The oncoplastic surgery is a branch of the oncology surgery—it is a cross edge discipline which involves multidiscipline; combines the theories, technologies, and methods of oncology surgery, plastic surgery, and microsurgery; and is characterized by planned radical tumor resection plus one-stage reconstruction. The treatment scope mainly covers the repair and reconstruction of defects in skin, mucous membrane, muscle, nerve, bone, and some organs; the surgical methods include the use of autologous, allograft, and xenograft tissues or synthetic biomaterials to repair the tissue and organ defects or deformities. We can say that this is a very young discipline with a promising future, only 10 years ago, and its related concepts and basic theories were presented and described in the *China Cancer* by Zhou Xiao, Hu Bingjiang, and Luo Yi. Before the publication of *Oncoplastic Surgery* edited primarily by Prof. Zhou Xiao et al., the relevant system theories and books on oncoplastic surgery in foreign data were also rarely reported.

One of the editors in chief, Prof. Zhou Xiao is a well-known expert in oncoplastic surgery in China. Under his organization, this book is jointly contributed by famous experts in the fields of plastic surgery, oncology surgery, radiotherapy, and chemotherapy. The book systematically introduces the basic concepts, basic theories, and clinical practices of oncoplastic surgery for the first time at home and abroad. Many important theories which are put forward for the first time reflect the latest progress of oncoplastic surgery. It is not only an essential tool for tumor surgeons but also is an important reference book for clinical medical professionals from departments of plastic surgery, microsurgery, ENT, head and neck surgery, oral and maxillofacial surgery, breast surgery, thoracic surgery, urinary surgery, and gynecologic oncology. We can say that the publication of this book not only fills the gaps in the field of oncoplastic surgery at home and abroad but also initiates the rapid development of a new branch of surgery and effectively develops the academic thoughts of relevant disciplines and surgeons to help improve the abilities to analyze and solve the clinical practical problems.

Therefore, my colleagues and I sincerely congratulate the publication of *Oncoplastic Surgery*.

Hence, I am delighted to write the foreword.
Academician of the Chinese Academy of Engineering
Chairman of Traumatology Branch of Chinese Medical Association
Dean of the College of Life Science of Chinese PLA General Hospital

Changsha, China
October 15, 2012

Fu Xiaobing

Foreword II

Oncoplastic Surgery primarily edited by Profs. Zhou Xiao, Cao Yilin, and Hu Bingqiang is now officially published. Before its publication, the book was written, edited, and revised repeatedly by dozens of well-known experts and professors from many famous medical colleges and universities across the country for several years. As one of the most special volumes among more than 20 volumes of *Encyclopedia of Plastic and Cosmetic Surgery*, it fills gaps in this field which lacked published books.

An important means of tumor treatment is surgical resection, and after tumor resection, the repair and reconstruction of organ and tissue defects are necessary for tumor treatment planning. In the tumor treatment, because the local area after tumor resection often can't be repaired and reconstructed, or the vital organs cannot be covered and protected, the patients would give up the surgical treatment, and thus many tumor patients have lost access to treatment. The application of repair and reconstruction techniques for tissue and organ defects provides more opportunities for the surgical treatment of cancer patients, and the repair and aesthetic reconstruction after removal of organ on body surface make survival and the quality of life of patients significantly improved; this is the basis for the birth of the academic monograph *Oncoplastic Surgery* in China. Since 1975, I have been cooperating with professors in institutions like Shanghai Tumor Hospital to explore the treatment methods of oncoplastic surgery in oncology surgery. In this field, Qiu Weiliu, Wang Hongshi, Zhang Disheng, Guo Entan, and Zhuang Fulian et al. have also reported their experiences.

Hunan Cancer Hospital (the Cancer Hospital affiliated to Xiangya School of Medicine of Central South University) is class A special cancer hospital; it covers an area of 27 acres and is equipped with 1300 beds. There are a total of 1613 medical professionals in the hospital, including 343 with senior titles. It is a hospital merging medical treatment, scientific research, prevention, teaching, and rehabilitation into a single whole. Twenty years ago, Doctor Zhou Xiao in the head and neck cancer surgery studied and practiced in the Department of Plastic Surgery of Shanghai Ninth People's Hospital. After Zhou Xiao returned to the Hunan Cancer Hospital, he was committed to research in repair and reconstruction of tissue and organ defects after surgical resection of tumors. Many years ago, I had the honor to participate in the achievements appraisal for his research on theories and series of clinical studies of the oncoplastic surgery. On the above basis, he made preparations to edit the book *Oncoplastic Surgery*, and it can be described as 20 years devoted to a scalpel. The book is now finally going to meet with readers, and I believe that its publication will not only fill gaps in literature of this field but also help expand and accelerate research and development of oncoplastic surgery and bring benefits to the vast number of cancer patients.

The manuscripts of *Oncoplastic Surgery* have been repeatedly reviewed by experts and professors like Zhou Xiao and Cao Yilin for several years, and I have also participated in the review of the whole book, but due to time constraints for publication, errors and lopsided views are inevitable, and the readers are expected to render criticism and correction for future revision and republication.

Hearty congratulations on the publication of *Oncoplastic Surgery*
The Ninth People's Hospital affiliated to Shanghai Jiaotong University School of Medicine

Beijing, China
October 16, 2012

Brief Introduction for Editors in Chief of *Oncoplastic Surgery*

From left: Zhou Xiao, Wang Wei, Cao Yilin and Hu Bingqiang

Zhou Xiao

He is a chief surgeon and expert with State Council Special Stipend, with certificate in plastic and cosmetic surgery; he graduated from Hunan Medical College (now renamed Xiangya School of Medicine of Central South University) in 1985. Now he is vice-president of Hunan Cancer Hospital (the Cancer Hospital affiliated to Xiangya School of Medicine of Central South University), director of the Hunan branch of National Tissue Engineering Research Center of China, and director of the research institute of oncoplastic surgery. Acting as the leader of the oncoplastic surgery group of the Plastic Surgery Branch Association of Chinese Medical Association, he is a member of the standing committee of Professional Committee of Reparative and Reconstructive Surgery of Chinese Association of Rehabilitation Medicine, a member of the standing committee of Professional Committee of Head and Neck

Surgery of Chinese Anti-Cancer Association, chairman of Hunan Tumor Professional Committee of Chinese Medical Association, a member of Hunan Vascular Surgery Professional Committee of Chinese Medical Association, and a member of Hunan Otolaryngology and Head and Neck Surgery Professional Committee of Chinese Medical Association; he is the editorial board of *Journal of Tissue Engineering and Reconstructive Surgery and Chinese Journal of Otorhinolaryngology-Skull Base Surgery.* He has published more than 50 papers and has hosted and participated in more than ten research projects. His research project "Theoretical and Clinical Series on Plastic Surgery" won the second prize of Hunan Science and Technology Progress Award in 2010. He won the Ninth "Chinese Medical Doctor Award."

Cao Yilin

He is a chief surgeon, professor, doctoral supervisor, and national model worker. Now he is vice-president of the Ninth People's Hospital affiliated to Shanghai Jiaotong University School of Medicine, director of Shanghai Institute of Plastic and Reconstructive Surgery Research, director of National Tissue Engineering Research Center of China, director of Shanghai Key Laboratory of Tissue Engineering, specially appointed professor in "Chang Jiang Scholars Program," and a two-term chief scientist of the National "973″ project. He serves as the chairman of the International Institute of Tissue Engineering and Regenerative Medicine in the Asia-Pacific region, council member of International Confederation for Plastic Reconstructive and Aesthetic Surgery, vice chairman of Chinese Committee for Biomaterials, council member of Chinese Medical Association, chairman of the Sixth Committee of Plastic Surgery Branch of Chinese Medical Association, chairman of committee of Tissue Engineering Branch of Chinese Society of Biomedical Engineering, deputy editor in chief in journals such as *Tissue Engineering* and *Biomaterials*, editorial board member in eight SCI journals such as *Plastic and Reconstructive Surgery*, editor in chief in journals such as *Chinese Journal of Plastic Surgery* and *Journal of Tissue Engineering and Reconstructive Surgery,* and the editorial board for more than 10 first-class national journals (i.e., *Chinese Journal of Surgery*).

Wang Wei, born in 1937, is tenured professor of Plastic Surgery Department of the Ninth People's Hospital affiliated to Shanghai Jiaotong University School of Medicine and a member of international editorial board of *Plastic and Reconstructive Surgery*. He has a number of inventions and innovations in the fields of skin flap transplantation, vascular anastomosis, thumb reconstruction, esophageal reconstruction, late facial paralysis, hand deformity, abdominoplasty, breast reduction, facial contouring surgery, rejuvenation and blepharoplasty. Having published more than 300 papers and edited or participated in editing more than 70 books, he has won more than 20 National Invention Awards.

Editorial Board of *Oncoplastic Surgery*

Preface

Oncoplastic Surgery is finally published as scheduled.

As the editor in chief, I feel extremely gratified with the publication of this the book, and at the same time, I would like to express my sincere thanks to all the experts who have participated in writing and editing of this book, and I need to thank many professors, especially Wang Wei, Cao Yilin, Qi Zuoliang, Guo Shuzhong, Qiu Shulin, and Gao Jingheng for their energetic support and help.

The oncoplastic surgery is a product resulted from the integration of oncology surgery and plastic surgery. Twenty years ago, as a younger doctor in the department of otolaryngology-head and neck surgery, I packed up and embarked on a train to Shanghai. From that moment on, I was destined to be closely linked with this new discipline. In Shanghai Ninth People's Hospital, a large number of difficult cancer operations were performed at that time by surgeons in the departments of plastic surgery and oral and maxillofacial surgery, which not only greatly widened my horizon but also made me think about such a question: if the difficult radical tumor surgery was combined with the superb repair techniques of plastic surgery, what benefits would it bring to the majority of cancer patients? Thereafter, I started to hold a firm belief in my mind that the cancer surgeons have the responsibility to eradicate the tumors and also have obligations to help the patients have a healthy and decent life. After returning to Hunan, I actively studied theories of plastic surgery and was open-minded in learning from the plastic surgery experts like Wang Wei and Cao Yilin. My colleagues and I carried out basic and clinical researches on oncoplastic surgery and combined a large number of techniques in plastic surgery with the techniques in oncology surgery, making the treatment level of the surgical oncology department in our hospital unprecedentedly increased and the quality of life and the survival of the majority of patients greatly improved. At the same time, a group of surgeons with superb techniques in oncoplastic surgery and research capabilities have emerged in our hospital. In 2001, my colleagues and I published an article entitled "An Initial Understanding on the Necessity of Forming Oncoplastic Surgery" in the journal *China Cancer* and formally proposed the concept of "oncoplastic surgery." In 2003, I wrote theoretical articles about oncoplastic surgery independently (see related contents in Chapter XVIII of *Practical Diagnosis and Therapy of Tumors*; Hunan Science and Technology Press, 2004). In the same year, the first research laboratory of oncoplastic surgery in China was established in Hunan Cancer Hospital, where the department of oncoplastic surgery was officially established in 2007. Meanwhile, the first, second, and third sessions of national continuing education classes on oncoplastic surgery were held in our hospital in 2004, 2005, and 2012, respectively. The Oncoplastic Surgery Group of the Plastic Surgery Branch Association of Chinese Medical Association was founded in Xi'an on October 12, 2012. The smooth development of the abovementioned work has been completed with the great help and support of colleagues in the hospital and in the country. Therefore, upon publication of this book, I would like to send heartfelt thanks to every expert and colleague.

The whole book consists of 23 chapters, with more than 0.8 million words and nearly 1000 pictures, covering the surgical contents related to oncoplastic surgery in clinical disciplines such as oncology surgery, plastic surgery, microsurgery, vascular surgery, otolaryngology-head and neck surgery, neurosurgery, oral and maxillofacial surgery, breast surgery, urinary

surgery, gynecologic oncology, bone surgery, thoracic surgery, and abdominal surgery, of which the oncology surgery is combined with the plastic surgery in most of the surgical cases, and the book systematically summarizes the basic theories and clinical experiences in oncoplastic surgery. In the process of writing this book, the contributors and I read numerous related books and literatures, thereby laid the theoretical framework of the book, and creatively constructed an academic system of oncoplastic surgery. We can say that the book, on the basis of extensively absorbing and summarizing clinical experiences in multidisciplines, presents a systematic summary and exploration of scientific theories and clinical experiences in oncoplastic surgery.

Today, upon publication of *Oncoplastic Surgery*, once again, I want to thank the experts who have instructed and guided me for many years, including Prof. Wang Wei and Cao Yilin from the Ninth People's Hospital affiliated to Shanghai Jiaotong University School of Medicine. Special thanks to academician Fu Xiaobing for his support and help in the establishment of oncoplastic surgery, and special thanks to Zhejiang Science and Technology Press for hard work related to the publication of this book, and I would like to express my deepest gratitude to all counterparts who contribute to the writing and editing of this book.

The publication of this book is intended to break ice in the development of oncoplastic surgery. Due to the past lack of professional teams and systematic research platforms for the theories of oncoplastic surgery, coupled with the absence of some new progresses in this field at home and abroad because of time limitation, I deeply believe that the contents of this book demonstrate only a limited view on oncoplastic surgery, and I hope that my counterparts feel free to criticize and correct omissions, shortcomings, and mistakes in this book; as some chapter contents of this book are less mature in depth and breadth, our counterparts are welcome to provide us with your precious research data for the revision of this book. Please send letters to cccdon@163.com.

Changsha, Hunan Zhou Xiao

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1 Overview of Oncoplastic Surgery

Xiao Zhou, Wei Wang, and Yue Zhou

Oncoplastic surgery is an interdisciplinary branch of oncological surgery that integrates theories and technologies in oncological surgery, plastic surgery, and microsurgery with characteristics of planned radical resection of tumors and one-stage repair and reconstruction of surgical defects on the basis of multidisciplinary treatment (MDT) of tumors [1]. As an emerging discipline, the development history of oncoplastic surgery has witnessed the progress of the plastic surgery and has experienced a combination of oncology surgery and plastic surgery, including the development and application of technologies such as microsurgery. To review the historical background for birth of this discipline, we believe that it should be traced back to the beginning of the formation and development of plastic surgery.

The plastic surgery is a branch discipline of modern surgery, and it mainly studies and treats the deformities or defects of some tissues and organs on the surface of the human body and within the human body so as to achieve the purpose of restoring their physiological functions and external morphologies. As an independent discipline of surgical specialty, the plastic surgery has a short history. In 1914, World War I led to the appearance of numerous patients with maxillofacial organ defects and limb defects, and a large number of medical staff accumulated a wealth of experience in the repair and reconstruction in the treatment of these patients, and thus, their technical levels were improved; a considerable amount of monographs on plastic surgery techniques were published in succession; thereby, the plastic surgery specialty was formed, of which, the application of free skin graft and the determination of the concept of tissue transplantation are recognized as signs of the birth of plastic surgery. On the track of development of the plastic surgery, the occurrence of a series of new technologies and new ideas played a huge role in promoting the development of this discipline [2]. In the 1960s, the microsurgical techniques were used in clinics, and then they developed rapidly and greatly contributed to the advancement of plastic surgery techniques; the complicated surgeries such as craniotomy, moving the eye socket frame and rearranging the craniofacial bone structure, and bone graft fixation had been performed in the craniofacial surgery to correct and reshape many types of severe craniofacial deformities and provide patients with an opportunity to transform the head and face and reconstruct the countenance. Skin expansion techniques were used in multiple sites on the whole body since the 1960s, which increased the flap areas and also expanded the areas of tissue defects to repair at the same time. The emergence and development of tissue engineering in the 1990s made it possible to cultivate some tissues and organs of the human body in vitro, which changed the traditional concept and pattern of trauma repair and organ reconstruction in plastic surgery [3]. The gene therapy, transplantation immunity, and computer technology had also entered the field of plastic surgery in different degrees, which promoted the

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development of plastic surgery, and made it a discipline with distinctive characteristics.

Currently, the malignant tumor has become the important cause of human death, and about 7 million people die of malignant tumors all over the world every year; the malignant tumor has become the second highest cause of death in China. The oncoplastic surgery is a product of mutual integration of oncology surgery and plastic surgery. The oncology surgery is to resect the tumor with surgical method. The surgery is still the preferred method of treatment for most of the early and earlier stage solid tumors [4]. The development of plastic surgery has laid the foundations for the birth of the oncoplastic surgery; the disfigurement, tissue and organ defects after the radical surgery in oncology surgery, and the cancer patients' desires for complete sound functions have provided the basis for the birth of the oncoplastic surgery. With the development of the tumor treatment concept, at the same time of achieving prolonged survival and even getting cured, the cancer patients also want to have intact physical forms and sound functions, so that they can adopt a positive attitude to participate in social production and social activities. Because the malignant tumors have the biological characteristics of unlimited growth and multiple metastases, the surgical method for lesion resection is still an important part of a comprehensive treatment model, which can create favorable conditions for improvement of the patient's own immune system and the body rehabilitation to achieve the purpose of improving the cure rate and prolonging survival. Common principles for radical resection of malignant tumors originated from the classic radical mastectomy invented by Halsted in 1894, which mainly include: (1) The tumor tissues are incised and exposed during surgery; (2) the en bloc resection of the original cancer and the affiliated regional lymph nodes are performed. Since the 1960s, the operators began to emphasize the intraoperative tumor-free technology with the purpose to prevent recurrence. At the moment, there was a trend that the oncology surgery was gradually distinguished from general surgery and became an independent discipline. With the rapid development of related disciplines, the oncology surgery has developed from just purely focusing on surgery into a specialty with strong technicality [5, 6]. However, the patients often have large and deep wounds after radical resection of tumors and even have concomitant exposures of blood vessels, nerves, and tendons. The radiation therapy and drug chemotherapy in the process of tumor treatment will have a negative impact on the healing of the abovementioned wounds; thus, the wound repairs for such patients are often more difficult, especially for patients with tumors in sites such as the oromaxillofacial region, chest wall, breast, and perineum where there is a higher demand for the appearance and function. It is difficult to repair this kind of wound using the general surgical method; therefore, we must learn from the plastic surgery technology to make the appearance and functions of the defect sites achieve more satisfactory recovery. The functional recovery is of great significance for reducing or eliminating the psychological burden of patients, enhancing the patient's self-confidence and improving the patient's quality of life at the same time, and it has created favorable conditions for other treatments such as postoperative radiotherapy and chemotherapy. In this context, the combination of oncology surgery and plastic surgery has become an inevitable trend of the medical development and has a broad development prospect.

In foreign countries, the combination of oncology surgery and plastic surgery can be traced back to the early nineteenth century. Dieffenbach et al. in German reshaped the patient's cheek and nose using local tissue transplantation after the removal of head and neck malignant tumor. Iginio Tansini in Italy firstly used the latissimus dorsi musculocutaneous flap to repair skin defects. In 1955, Owens used the myocutaneous flap transfer to repair the facial damage after head and neck tumor surgery [7]. Since the twentieth century, the oncology surgeons have increasingly recognized that the plastic and reconstructive surgery plays an important role in tumor resection surgery; thus, they have carried out various forms of exploration continuously. McGregor firstly used the skin flap to carry out one-stage repair of soft tissue defects after oral cancer surgery in 1963. In 1964, some scholars and medical workers believed that one-stage repair was not only necessary for tumor patients but also feasible for trauma patients, and it was listed as the preferred treatment of oral and maxillofacial defects. In 1965, Bakamjian extracted the skin flap (i.e., pedicled pectoralis major myocutaneous flap) from the front chest area to repair the defects of the oral and maxillofacial region. Thereafter, the pedicled pectoralis major myocutaneous flap became a commonly used flap in defect repair after oral and maxillofacial tumor resection. In 1977, Bakamjian and Littlewood reported that the pedicled skin flap from the cervical region was applied to repair the soft tissue defects after oral and maxillofacial tumor resection. In 1996, McGregor and Reid et al. reported that the skin flap was used to immediately repair the cheek defect after resection of squamous cell cancer. In the 1970s, the transplant techniques of the musculocutaneous flaps and the microvascularized tissue flaps gradually matured and developed and became the mainstream of defect repair after tumor resection. The massive clinical practices prove that the plastic surgery, oncology surgery, and other related disciplines are closely integrated and cooperated with each other, which have great significance for the comprehensive treatment of tumors [8–10].

In China, the plastic surgery and the surgical oncology started relatively late, and the use of skin flap for repair of partial tissue defects began in the 1970s. In 1973, Yang Dongyue firstly repaired the defect after cheek tumor resection with groin flaps using vascular anastomosis. More

reasons exist for the relatively slow development of the oncoplastic surgery, of which the limitation of the technology is a more important influence factor. Before the 1970s, it was required to perform a pedicled flap procedure for all skin flap transplantations in plastic surgery, which required carrying out multiple pedicled flap transplantations and fixing the limb for a certain time; thus, the patient would be hospitalized for a long time and have more pains. The traditional transfer method limited the operation scheme design for one-stage repair and reconstruction after radical resection of many tumors. For a long time, awed by the consequences of the cancers, the cancer patients actively sought the removal of cancerous lesions in the department of surgical oncology at first, and then they would be hospitalized again into the department of plastic surgery for actively seeking repair and reconstruction of the deformities after tumor resection. Due to the lack of communication between cancer surgeons and plastic surgeons, the treatment mode that the cancer radical surgery and the reparative and reconstructive surgery were performed by stages had made many patients lose the chance of one-stage repair and reconstruction with the best effects. Because there was a lack of tissue flap techniques in the past, and the local area after tumor resection often couldn't be repaired and reconstructed, many patients with advanced cancers turned down the opportunities to undergo operative treatments; even if the radical operations were carried out with an effort, this would lead to the consequences of serious disfigurements and organ function defects due to severe local tissue defects in the patients. At present, because the plastic surgery offers a wide range of tissue repair technologies, this not only ensures the completion of radical operation and the increasing rate of local resection but also reaches the purpose of repairing the local tissue defects and reconstructing the local functions. In order to complete the tissue defect repair and functional reconstruction with high quality, it is required that the surgeons who are engaged in oncoplastic surgery have a solid knowledge and skills in cosmetic surgery. In the process of tissue repair and reconstruction, more attentions should be paid to the repair of the subunits of tissues and organs, the cosmetic repair and the tissue regeneration, and functional recovery, so as to greatly improve the quality of life of patients after surgery. Since the 1980s, the tumor resection scope has almost reached the limit the patient's body can withstand. Under this context, how to design more reasonable surgical treatment options which can improve the qualities of life of the patients at the same time of treating the diseases has become a concern of many scholars' focus. From the beginning of the 1970s, with the development of microsurgical techniques, the oncology surgeons at home and abroad constantly have absorbed the microsurgical techniques and plastic surgery techniques into their own specialties, which have opened up a new chapter of one-stage repair and reconstruction of tumors. For example, Zhang Disheng et al. have successively reported the use of pectoralis major myocutaneous flap, free forearm flap, latissimus dorsi musculocutaneous flap, and esophageal replacement with free jejunum for one-stage repair and reconstruction of the defects after head and neck surgery with microsurgical techniques. In the 1980s, Wang Hongshi firstly reported that the infrahyoid myocutaneous flaps were used successfully in one-stage repair of tongue and mouth floor defect by the oncology surgeons. In the 1990s, in order to solve the problem of venous reflux disorder occurring in the infrahyoid myocutaneous flap, Zhou Xiao reported two surgical methods such as the infrahyoid myocutaneous flap in which the venous variants were reserved and the infrahyoid myocutaneous flap in which the veins were severed and then were anastomosed. In addition, there are a large number of reports on one-stage repair and reconstruction after breast cancer radical surgery. Hence, the maturing and development of microsurgical techniques promotes the development of the entire discipline by providing necessary technical supports for the full integration of oncology surgery and plastic surgery, a guarantee for innovation in treatment programs in oncology surgery, and the birth of oncoplastic surgery.

"Necessity is the mother of invention and innovation," the necessity is also the driving force for the development of all things. In the historical process of the full integration of oncology surgery, plastic surgery, and microsurgical techniques and the emergence of a new cross discipline (oncoplastic surgery), the one-stage repair and reconstruction after radical tumor resection get rapid development in the head and neck surgery and the breast surgery. The reason can be summed up as follows:

1. After treated by the comprehensive treatment such as the operation combined with radiotherapy and chemotherapy or the radical surgical resection alone, the survival period in most of the patients with malignant tumors has been prolonged, and some patients have been cured. However, the traditional head and neck cancer surgery and breast cancer radical surgery cause serious damages to the appearance beauty, and the patients are eager to be treated by a method which cannot only cure the disease but also restore their body shapes, and thus, the patients can return back to the family and society and live on happily. Only achieving recovery in organ function and appearance beauty, the patients can have an improved quality of life after surgery, and therefore, all their physiological needs, security needs, belonging and love needs, esteem needs, and self-actualization needs can be satisfied.
2. In the past, because some oncology surgeons were not familiar with microsurgery and plastic surgery techniques, they often had no effective measures for defect repair after radical surgery; even if they had tried to perform the

surgery, the quality of life in patients was often decreased due to the serious complications after surgery. Since the 1970s, the development of microsurgery and plastic surgery techniques has provided a wealth of surgical approaches for one-stage repair and reconstruction of the defects after radical tumor surgery; hereby, the surgeons can remove the lesion focus thoroughly and do not worry about the issues of repairing the local tissue defects after lesion resection. This not only improves the 5-year survival rate of patients but also shows a higher and newer level in the aspects of reducing complications, preserving the function and improving the appearance. The radical tumor surgeries such as the head and neck tumor surgery and the breast tumor surgery plus one-stage reparative and reconstructive surgery have become one of the trends of contemporary development of oncology surgery, and this will also provide a new way of thinking for designing operation scheme for the tumors in other sites.

2 Concept and Therapeutic Range of Oncoplastic Surgery

Xiao Zhou

In the 1970s, Yang Dongyue firstly repaired the defects after cheek tumor resection using the skin flap in China, and then he applied some plastic surgery techniques into the treatments in the oncology surgery, but he did not clearly put forward the concept of oncoplastic surgery. Academician Qiu Weiliu proposed the application of microsurgical techniques in reparative and reconstructive surgery and promoted the development of oral and maxillofacial surgery in China. Zhou Xiao et al. firstly discussed in detail the relationship between the oncology surgery and other related disciplines at home and abroad from the perspectives of plastic surgery, microscopic surgery, plastic and cosmetic surgery, tissue engineering, and evidence-based medicine and put forward the concept of oncoplastic surgery: The oncoplastic surgery is a branch of the oncology surgery, and it is a surgical cross edge discipline which combines the theories and technologies of oncology surgery, plastic surgery, and microsurgery and is characterized by planned radical tumor resection plus one-stage reconstruction. The treatment scope mainly covers the repair and reconstruction of defects in the skin, mucous membrane, muscle, nerve, bone, and some organs; the surgical methods include the use of autologous, allograft, and xenograft tissues or synthetic biomaterials to repair the tissue and organ defects or deformities. When making the operation scheme, we should give full consideration to the effects of radiation therapy, chemical therapy, tumor recurrence, tumor deposit, tumor metastasis, and other relevant factors. In the treatment of malignant tumors, the radical resection of the tumors is the main aspect of the treatment, and the purpose of the implementation of reparative and reconstructive surgery is to perform defect repair and functional reconstruction on the basis of ensuring complete excision of tumor lesions in tissues and organs. The anatomic sites involved in oncoplastic surgery are more extensive. For example, the repair of head and neck defects is cross-linked with otolaryngology – head and neck surgery, oral and maxillofacial surgery, ophthalmology, and brain surgery; the repair of the defects in the breast, body, and limbs is cross-linked with breast surgery, thoracic surgery, general surgery, hand surgery, and bone surgery; the repair of the defects in the genitals is cross-linked with gynecologic oncology, gynecology, and urinary surgery. The operation scheme of one-stage repair and reconstruction after radical tumor resection should be personally designed by the oncology surgeon, which puts forward a higher requirement on the oncology surgeon. A surgeon of oncoplastic surgery must be equipped with solid basic theories and skilled operation techniques in oncology surgery, plastic surgery, microscopic surgery, and vascular surgery and should also be equipped with basic knowledges in related disciplines such as anesthesiology, radiation therapy, chemical therapy, thermatology, interventional therapy, minimally invasive surgery, laser therapy, cryotherapy, surgical nutrition, tissue engineering, ethics, and psychology. Attentions should be paid to the following aspects during the working process:

1. The operator should abide by the medical ethics, have a high degree of medical responsibility, preclude any deceptive or exaggerated behavior in the medical treatment activities, and avoid directly selecting the patients as subjects of practice in the case that the condition or opportunity is not mature.
2. The operator should be fully aware of one's own abilities and should not perform a surgery which is uncertain.
3. When the patients are admitted to hospital, attention should be paid to organizing the multidisciplinary expert consultations for intractable cases and formulating a scientific and reasonable sequential treatment program.
4. Any surgeons who are engaged in the plastic surgery must undergo strict formal training in technical operations of plastic surgery and microsurgery and try to achieve fine repair effect in the process of carrying out the oncoplastic surgery. Especially when repair and functional reconstruction of defects in subunits are carried out, it should be noted that the surgical operations conform to the surgical principle of cosmetic and plastic surgery.
5. The operator should cultivate the medical aesthetic knowledges and improve one's own aesthetic level.
6. The operator should cultivate the medical psychology knowledges and improve one's identifying and guiding abilities to help patients with psychological problems.

3 Objective and Therapeutic Principle of Oncoplastic Surgery

Xiao Zhou and Chaohui Zuo

3.1 Therapeutic Principles of the Oncology Surgery

The radical surgical treatments in oncoplastic surgery must comply with the therapeutic principles of the oncology surgery. The surgical treatments of tumors mainly refer to the surgical treatments of the malignant tumors. The malignant tumors have biological characteristics such as invasiveness and metastasis, and most malignant tumors not only show an invasive growth in local areas but also show a metastasis to the lymph nodes surrounding neoplastic foci and the distant lymph nodes. Based on the above characteristics of the tumors, in addition to following the general principles of the surgery, the surgical treatment of the tumors should also follow the basic therapeutic principles of the oncology surgery. The general therapeutic principles of the oncology surgery are summarized as three points, namely, the patient selection before surgical treatment, the determination of surgical method in the treatment, and the comprehensive treatment on the basis of individualization.

3.1.1 Selecting Appropriate Patients for Carrying Out Surgical Treatments According to the Characteristics of the Different Tumors

The surgical treatment of the tumors is closely associated with the pathological diagnosis. The pathological diagnosis can provide important results such as histological type, histological grade, and primary site as well as whether the surgical margin is safe, which are the most important evidences for surgeon to treat the patients, namely, the "gold standard" for diagnosis and treatment [11]. The clinical diagnosis and staging include the size of the primary tumor, the situation of regional lymph nodes, and the metastatic sites, which can fully reflect the basic situation of the patient, reveal the general biological characteristics of malignant tumors, and help surgeons to confirm the surgical treatment and select the surgical method.

3.1.2 Maximizing the Removal of the Tumor Tissues and Maximizing the Preservation of Normal Function of the Body and Organs

Since Halsted invented the classical radical mastectomy in 1894, the principles of two maximizations have been established and accepted by the majority of the oncology surgeons. When these two principles are in conflict with each other, the latter should be subjected to the former. However, if the removal of excessive tissues affects organ function, it is needed to reduce the extent of surgery. It should be emphasized that the preoperative evaluation is relative, and the specific surgical method is determined according to the intraoperatively explored situation for most of the oncology surgical operations. For example, whether the tumor is cleanly removed is determined according to whether there are cancer cells in the rapid intraoperative pathology report [12].

3.1.3 Fully Understanding the Limitations of Surgical Treatment and Following the Principle of Comprehensive Treatment on the Basis of Individualization

We still emphasize the general principles of cancer treatment such as early detection, early diagnosis, and early treatment; we should also follow the law of development of different tumors and rightly master the indications for the surgical treatment of tumors; we oppose the unprincipled surgical overtreatment and also don't appreciate the overly negative and conservative attitude, which make some patients who may have a chance for surgery lose the chance of surgical treatment. Today, the goal of surgical treatment of the tumors is to make tumor patients not only survive for longer period but also have a better quality of life. The treatment of tumors is not the kind of treatment based on the single discipline, and the key to improve the efficacy of tumor treatment is to advocate the comprehensive treatment based on the multidisciplinary cooperation. The comprehensive treatment program is developed primarily based on the biological characteristics and clinical stage of the tumor and the general condition of the patient. In the past, there was too much emphasis on expanding the scope of surgical resection, but it is later confirmed that it cannot improve the survival rate. With the increasing level of the surgical operation, the surgical treatments of tumors develop increasingly into the direction of individualization. At present, the therapeutic methods such as preoperative chemotherapy, radiotherapy, or chemoradiotherapy (namely, the neoadjuvant therapy) are considered for tumors at the late stage, which aims to improve the surgical resection rate, remove the occult metastases, reduce postoperative recurrence and metastasis, relieve the clinical symptoms such as pain, determine the sensitivity of the tumor to chemotherapy through downstaging treatment, and provide the basis for the choice of chemotherapy after surgery [13].

3.1.4 Following the Principle of Non-tumor Operation

In the process of diagnosis and treatment of tumors, the improper inspections or operations of the medical workers

may cause the spread of tumor cells. The oncology surgery not only emphasizes the aseptic principles required in the general surgery but also follows the principles of tumor-free operation.

For each patient who needs to receive the treatment of the oncoplastic surgery, the surgical indications should be strictly controlled in accordance with the therapeutic principles of oncology surgery, and an integrated comprehensive treatment plan should be made before surgery. Of which, the treatment measures such as surgery, radiotherapy, and chemotherapy are reasonably selected; the therapeutic regimen of the radical surgery is rationally established, and the program for tissue defect repair after radical surgery is properly selected. The treatment contains the contents of the two aspects such as the tumor lesion resection and the repair and reconstruction after surgery. Harri et al. reported that the repair and reconstruction after tumor surgery has the following two goals: (1) The immediate repair and the appropriate reduction of the surgical damages during the tumor resection are beneficial to protecting the vital organs, preventing infection, preserving the necessary functions, and promoting the early rehabilitation; (2) the function and appearance will be repaired and reconstructed after tumor surgery, and the techniques for the functional reconstruction and the cosmetic and plastic surgery should be applied as far as possible. In these two objectives, the improvement of quality of life of tumor patients is the core of the treatment [14]. The oncoplastic surgery can provide technical supports for comprehensive treatments such as radical tumor resection and postoperative chemotherapy and lay the foundation for the intraoperative radical tumor resection. The oncoplastic surgery is performed mainly for head and face reconstruction, breast and chest wall reconstruction, abdominal and perineal reconstruction, limb reconstruction, etc.

3.2 The Therapeutic Principles of the Oncoplastic Surgery

The treatment of the oncoplastic surgery contains the contents of two aspects such as the tumor lesion resection and the repair and reconstruction of postoperative defects. In radical surgeries of malignant tumors, emphases are attached to the biological characteristics and occurrence law of cancers, the comprehensive treatment principle for cancers, the aseptic technique, and the tumor-free technique, and the choices of surgical indications are in full compliance with the therapeutic principles of the oncoplastic surgery. After completion of tumor resection, the plastic surgery and microsurgical techniques will be applied to repair the defects in some important sites caused by surgery, and every effort is made to restore function and appearance.

3.2.1 The Principles for the Selection of Reparative and Reconstructive Surgery

1. If the application of simple surgery can achieve the same effect, the complex plastic surgery or microsurgery will be not performed.
2. Only the donor tissues from the secondary sites can be transplanted to repair the defects in the important receptor sites.
3. It is necessary not only to ensure a good recovery of the function and appearance of the donor site but also to minimize the damages to the function and appearance of the receptor site, and it should be avoided by all means to cause secondary deformity or dysfunction in receptor sites.
4. The operation scheme of one-stage repair and reconstruction of tissues and organs is selected as far as possible.
5. The site after radical radiotherapy should not be selected as a flap donor site.

3.2.2 Surgical Classification of Repair and Reconstruction After Radical Tumor Surgery

The repair and reconstruction after radical tumor surgery can be divided into two types according to the time schedule: one-stage repair and deferred reconstruction.

1. One-stage repair, the one-stage repair has become the mainstream of oncoplastic surgery since the twenty-first century.
   (1) Its advantages include: (1) It can reduce the postoperative dysfunction and deformity at early phase, protect the wound for securing primary wound healing, create favorable conditions for the postoperative recovery of the patient, and create the conditions for undergoing other additional therapies such as radiation therapy and chemotherapy; (2) it can reduce the number of operations, reduce the occurrence of complications, and alleviate the patient's suffering and save money; (3) the radical tumor surgery is more thorough and can reduce the local recurrence rate.
   (2) Its shortcomings include: (1) The micrographic surgery is difficult, and it is required that the oncology surgeons have extensive surgical experience and expertly master the plastic surgery and microsurgical techniques; (2) after restoration, it is not convenient to directly observe and early detect the recurrent lesions in some sites, especially in the deep hidden sites.
2. Deferred reconstruction

(1) Its advantages include: (1) The surgical area is exposed after surgery in some tumor patients, and this facilitates early detection of local tumor recurrence; (2) the surgery is relatively easy.
(2) Its shortcomings include: (1) If the important tissues and organs such as large blood vessels are exposed, this can lead to serious complications after surgery; (2) if the patient receives other treatments such as radiation therapy after surgery, the difficulty of the reconstruction will be increased due to tissue damage; (3) the long-standing defect and dysfunction in tissues and organs such as the nasal defect and the language and swallowing disorders will seriously affect the physical and mental health of the patient, and this is not conducive to making them return to normal social activities.

4 Diagnosis and TNM Staging of Tumors in Oncoplastic Surgery

Chaohui Zuo and Xiao Zhou

The correct diagnosis and TNM staging of the tumor are a prerequisite for carrying out the oncoplastic surgery, and it can accurately assess the efficacy and prognosis. The tumor diagnoses include the pathological diagnosis, the diagnosis by molecular tumor markers, and the imaging diagnosis. The tumor diagnosis and TNM staging in oncology surgery are proposed by the International Union Against Cancer [15] , and the staging method which is currently widely used is also applicable to the oncoplastic surgery.

4.1 Tumor Diagnosis

The tumor diagnosis in oncoplastic surgery is a multidisciplinary comprehensive analytic process, and it is mainly dependent on the pathological diagnosis, the diagnosis by molecular tumor markers, and the imaging diagnosis.

1. The pathological diagnosis. The pathological diagnoses mainly include cytopathological diagnosis and histopathological diagnosis. The former is the diagnosis of tumor which is made based on the examinations of the exfoliocytology or the fine-needle aspiration biopsy and peripheral blood smears; the latter is the diagnosis which is made after the histological examination of the pathological sections of tumor tissues obtained by puncture, forceps biopsy, cutting, or resection. Among various kinds of tumor diagnostic techniques, the pathological diagnosis is still considered the "gold standard." However, the pathological diagnosis also has some limitations, which have a certain relationship with the specimen acquisition, the quality of section making, and the professional skill. Sometimes it is needed to draw materials repeatedly. Therefore, the conclusion of pathological diagnosis is often made after comprehensive judgment on characteristics such as clinical manifestations, surgical findings, gross morphological changes, and morphologies under light microscopy [16] .

   The diagnosis by molecular tumor markers. The tumor markers often appear along with tumors. They are produced and secreted by the tumor cells and can reflect the existence of the tumor within the body. They have the characteristics of high sensitivity and specificity. They include (1) the tumor markers belonging to enzymes, such as prostate-specific antigen (PSA), matrix metalloproteinase (MMP), and acid phosphatase (ACP); (2) the tumor markers belonging to hormones, such as human chorionic gonadotropin (HCG); (3) the tumor markers belonging to embryonic antigens, such as alpha-fetoprotein (AFP) and carcinoembryonic antigen (CEA); (4) the tumor markers belonging to glycoproteins, such as CA125 and CA199; and (5) the tumor markers belonging to receptors, such as epidermal growth factor receptor (EGFR).
2. Imaging diagnosis. The imaging diagnosis is the diagnosis which is made based on the images of human tissues or organs formed by some kinds of methods, and it plays a very important role in the early detection, diagnosis, and treatment of tumors. It relates to disciplines such as X-ray, computed tomography (CT), magnetic resonance imaging (MRI) and nuclear medicine (such as PET-CT), ultrasonic medicine, and interventional radiology, and various examinations have their own advantages and disadvantages. The ultrasound examination is a noninvasive examination, which can be used for repeatable observation and is easy to operate, but has a lack of specificity. MRI has excellent tissue resolution and can show clearly the anatomic structures and lesions, but it cannot be carried out in the patients who have cardiac pacemakers or magnetic materials within the body. As a noninvasive and safe tumor imaging technology, PET-CT can display the characteristics of tumor cells from the molecular level and provide clinicians with relevant information for the diagnosis and treatment of tumors and can also determine the recurrence and metastasis of tumors, but it is costly and can only be listed as an optional item.

4.2 Staging Diagnosis of Tumors

After determining the nature of the lesions, the staging diagnosis of the malignant tumor contributes to establishing a reasonable treatment plan and correctly assessing the efficacy

and prognosis. The clinical staging should be completed before the start of treatment. TNM staging is a prerequisite for the diagnosis in oncoplastic surgery. T (tumor) refers to the primary tumor; N (node) refers to the regional lymph node metastasis; M (metastasis) refers to distant metastasis. Then the letters are followed by 0–4 numbers according to tumor size and infiltration depth to indicate the development degrees of the tumors: 1 represents small, 4 represents large, and 0 represents nothing, and the staging is decided based on these three items. If the tumor size cannot be judged in clinic, it will be represented with TX. The tumor staging includes clinical staging (cTNM) and postoperative clinicopathologic staging (pTNM), and their specific standards are negotiated and established by various professional meetings [17]. For example, the staging of the thyroid cancer is as follows: stage I stands for $T_1N_0M_0$; stage II stands for T2 or $T_3N_0M_0$; stage III stands for $T_4N_0M_0$ or any TN_1M_0; and stage IV stands for any TNM_1.

5 Application of PET-CT in Diagnosis in Oncoplastic Surgery

Yi Mo, Yi Luo, and Bo Zhou

The advances in diagnostic imaging technology have promoted the development of the oncology surgery. The statuses of the primary lesion and distant metastasis of the tumor have the very vital significance for TNM staging of the tumor and the prognosis of the patient. Making an accurate judgment on the condition and the prognosis of the tumor patient is also the basic requirement for the oncoplastic surgery. The oncoplastic surgeons must have a detailed understanding of the statuses such as the benign and malignant natures of tumors, the size of the primary lesion, the exact boundary, and the distant metastases. The existing X-ray, CT, and MRI technologies can provide the more accurate positioning information of the primary lesions and the metastases in middle and advanced stage, but they are less effective in the determination of early metastatic lesions of malignant tumors and the accurate delimitation of infiltrating tumor border. It is because that the number of these metastasized early-stage tumor cells is small and no significant changes occur in the anatomical structures, while the qualitative changes have taken place in the local histopathologic feature and metabolic status. Accurately determining the statuses of the early metastasis and infiltration of the tumor has a decisive role in the selection of surgical programs, and the research and development and application of PET-CT would better solve this problem. The first PET-CT was successfully developed by two scientists, Townsend and Nutt, and it is a milestone in the development of today's life science and medical imaging technology. The full name of PET is positron emission tomography, and it is mainly used to display the tissue metabolic changes; the full name of CT is computed tomography, and it is mainly used to display the tissue structures. PET-CT combines the advantages of both. Furthermore, it can early detect and accurately position the tumor cells with abnormal energy metabolism. Therefore, it can provide a reliable means to assess the tumor status and make a surgical plan for the oncoplastic surgeons.

5.1 The Operating Principles and the Imaging Agents of PET-CT

5.1.1 The Operating Principles of PET-CT

The operating principles of PET-CT are that the necessary materials for human body metabolism such as glucose, protein, nucleic acid, and fatty acid are marked with short-lived radioactive nuclides to become an imaging agent. After being injected into the human body, the positive electrons emitted by the imaging agent will interact with the electrons from the adjacent tissues to produce gamma photons, then the photon signals are detected with PET scanning probe, and the signals will be transmitted into the computer for processing. The anatomical images and their corresponding physiological parameters are used to display the status of the target organ or diseased tissue, understand the function and metabolic state of the lesions, and thereby diagnose the disease. PET is a molecular imaging equipment for functional and metabolic imaging, and it can clearly display the tomographic images of the human body through the penetrative scanning of CT and provide the anatomical information of the lesions, such as location, distribution, number, size, morphology, tissue structure, and adjacent relations; hereby, the reasoning analysis for the differentiation of benignancy and malignance of the lesions is carried out. PET-CT equipment is not a simple combination of PET and CT equipments, while it is a more complete equipment which organically integrates PET and CT equipments together. PET-CT simultaneously has the functions of PET and CT. It cannot only reflect the tissue metabolism and early detect the lesions but also accurately position the lesions detected by PET and provide CT information. PET can display the pathophysiological characteristics and make it easier to discover the lesions: CT can accurately locate lesions and display structural change in the lesions. In addition to possessing the respective functions of PET and CT, the unique image fusion technology of PET-CT can simultaneously reflect pathophysiologic change and the morphological structure of the lesions, and this significantly improves the accuracy of diagnosis. Therefore, PET and CT can make their respective advantages complementary to each other.

5.1.2 The Imaging Agents of PET-CT

In addition to the use of the equipment for PET-CT examination, another important condition is the use of the positron-emitting radiopharmaceuticals which are taken as PET tracers. In recent years, the researches in this field are very active, and their clinical applications have achieved rapid development. These drugs involve multiple aspects such as perfusion, metabolism, receptors, and gene imaging. Meanwhile, a wide range of exploration and research on cell apoptosis, hypoxic tissue, cell proliferation, and enzyme activity and the multidrug resistance of tumors such as PET drugs have been conducted. Commonly used positron-emitting radiopharmaceuticals include fluorine-18 (^{18}F), carbon-11 (^{11}C), nitrogen-13 (^{13}N), and oxygen-15 (^{15}O). Currently, the most widely used tracer is ^{18}F-fluoro-deoxy-glucose (^{18}F-FDG), which plays a leading role in the oncology. Along with the constant application of new types of positron-emitting radiopharmaceuticals such as 18F-fluoro-L-thymidine (^{18}E-FLT), 18F-fluorine estradiol (^{18}F-FES), imaging agent of hypoxic cells (^{18}F-FMISO), 11C-methionine, and 11C-choline positron in the clinics, we are prompted to promote the combined application of various positron-emitting radiopharmaceuticals which can reflect different metabolic processes in the PET-CT imaging to improve the sensitivity and specificity for the early diagnoses of the tumors to achieve the purpose of early diagnosis of tumors. The carbon 11-labeled positron-emitting radiopharmaceuticals are the most important new tracers.

5.2 Characteristics of PET-CT

5.2.1 High Sensitivity

PET-CT is a kind of imaging technology which reflects the molecular metabolism. When the changes occur at the molecular level in the early stage of the disease, the morphological structure of the lesion area has not showed abnormalities. When MRI and CT examinations cannot confirm the diagnosis, PET-CT examination can detect the location of the lesion and get three-dimensional images and then conduct a quantitative analysis, thus achieving the purpose of early diagnosis. This is unmatched by other imaging examinations.

5.2.2 High Specificity

When MRI and CT examinations reveal a tumor in the organ, it is quite difficult to determine whether it is benign or malignant, but PET-CT can make a diagnosis according to the characteristics of hypermetabolism in the malignant tumor.

5.2.3 Whole Body Imaging

We can obtain the images of all areas of the whole body through carrying out PET-CT whole body imaging once.

5.2.4 Good Safety

Although the nuclides used in PET-CT have radioactivity to some extent, their retention time within the body of the subject is short due to the fact that the dose is small and the half-life is short under the dual action of physical decay and biological metabolism (2–110 min). The radiation dose in a PET-CT whole body imaging is much lower than that in the routine CT examination of a site, and thus, it is safe and reliable.

5.3 Advantages of PET-CT

With the rapid development of tumor molecular imaging, especially the emergence of PET-CT, the indications of PET-CT examination in oncology have been recognized, including the identification of benign and malignant tumors or lesions, tumor staging, follow-up and monitoring of the efficacy, detection of the primary tumors and metastases, assessment of malignant degree and clinical prognosis, and development of radiation treatment plan. Compared with PET, PET-CT has the following advantages:

5.3.1 Short Examination Time and Improved Image Resolution

The dedicated PET uses the photons emitted by radionuclides to make attenuation correction. The total body scan from the base of the skull to the upper end of the femur (including the neck, chest, abdomen, and pelvis) normally takes six to eight bed spaces, and PET and CT image fusion is more accurate, which contributes to the use of positron nuclides of short half-life. It is more comfortable and convenient for the patients, and can increase the number of daily examined patients.

5.3.2 Locating the Abnormal Space and Identifying the Tracers

CT can locate the abnormal space detected by PET, and it is easy to identify whether the tracer uptake is physiologic. Some normal tissues and organs such as the muscle, blood vessels, gastrointestinal tract, and urinary tract have different degrees of physiologic tracer uptake or accumulation. Sometimes, they are easily confused with the lesions with increased metabolic activity on the PET images. The fused PET-CT images can clearly display the anatomical site of high metabolism; thus, this not only avoids misdiagnosing the physiologic uptake as lesions but also prevents the judgment in which the high metabolic lesions are mistaken as the physiologic uptake, resulting in unnecessary missed diagnosis.

5.3.3 Improving the Accuracy of Cancer Diagnosis, Staging, and Efficacy Tracking

PET-CT can reflect the physiological or pathological changes in the human body at the molecular level and sensitively detect the metabolic abnormalities in the early stage of the disease; it can detect the early lesions and provide valuable information about the function and metabolism through qualitative and quantitative analysis. CT can accurately locate the anatomical sites of the lesions detected by PET, while PET can increase the diagnostic specificity of the suspicious lesions detected by CT; thus, the informations from both PET and CT are complementary. This can avoid or reduce the missed diagnosis of PET-negative tumors or small lesions, better monitor the response to treatment, and identify the tumor recurrence and scar lesions after treatment.

The tumor staging is an important basis for making a therapeutic regimen for the patient, and a PET-CT whole body imaging can provide information about whether the organs in whole body have tumor metastasis, which is beneficial for accurate clinical staging of multiple tumors such as lung cancer, breast cancer, colon cancer, ovarian cancer, and lymphoma. For example, in the diagnosis of lymph node metastasis, CT or MRI may detect the enlarged lymph nodes (diameter > 1 cm) as the metastasis; among them, there is no lack of enlarged lymph nodes caused by chronic inflammation; in addition, CT or MRI may misjudge the normal-sized lymph nodes which have been violated by tumor tissues as normal lymph nodes, while PET can judge whether there is metastasis according to the metabolic activity of lymph nodes, and this is more accurate than that only according to the size of the lesions.

5.3.4 Optimizing the Radiotherapy Plan for Tumor Target Area and Improving the Clinical Curative Effect of Radiotherapy

In addition to the accurate positioning of CT, the PET imaging with multiple positron-emitting radiopharmaceuticals can reflect different processes of metabolism and proliferation of tissue cells. For instance, it can reflect the information about the glucose metabolic activity in tumor tissue, the distribution of hypoxic cells, and the cellular proliferation and summarize the informations from many aspects to outline the boundaries of molecular biological target area, and thus, it can more accurately implement the conformal intensity-modulated radiation therapy (IMRT).

5.3.5 Accuracy

PET-CT helps determine the biopsy site of lesion.

5.4 Limitations of PET-CT

Although the commonly used FDG PET-CT imaging is a high-tech examination, there is also the occurrence of false positives (such as active tuberculosis, acute inflammation, active sarcoidosis, and inflammatory pseudotumor) and false negatives (such as alveolar carcinoma, well-differentiated hepatocellular carcinoma, renal clear cell carcinoma, signet ring cell carcinoma, mucinous cystadenocarcinoma, carcinoid, and well-differentiated adenocarcinoma), and the overall diagnostic accuracy rate is about 90%. Special attention should be paid to that the CT in PET-CT is mainly used for attenuation correction and localization of PET images under normal circumstances, and it is not a substitute for CT diagnosis; in order to match with PET images, the breath is not held during scanning. Under normal circumstances, only the plain scan rather than enhanced scan is performed; it is not synchronized in real time with PET scan, and there is a certain time interval. The problems in clinical application of PET-CT and the improvement measures have aroused the attentions of some scholars. Among 300 patients examined by PET-CT, Osman et al. found that after the use of CT for attenuation correction of PET images or the fusion of PET and CT images, there were six cases (2%) of positioning error, and the lesions in the liver under the right diaphragmatic dome were mistaken as the lesions in the basal segments of the right lung. The cause analysis showed that this may be caused by the difference in breathing exercises among patients during PET acquisition or CT acquisition. During the application of PET-CT, Antoch et al. found that after the use of the intravenous or oral iodinated contrast agent enhanced CT images for attenuation correction of PET images, among 30 patients, the PET images in four patients showed artifacts, which were thought to be due to the transient "projection" of the undiluted contrast agents.

6 Principles of Tumor-Free Techniques

Xiao Zhou, Feiyue Wu, and Yongyi Chen

The oncoplastic surgery operation is often divided into the primary tumor group and the donor site flap preparation group. Because the gloves, clothings, and equipments used by the surgeons in the primary tumor group may carry tumor cells, the used items such as the gloves and surgical instruments which may be contaminated with tumor cells should be promptly replaced after the completion of radical tumor surgery. The surgeons in the primary tumor group must have strict aseptic sense and tumor-free consciousness. The staffs in the primary tumor group who want to participate in the surgical operation of the flap preparation group must change their sterile surgical gowns and gloves. The surgical instruments used in primary tumor group are strictly prohibited to be used in the surgical procedure for flap preparation.

The contents of tumor-free principle of the operations in the oncology surgery are as follows:

1. Requirements for preoperative examination: The preoperative examination should be gentle, and it is needed to prevent the brutal examination and reduce the examination frequency. For example, if the patients with head and neck malignant tumors have excessive punctures and multiple biopsies, this may easily cause cancer cells to fall off [18, 19].
2. Reducing local anesthesia. The time interval between biopsy and radical surgery should be shortened. The local anesthesia in the cancer surgery should be reduced as far as possible, because the local anesthesia can increase the local pressure, and the risk of tumor cell dissemination is increased. The time interval between biopsy and radical surgery should be as short as possible, and it is advocated to carry out an intraoperative rapid frozen pathological examination. For example, for the highly suspected breast cancer, it is necessary to carry out the intraoperative rapid frozen pathological examination, and the routine pathological examination should be performed as seldom as possible.
3. The sequence of surgical exploration. Attention should be paid to the gentle movements. The exploration is carried out from far to near, and the areas around the cancer foci are explored finally.
4. Isolation. The strict isolation techniques should be adopted during surgery, and the wound surface and the incisal edge should be protected with the gauze pad. For the tumors which have invaded the tissues outside the serous membrane, they should be covered with gauzes or sterile membranes during surgery to reduce the shedding and planting of cancer cells. The electric knife or the ultrasonic knife is applied during surgery as much as possible, and the sharp dissection is performed along the level of surgical space, while less blunt dissection is performed. The electric knife or ultrasonic knife can be used to seal the small lymphatic or blood vessels to reduce the chance of intravasation of cancer cells into the vasculature. Meanwhile, it has the function of killing cancer cells. But the squeezing in blunt dissection is easy to cause the spread of cancer cells.
5. The requirements for cancer resection. The cancer tissues are not incised during surgery. When dealing with the blood vessels around the cancer, the surgeon should try to firstly ligate the veins and then ligate the arteries, which can reduce the intraoperative incidence rate of intravasation of cancer cells into the blood circulation and reduce the likelihood of metastasis by bloodstream. The lymph node dissection should be performed from far to near, and the en bloc resections of cancer foci and lymph nodes should be completed as far as possible to reduce the lymphatic metastasis of cancer cells. The scope of surgical resection is determined according to the biological characteristics of the tumor. The incisal edges should be cancer-free and have some normal tissues.
6. Rinse. After complete resection of the specimens, the surgeons and the scrub nurse should change gloves and instruments, and then the wound is rinsed with a large volume of distilled water at 42°C; meanwhile, it can also be rinsed with iodine water or chemotherapeutic drugs to reduce the possibility of survival of residual cancer cells in the wound and body cavities.

It is necessary to further develop the strict tumor-free operation procedures for all kinds of surgeries in oncoplastic surgery under the guidance of the tumor-free principle and aseptic technique principle.

7 Principles of Aseptic Techniques

Chaohui Zuo and Jianping Liang

Microorganisms commonly exist in the human body and the surrounding environment in which we live. In the process of surgery, if the effective measures are not taken, the pathogenic microorganisms can enter into the wound and cause infection either directly or through airborne droplets. The aseptic technique is an effective prevention method taken against the possible infection sources and pathways, and it includes sterilization, disinfection, aseptic operating rules, and management system. In the process of tumor surgical operation and wound management, the principles of aseptic techniques must be strictly observed [20, 21].

Sterilization refers to kill or eliminate all microorganisms on the media, and the medical equipment and surgical materials used in surgery must meet the sterilization standards. The common methods include three methods such as high-temperature sterilization, low-temperature sterilization, and ionizing radiation sterilization.

Disinfection refers to kill or eliminate the pathogenic microorganisms and other harmful microorganisms on the media, and it is applicable to disinfection for the hospital environment, object surface, skin and mucous membranes, and indoor air. The commonly used disinfectants include alcohol, iodine, peracetic acid, active chlorine, etc. The ultraviolet circulating wind air disinfector and electrostatic adsorption-type air disinfector are mainly used for the indoor air disinfection.

The medical staffs in the department of oncology surgery who will participate in the surgery should be fully prepared before surgery, and they should put on the isolation shoes and clothes, wear masks and hats, and clip off the fingernails before entering the operating room. The medical staffs with broken arm skin or purulent infection are advised not to participate in the surgery. The surgical hand-washing method includes two steps of hand-washing and disinfection. Hereinto, the seven-step hand-washing method is adopted for hand-washing, which is repeated twice for a total of

5 min; the disinfectants must acquire the health licensing certificate issued by the Ministry of Health and should be used within the validity period. Certain rules must be followed for wearing the sterile gown and gloves.

Adequate preoperative preparation should also be made for the surgical patients, and the skin in surgery area should be cleaned and shaved. Currently, the povidone-iodine disinfection is commonly used in China, and the sterilization precautions are as follows: (1) The surgical incision is generally taken as a center, and the skin around the center is scrubbed and disinfected. If the wound is infected, or the surgical areas locate in the perineum and anus, the surgical area should be scrubbed and disinfected from the outer periphery inward; (2) the skin disinfection range of the surgical area should include the area around the incision with a distance of at least 15 cm; (3) the facial and perineal skins should be disinfected using type III iodine mucocutaneous disinfectant; (4) the skin and mucous membranes should be cleaned before disinfection and then are disinfected with iodine; otherwise, it will affect the disinfection effect.

During surgery, maintaining a sterile environment in the surgical area is directly related to the effect of surgery, and therefore, it must strictly abide by the principles of aseptic technique:

1. Once the surgical staffs have washed and disinfected their hands and have worn sterile gowns and gloves, they are not allowed to get in touch with unsterilized items; the back and the areas below the waist and above the shoulders of the surgical staff should be regarded as non-aseptic area, which cannot be touched; the hands and forearms shall not hang down to the waist and below the operating table.
2. The surgical instruments and materials cannot be passed on from the behind of the surgical staffs; once the items used in surgery fall below the operating table, they cannot be picked back and used.
3. During surgery, if the gloves are damaged or have contacted an area outside the sterile field, they should be replaced immediately with new sterile gloves; the contaminated fingers should be scrubbed with 0.5% povidone-iodine or 75% alcohol wipes; if the arms have reached the non-aseptic area, the surgical staff should change his sterile gown or wear oversleeves; the drenched sheet should be covered with an aseptic towel.
4. When the surgical staffs at the same side exchange positions, they should take a step back and then turn around back to back to exchange the positions, so as to prevent contamination.
5. The incisal edges should be covered and protected with a large gauze or surgical towel, which is fixed with sutures. Only the surgical incision is exposed, and the surgical incision should be protected especially in contaminated surgery and tumor resection.
6. Before the hollow organ is incised, the surrounding tissues would be protected firstly with the dry gauzes, and then the used gauzes should be promptly removed from the abdominal cavity; the incisal area in the stomach or enteric cavity is scrubbed with the cotton balls soaked in disinfectant to prevent and reduce pollution; the instruments which have contacted the contaminated sites should be isolated for exclusive use and should not be used in the sterile area.
7. The surgical instruments and dressings should be counted before the start of surgery; the surgical area should be examined at the end of surgery. Only after the numbers of surgical instruments and dressings are checked and verified correctly, the incision can be closed to avoid that the foreign objects are left in the body cavity to lead to adverse consequences.
8. After the completion of the peritoneal suture, the incision should be flushed with normal saline; before the skin incision is sutured, the skin surrounding the incision is scrubbed with the disinfectant (e.g., 75% alcohol or 0.5% iodine).
9. The people who look over the operation cannot get too close to the surgical staff or stand too high, so as to reduce the chance of contamination.
10. During the operation, the windows should not be opened for ventilation or the electric fan should not be used, and the vents of the indoor air conditioning should not blow toward the operating table, so as to avoid stirring up dust and contaminating the air within the operating room.

In short, the medical staff in the oncology surgery department should have strong aseptic principles and tumor-free concept and strictly and consciously abide by the principle of aseptic technique and abandon all behaviors which ignore the principle of aseptic technique.

8 Anesthesia Management of Oncoplastic Surgery

Jinfeng Yang, Jingshi Liu, and Jiannan Shen

8.1 Effect of the Basic Condition of the Patient on the Anesthesia

The ages of the patients undergoing oncoplastic surgery are often relatively greater, and the nutritional statuses are poor. The patients often have concurrent diseases such as water and electrolyte disorder, acid-base disturbance, cardiac-cerebral vascular disease, endocrine disease, and chronic respiratory disease. Some patients have a long history of smoking and drinking, which largely increases the difficulty of anesthetic management and makes the incidence of intraoperative and postoperative complications increased significantly. The

anesthesiologist should carry out a careful preoperative evaluation, make strict controls, and assist the surgeon to treat the primary diseases, so that the patients can undergo the surgery in the best condition [22].

8.1.1 Effect of the Surgical Site on the Anesthesia

Among the tumor patients who need to undergo plastic surgery and skin flap graft, the patients with tumors in the head and neck, oral and maxillofacial area, or craniomaxillofacial area are most commonly seen, whose surgical sites are adjacent to the respiratory tract; thus, there is a risk that the intraoperative foreign bodies, secretions, and blood are inhaled by mistake into the airway. It is required to change the head positions of these patients repeatedly during surgery, while the anesthesiologist is far away from the respiratory tract; thus, there is often the risk of the tube falling off, and this may bring a lot of inconvenience for perioperative airway management. This is also the type of surgery for which the surgeon and anesthesiologist have to communicate mostly with each other. Faced with different patients, these problems such as how to establish an airway, how to manage the airway during surgery, and how to choose the extubation time after surgery often require the anesthesiologists and surgeons to discuss repeatedly and finally reach a consensus. When the primary lesion in craniofacial area is being resected, the deep layer of the lesion is adjacent to the brain tissues, the brain tissue may be pulled in the process of separation and exposure, and the hemorrhagic secretions can penetrate into the cranial cavity and cause an increase of the intracranial pressure. Sometimes, the continuous bleeding may occur, which is difficult to estimate in practice. Therefore, the anesthesiologists should closely monitor the vital signs and always maintain a stable internal environment and timely control the intracranial pressure to prevent the occurrence of cerebral edema.

8.1.2 Effects of Surgical Scope and Time on Anesthesia

In the oncoplastic surgery operation, it is not only needed to deal with the primary lesion, but it is also needed to take the neighboring skin flap or free skin flap to repair the defect and carry out the microvascular anastomosis for the free skin flap. The operation time is long, and the operation is complicated and delicate. Sometimes, the vasospasm or even the embolism occurs after microvascular anastomosis; thus, the blood supply of the skin flap tissue cannot be fully guaranteed, and the skin flap repair needs to be carried out again, which not only brings pain to the patient but also significantly extends the length of hospital stay and increases the medical costs. Therefore, the anesthesiologist must guarantee the hemodynamic stability and the microcirculation perfusion during surgery so as to ensure a smooth flowing blood after microvascular anastomosis.

8.1.3 Intraoperative Blood Loss and Fluid Replacement

In the oncoplastic surgery operation, the blood loss would often be increased due to the great trauma and long operation time. Especially because the craniofacial tumor resection includes multiple operation steps such as osteotomy, displacement and recombination of the skull, basis cranii, eye socket, eyeball, nasal cavity, nasal sinus, and upper and lower jawbones, it is difficult to stop the bleeding before tumor resection, and more blood loss may occur in the process of tumor resection. The anesthesiologists should strengthen the monitoring and management of the blood circulation in the perioperative period, timely replenish the blood volume, and pay attention to the matching of intraoperative crystalloid fluid and colloidal fluid, thus preventing the effect of the tissue edema on the growth of skin flap.

8.2 Preoperative Evaluation and Management

8.2.1 Preoperative Examination and Treatment

1. Preoperative examination. The tumor belongs to systemic diseases. The patients are generally older, and they may have a long history of drinking and smoking and have comorbidities such as atherosclerosis, heart disease, peripheral vascular disease, and chronic obstructive pulmonary disease. The oncoplastic surgery is complicated and delicate and has a long operation time. Before the surgery, the anesthesiologist should ask for details of the history, carry out a medical examination, and discuss with the surgeons about how to complete necessary preoperative examinations. In addition to examinations such as blood routine, urine routine, liver and kidney function, lung function, blood clotting function, electrolytes, and electrocardiogram, some patients who have a special medical history should be specially treated:
   (1) Hypertension: The effect of hypertension on the whole body depends on the extent of damage of the target organ, and the surgeon should regularly monitor the blood pressure and check the functional statuses of the eye ground and other target organs.
   (2) Heart disease: The patient should be asked whether he or she has a history of angina or myocardial infarction in recent time, whether he or she has been already implanted with the coronary stent, whether he or she is taking oral antiplatelet drugs, and whether he or she has been examined with the compensatory cardiac failure and the arrhythmia with clinical significance. Table 1.1 lists some clinical predictive factors which increase the perioperative cardiovascular risk.

Table 1.1 The clinical predictive factors which increase the perioperative cardiovascular risk

Classification	Clinical predictive factors
High-risk factor	Unstable coronary syndrome
	Decompensated heart failure
	Arrhythmia with clinical significance
Median-risk factor	Patients with the past medical history of ischemic heart disease Patients with compensated heart failure or a precursor of heart failure
	Patients with the past medical history of ischemic heart disease
	Patients with diabetes mellitus (especially insulin injections)
	Patients with renal insufficiency
Low-risk factor	Old age
	Electrocardiographic abnormality
	Electrocardiogram (ECG) showed a non-sinus rhythm
	A history of stroke
	Uncontrolled hypertension

Attentions should be paid to the following issues for the heart disease patients: (1) The noninvasive heart function examination should be carried out for patients with unexplained dyspnea, heart failure with progressive dyspnea at present or in the past, previously diagnosed cardiomyopathy which is not clarified, and stable clinical symptoms. (2) The exercise stress test must be carried out before oncoplastic surgery in the patients with active heart disease and the patients with poor exercise tolerance due to possessing three clinical risk factors (the clinical risk factors refer to the previous histories of ischemic heart disease, congestive heart failure, cerebrovascular disease, diabetes, renal insufficiency); the exercise stress test can be considered for the patients with one to two clinical risk factors. (3) The cardiac ultrasound examination must be performed for the patients with valvular heart disease, hypertensive heart disease, and pulmonary heart disease to understand the opening and closing statuses of the valves, whether the myocardial motion is coordinated, whether the heart is enlarged, and whether the left ventricular ejection fraction, diastolic function, and ventricular wall motion are coordinated. (4) The patients with sinus bradycardia can have atropine tests firstly. If the patient has a heart rate of more than 90 beats/min in the atropine test, with no history of syncope, the sick sinus syndrome can be generally excluded in the patient. If the patient has a heart rate of lower than 90 beats/min in the atropine test, he or she can undergo 24 h dynamic ECG examination. If the lowest heart rate is more than 40 beats/min, the average heart rate is more than 50 beats/min, and the maximum heart rate is more than 90 beats/min, with no history of syncope, a sick sinus syndrome will not be generally considered. The cardiac electrophysiological examination can be carried out for the patients who still cannot be excluded with sick sinus syndrome by 24 h dynamic ECG examination.

(3) Respiratory diseases: The pulmonary infection patients need to undergo blood routine examination, lateral chest X-ray examination, sputum bacterial culture, drug-sensitive examination, and pulmonary function examination. The blood gas analysis may be carried out for the patients with dyspnea, and the bedside breath holding test can also be used to simply assess the lung function.
(4) Endocrine system diseases: The fasting and postprandial blood glucose level and the urine sugar level should be regularly detected in the patients with diabetes, and the free T3, free T4, and thyroid-stimulating hormone (TSH) should be detected in the patients with hyperthyroidism.

2. Preoperative treatments
   (1) Hypertension: Evaluating the effect of hypertension on the whole body is to mainly evaluate the damage statuses of the target organs, and the antihypertensive drugs must be continuously used until the morning of surgery. American College of Cardiology-American Heart Association (ACC-AHA) stated in 2009: The elective surgery can be performed for the patients with blood pressure < 180/110 mmHg and without cerebrovascular and cardiovascular symptoms, and the risk of perioperative cardiovascular complications will not be increased; the surgery should be postponed for the patients with blood pressure > 180/110 mmHg (this was also mentioned in the Guidelines for Prevention and Treatment of Hypertension in China 2010), but the statistical results of Dix and Howell showed that most physicians believe that the anesthesia and elective surgery should be postponed or canceled for the

patients with blood pressure > 160/95–100 mmHg, particularly for those patients with clinical symptoms. Therefore, it would be better for the hypertensive patients to be treated for 3–5 days before surgery, so as to prevent the postoperative cerebrovascular accident [23, 24].

(2) Heart diseases: Firstly, it should be considered to install the temporary or permanent cardiac pacemaker for the patients with confirmed symptomatic sick sinus syndrome and the patients with second-degree atrioventricular block type II and third-degree atrioventricular block, and then the surgeries are performed. The bilateral bundle branch block is mostly the right bundle branch block with left anterior fascicular block or left posterior fascicular block, and the left anterior branch can be blocked more easily; the left posterior branch is thicker, with dual blood supply. If it is blocked, this will indicate a heavier lesion. The patients with bilateral bundle branch block may have trifascicular block or develop complete atrioventricular block, and the preparation should be made to carry out cardiac pacing for these patients in perioperative period. The pacemaker should be installed for the patients with trifascicular block before surgery.

According to the guidelines of American College of Cardiology and Canadian Cardiovascular Society, the active heart diseases which require preoperative treatment are shown in Table 1.2.

The patients with cardiac dysfunction who have a significantly expanded heart should be treated preoperatively with digitalis drugs, and the potassium-sparing diuretics are applied when it is necessary and the application should be stopped on the date of operation. In the patients with unstable coronary syndrome, it is required that pentaerythritol tetranitrate (long-acting nitroglycerin) is used to expand the coronary artery, and the β-receptor blocker is used to slow the heart rate and reduce the myocardial oxygen consumption, and the tanshinone and the polarized solution can also be intravenously injected to improve myocardial ischemia. The patients for whom the drug treatments are invalid can temporarily undergo percutaneous coronary angioplasty or bare-metal stent implantation when time permits. Because the tumor surgery belongs to deadline surgery, it is not an ideal choice to carry out coronary bypass surgery or drug-eluting stent implantation before surgery. The clinically significant arrhythmias must be corrected as much as possible before surgery to avoid a serious accident. The patients with severe valvular disease are treated mainly for improvement of cardiac dysfunction and adjustment of ventricular rate in the normal range.

(3) Respiratory disease: The smoking patients should stop smoking for at least 2 weeks. The patients with acute pulmonary infections require anti-infection treatment until the symptoms such as the cough and sputum disappear, the blood routine examination is normal, and the chest X-ray shows that the lung shadows disappear, and then they can only be scheduled for the surgery. If the patients with chronic obstructive pulmonary disease have no symptoms of acute infection, they will mainly carry out the exercise of respiratory function. The nebulization which assisted expectoration is applied when

Table 1.2 The active heart diseases which require preoperative treatment

Type	Diseases
Unstable coronary syndrome	Unstable or severe angina
	Acute myocardial infarction or recently occurred myocardial infarction attack (7–30 days)
Decompensated heart failure	(New York Heart Association) The cardiac functional grading is grade IV
	Deteriorated or newly occurred heart failure
Significant arrhythmia	High-grade atrioventricular block
	Mobitz type II atrioventricular block
	Third-degree atrioventricular block
	Symptomatic ventricular arrhythmia
	Supraventricular arrhythmia of uncontrolled ventricular rate (including atrial fibrillation) (resting heart rate > 100 beats/min)
	Symptomatic bradycardia
	Newly occurred ventricular tachycardia
Severe valvular disease	Severe aortic stenosis (mean pressure across the valve > 40 mmHg, aortic valve area < 1 cm^2, or there are symptoms)
	Symptomatic mitral stenosis (exertional dyspnea, exertional syncope, or heart failure)

necessary to prevent a decrease in postoperative respiratory function.

(4) Endocrine system diseases: Before surgery, diabetes patients' fasting blood glucose level should be no more than 11.2 mmol/L, and the urine ketone test should show a negative result. For the moderately severe hyperthyroidism patients before surgery, it must be required to use the methimazole to interfere with the synthesis of thyroid hormones, use the β-receptor blocker to slow the ventricular rate down to lower than 90 beats/min, and use the compound iodine preparation to reduce the release of thyroid hormones. Furthermore, the hydrocortisone is additionally used to reduce the toxic response of the thyroid gland at 3–5 days before surgery, and a month of treatment is often needed at least to prevent the occurrence of postoperative thyroid crisis. The moderately severe hyperthyroidism patients must be supplemented with thyroid tablets before surgery, and the dose is gradually increased. Otherwise, it is prone to result in postoperative cardiopulmonary complications.

3. Surgical opportunity selection. For the patients who have an angina attack within a month and the onset of a myocardial infarction within 6 months, it is needed to postpone the elective surgery. Within 4–6 weeks after bare-metal stent implantation and within 12 months after drug-eluting stent implantation, if the dual antiplatelet therapy is prematurely stopped, this will significantly increase stent thrombosis and the risk of death or myocardial infarction, and thus, it is needed to postpone the elective surgery. The patients beyond the above time limit should stop using antiplatelet drugs for 7–15 days before undergoing the surgery.
4. Preoperative fasting and preanesthetic medication. The general anesthesia is usually performed for the patients who undergo oncoplastic surgery. The preoperative fasting time is 6–8 h for adults to prevent intraoperative vomiting, regurgitation, and aspiration. Because the oncoplastic surgical operation time is long, and the head and neck and facial surgeries are more commonly seen, the patients need to be treated preoperatively with oral anticholinergics to inhibit glandular secretion, with narcotic analgesics or sedatives to reduce the stress response in patients and with antacids to prevent the gastric mucosal damage caused by excessive gastric acid.

8.2.2 Anesthesia Plan

1. Airway management plan. The anesthesiologist should read the medical records carefully before surgery and refer to relevant imaging data to understand the scope of surgery, discuss with surgeons about the methods to establish an airway, and develop a detailed anesthesia plan. The methods to establish an airway mainly include the orotracheal intubation under rapid induction, transnasal intubation under rapid induction, awake oral or nasal intubation, and tracheotomy. If the patient has no obvious difficulty breathing before surgery, and the imaging data confirms that there is no airway obstruction, the fast-induced tracheal intubation can reduce a lot of pain in patients. The transnasal intubation is more conducive to fixation and preventing the tube from falling off due to changes in head position and is also conducive to postoperative indwelling tube to prevent possible occurrence of airway obstruction, and this ensures that the respiratory tract is unobstructed. If the patient has obvious symptoms of airway obstruction before surgery, it is supposed to carry out the awake nasal intubation guided by fiber-optic bronchoscope; if the scope of surgery involves the upper airway, for example, after reconstruction surgery of hypopharyngeal cancer and laryngeal cancer, there is still the possibility of airway obstruction, and thus, the tracheostomy tube can directly be used for ventilation.
2. Blood preparation. For the patients who have an estimated possibility of obvious and rapid blood loss, the red blood cells and plasma of the same blood type as the patient should be prepared. If the estimated blood loss exceeds 50% of the total blood volume, it should be considered to prepare the blood platelets; if the estimated blood loss exceeds 100% of the total blood volume, it is supposed to prepare the cryoprecipitate or the whole blood.
3. Psychological preparation. The tumor patients who need to undergo plastic surgery usually have larger masses, which locate most commonly in the face, mouth, and hypopharyngeal area. It is much more likely that the airway should be established firstly when the patient is awake, and then the general anesthesia is performed. The patients with tracheotomy are unable to speak for some time after surgery. Furthermore, there are some differences in color between the free skin flaps transplanted from different sites and the skins in the primary tumor sites, and this will affect the appearance. All these problems make patients face a lot of psychological pressures. The anesthesiologists should conduct detailed communications with the patients before surgery to obtain the trust of the patients and make them actively cooperate with treatments, thus preventing the occurrence of offensive behaviors in patients.
4. *Intraoperative anesthesia options and management*

(1) Anesthesia options: The oncoplastic surgeries mainly include the tumor resection and skin flap repair for scalp cancer, eyelid tumor, lip cancer, tongue cancer, maxillofacial tumor, maxillary tumor, mandibular tumor, hypopharynx and cervical esophagus cancer, breast cancer, chest wall tumor, abdominal wall tumor, upper limb tumor, limb tumor, etc.; in addition

to the use of intraspinal anesthesia in abdominal and lower limb surgeries and the use of brachial plexus nerve block in the upper extremity surgery, it is supposed to choose general anesthesia for the surgeries in other sites of the body to ensure that the surgery is painless and safe.

(2) Induction and maintenance of the general anesthesia: It is common to carry out the total intravenous anesthesia or the intravenous inhalational anesthesia. The use of the mutual synergy between analgesics, intravenous or inhaled anesthetics, and muscle relaxants makes patients obtain the ideal anesthesia effect. In intravenous and inhaled anesthetics, it can be selected to use the midazolam and propofol for induction or the sevoflurane for induction, and the general anesthesia can be maintained with propofol target-controlled infusion or continuous infusion and the isoflurane and sevoflurane inhalation. Among the analgesics, the fentanyl, sufentanil, or remifentanil can be selected and used for induction and maintenance; among the muscle relaxants, the depolarizing muscle relaxant succinylcholine or the non-depolarizing muscle relaxants rocuronium, cisatracurium besylate, and vecuronium bromide can be selected and used for induction, and the rocuronium bromide, vecuronium bromide, atracurium, and cisatracurium besylate can be selected and used for maintenance. Since the advent of the non-depolarizing muscle relaxant rocuronium and cisatracurium besylate, the safety degree of anesthesia induction and intubation is greatly improved, while the depolarizing muscle relaxant succinylcholine with rapid onset and fast fading and with more side effects has been rarely used. Because the operation time for the tumor is very long, it is mostly advocated that the intraoperative anesthesia is maintained directly with micro pump injection or target-controlled infusion to avoid drug overdose and the occurrence of body movement in patients.

8.2.3 Anticoagulant and Antispasmodic Drugs Commonly Used in Surgery

1. Low molecular dextran. The relative molecular mass of the low molecular weight dextran is about 40 KD, and the application concentration is 10%. It has a higher permeability compared to the plasma, and its colloid osmotic pressure is two times larger than that of the albumin.
   (1) Main functions: (1) It can increase the plasma colloid osmotic pressure and can provide an effect of expanding blood volume for 6 h; (2) it can reduce blood viscosity, thereby improving microcirculation to prevent intravascular coagulation in the later period of shock; (3) it can suppress the activation of blood coagulation factor II, decrease the activities of coagulation factors I and VII, and prevent platelet adhesion and aggregation to prevent thrombosis; (4) it has a good rheological effect on leukocyte adhesion, which may be beneficial to the ischemia-reperfusion injury.
   (2) Main indications: (1) Blood loss, trauma and toxic shock, and early prevention of disseminated intravascular coagulation caused by shock; (2) thrombotic diseases such as cerebral thrombosis, angina and myocardial infarction, thrombosis obliterans, and retinal arteriovenous thrombosis; and (3) limb replantation and vascular surgery operation and the improvement of the success rate of vascular anastomosis and replantation
2. Anisodamine. Anisodamine mainly refers to the artificially synthesized 654–2. Its main role is to relieve vasospasm and improve mini circulation, and thus, it can be used to treat shock. The efficacy will be observed at 1–4 min after intravenous injection, and it is demonstrated as the face turns red and the blood circulation in nail bed is improved. 5–10 mg anisodamine is injected intravenously every time, or 10–20 mg anisodamine is added into 500 ml solution for intravenous drip.
3. Dipyridamole. Dipyridamole is an antianginal drug, and it is used to reduce platelet aggregation and inhibit thrombosis during microsurgery. After the intraoperative intravenous infusion of dipyridamole, the wound bleeding will not be easily solidified. Usage: 5–10 mg dipyridamole is added into 500 ml solution for intravenous drip.
4. Tolazoline. The tolazoline is an α-receptor blocker, and it can expand the blood vessels. Usage: 25 mg tolazoline is used for intramuscular injection, and the intramuscular injection can be performed once every 8 h after surgery.
5. Phentolamine. The phentolamine is an α-receptor blocker, and it can expand the blood vessels. Usage: 5 mg phentolamine is added into 500 ml solution for slow intravenous drip.
6. Heparin. The heparin was systemically used when the blood vessels were anastomosed in the past, but now it is rarely used. Furthermore, it only is used in exceptional circumstances by experienced physicians. The heparin has a good efficacy in preventing coagulation and improving microcirculation. Usage: The topical area is washed with diluted heparin. 50–100 U heparin is added into 200 ml of normal saline, and then the local vascular anastomotic stoma is lavaged or washed with a syringe.
7. Local anesthetics. 0.25% to 0.5% lidocaine or 0.5% to 2% procaine solution can be used to wash the anastomotic stoma, but such usage results in minimal absorption. Generally, it is available for use after being added into diluted heparin solution.

8.2.4 Application of Special Techniques in the Surgery

1. Controlled hypotension. In huge craniofacial surgery and the surgery with double skin flap graft, the controlled hypotension can be performed to reduce blood loss and maintain a clear operative field. During depressurization, attention should be paid to recovering the blood pressure to near basal level before the end of surgery to avoid the incidence of postoperative recurrent wound bleeding caused by imperfect hemostasis under hypotension.
2. Cryogenic techniques. The application of cryogenic techniques aims to reduce the metabolism of the vital organs in vivo, especially the brain, so as to reduce the oxygen consumption and thus significantly prolong the duration of tolerance to ischemia and hypoxia in the body. In the operations of oral and maxillofacial surgery and plastic surgery, the cryogenic techniques are often used in the operations with larger trauma and more bleeding as well as involving the craniocerebral region, such as the resection of huge facial neurofibroma and carotid body tumor, the craniofacial extended radical surgery, and the repair and reconstruction of complicated deformities in the cranial maxillofacial area. During the implementation of the cryogenic techniques, the degree of hypothermia should be determined based on the specific circumstances of the surgery or treatment. In most of oral and maxillofacial surgery, it is not needed to block the blood supply to the whole body or the great vessels, and the main purpose is to reduce metabolism and reduce oxygen consumption. Therefore, the mild hypothermia (30–34 °C) is more commonly used. In some special cases, when blocking the blood supply to large vessels (such as the carotid artery) or carrying out the complex craniofacial surgery, it is appropriate to decrease the body temperature to a lower level to reduce the damages caused by the cerebral compression and the cerebral ischemia-hypoxia.

8.3 Intraoperative Monitoring

The oncoplastic surgery lasts long, and the surgeons stand around the patient's head, which keeps the anesthesiologist away from the respiratory tract of the patient. Therefore, strengthening intraoperative monitoring is very important.

8.3.1 Routine Monitoring Items

ECG, noninvasive blood pressure, oxyhemoglobin saturation, and urine output are the essential monitoring items in any surgical procedures.

8.3.2 Hemodynamic Monitoring

The operators should understand timely the statuses of the hemodynamics, pulmonary circulation, and cardiac function and maintain a stable circulatory function.

1. Invasive arterial blood pressure monitoring. It can quickly reflect the blood circulation status. The catheterization of the radial artery or the dorsalis pedis artery is commonly used. The arterial pressure is converted into electrical signals through the transducer, and the result is expressed as digital numbers after computer processing. Although all stroke volumes can be displayed into blood pressure values, the arterial blood doesn't flow all the way within the whole length of the catheter during the monitoring period. Therefore, the catheter must be washed with heparin solution every once in a while to prevent blood clotting which will affect the results of blood pressure monitoring.
2. Determination of central venous pressure and pulmonary artery pressure. The relative changes in central venous pressure often indicate the change in blood circulation volume, thus providing a reference for blood and fluid transfusion. The jugular vein catheterization or subclavian vein catheterization is commonly carried out, and the femoral vein puncture can also be carried out. The femoral vein puncture can be performed in a place away from the surgical area, but it is prone to cause infection. The catheter is required to reach the level above the diaphragm (about more than 40 cm); thus, the pressure measurement can only be accurate. If the catheter only reaches the level under the diaphragm, the pressure measurement will be inaccurate due to the impact of the abdominal pressure.
3. Determination of mixed venous oxygen saturation (SvO_2). It may be considered necessary to dynamically monitor the SvO_2 (the normal values are 68% to 77%, with an average value of 75%) in some patients with moderately to severely decreased cardiopulmonary function. When SvO_2 is less than 60%, this usually indicates the increased tissue oxygen consumption or poor cardiopulmonary function. The arterial venous oxygen content difference is calculated through determination of SvO_2, and it can more accurately reflect the cardiac output. Waller et al. have pointed out that SvO_2 has a strong correlation with cardiac index, stroke volume index, and left ventricular stroke work index. When SvO_2 is decreased, and the arterial oxygen saturation and oxygen consumption are still normal, this proves that the cardiac output is also low. Therefore, it is now considered that the determination of mixed venous oxygen saturation has an important value in monitoring the serious cardiopulmonary diseases.

8.3.3 End-Tidal Carbon Dioxide Partial Pressure ($PetCO_2$) Monitoring

$PetCO_2$ must be monitored during the implementation of the oncoplastic surgery under general anesthesia, and the normal value is 4.66–6.00 kPa (35–45 mmHg). $PetCO_2$ monitoring has the following advantages: (1) Whether the endotracheal catheter is located within the trachea can be determined from end-tidal carbon dioxide waveform. (2) It can provide guidance in the setting of respiratory parameter. If $PetCO_2$ is increased higher and higher, this will indicate insufficient ventilation and carbon dioxide accumulation. On the contrary, if $PetCO_2$ is decreased lower and lower, this will indicate excessive ventilation, and it is needed to reset the parameters of the anesthesia respirator. (3) If the end-tidal carbon dioxide waveform is presented as a straight line, this usually suggests that the catheter has fallen off. (4) If $PetCO_2$ is unusually decreased, this suggests the possibility of massive blood loss.

8.3.4 Body Temperature Monitoring

The duration of oncoplastic surgery is longer, and the changes in body temperature should be continuously monitored during surgery.

8.3.5 Monitoring of Anesthesia Depth and Muscle Relaxation

During surgery, Bis or Neotrend can be used to continuously monitor the anesthesia depth, and the muscular relaxation monitor is used to continuously observe the muscle relaxation to keep the patient at an appropriate level of anesthesia and avoid that the light anesthesia may cause body movement in the patient and thus lead to the intraoperative awareness and even affect surgical operation; it should be avoided that too deep anesthesia induces delayed postoperative recovery and increases the incidence of postoperative respiratory complications.

8.3.6 Intracranial Pressure Monitoring

The intracranial pressure should be continuously monitored during the large craniofacial surgery, and the intracranial pressure can be regulated and controlled timely in a relatively safe range according to the dynamic monitoring results. A certain depth of anesthesia is maintained during surgery to avoid agitation and movement. Some methods can be used to reduce the intracranial pressure when necessary: (1) The hyperventilation is carried out. If PetCO2 is controlled between 25 and 30 mmHg, a sufficient decrease in the intracranial pressure can be achieved; (2) the right amount of mannitol or glycerin fructose is intravenously infused; (3) the adrenal cortical hormone is applied; (4) the subarachnoid catheter placement is performed to drain the cerebrospinal fluid.

8.3.7 Determinations of Blood Gas Analysis, Electrolytes, Blood Glucose, Hemoglobin, and Hematocrit

Blood gas analysis and electrolyte can be determined for avoiding hypoxia, carbon dioxide accumulation, and acid-base imbalance; the blood glucose can be determined for maintaining a stable blood sugar level and preventing the occurrence of high blood sugar or hypoglycemia; the hemoglobin (Hb) and hematocrit (Hct) can be determined for guiding the intraoperative blood transfusion and maintaining an appropriate degree of blood dilution.

8.4 Airway and Respiratory Management

8.4.1 Intubation Pathway

The oral intubation, nasal intubation, and transtracheostomy intubation are available for selection. The oral intubation is firstly preferred, and it can prevent the damage to the nasal mucosa caused by the tube. But the oral intubation is not conducive to postoperative indwelling tube. Therefore, for the patients who may have difficulty breathing after surgery, it is preferable to carry out the nasal intubation and transtracheostomy intubation.

8.4.2 Intubation Method

The intubation under intravenously induced rapid anesthesia, the awake intubation under topical anesthesia, and the intubation under inhalation anesthesia are available for selection. The tools which are used to examine the glottis include ordinary laryngoscope, video laryngoscope, rigid laryngoscope, fiber-optic laryngoscope, etc. The tools for managing the difficult airway also include laryngeal mask, esophageal-tracheal combined tube, blind tracheal intubation instrument, optical cable, thyrocricotomy devices, and percutaneous tracheostomy devices.

8.4.3 Intraoperative Respiratory Support

The endotracheal tube is properly fixed. A long extension tube and an end-expiratory carbon dioxide sensor are connected to the anesthesia respirator for mechanical ventilation. The parameters of the respirator are set according to the specific circumstances of the patient and are adjusted at any time in accordance with oxyhemoglobin saturation, end-tidal carbon dioxide partial pressure, and blood gas analysis results. The anesthesiologists should always observe the position of the tube to prevent twisting, folding, and slippage of the tube and observe the color change of the carbon dioxide absorbent, which should be replaced in time combined with the objective indicators such as end-tidal carbon dioxide partial pressure.

8.4.4 Volume Replacement and Blood Conservation

The modern view is that the volume replacement not only aims to maintain hemodynamic stability, avoid volume overload, and ensure the normal blood clotting function and renal function, more importantly, but it also aims to guarantee the tissue oxygen supply and optimize the tissue perfusion. Therefore, selecting the appropriate plasma substitute is the key for safe and effective volume replacement. The anesthesiologists should select the appropriate plasma substitutes based on the characteristics of the patient's disease, blood pressure, central venous pressure, and urine output changes to replenish the fluid volume for fluid loss and redistribution as well as the evaporation in wounds and surgical field due to the preoperative fasting, surgical trauma, and anesthesia and ensure adequate volume and microcirculation in the patient.

8.4.5 Choice of Plasma Substitutes

The ideal plasma substitute should have stable physical and chemical properties, and it can quickly supplement the blood volume, increase tissue perfusion, and have sufficient residence time in blood vessels. Meanwhile, it has no significant effects on the blood clotting function and the renal function and has no allergic reaction and tissue toxicity. It can improve oxygen supply and organ function, and it is easily metabolized and removed in the body.

Plasma substitutes can be divided into two categories according to the relative molecular mass size, namely, the crystalloid solution and the colloidal solution. The solution, in which the diameter of the solute molecule or ions is less than 1 nm, or it will not generate a light reflex phenomenon when it is penetrated through by the light beam, is called the crystalloid solution, such as normal saline, Ringer's lactate solution, invert sugar and electrolyte solution, and hypertonic saline; the solution, in which the diameter of the solute molecule or ions is greater than 1 nm, or it will generate a light reflex phenomenon when it is penetrated through by the light beam, is called the colloidal solution. The colloid is divided into three categories according to different structures: (1) proteins (gelatin), such as human serum albumin, succinylated gelatin (Gelofusine), and polygeline; (2) starches (polysaccharide), such as hydroxyethyl starch (706 plasma substitute, HES, Voluven) and dextran (70, 40); and (3) others, such as hypertonic sodium chloride hydroxyethyl starch (Holme).

The effect of expanding blood volume and the adverse reactions are compared between the plasma substitutes, and the results showed that the colloidal solution is superior to crystalloid solution. The natural colloid albumin has limited resources and is expensive and has a risk of spreading disease. In the clinic, it is only used in special circumstance such as correcting hypoalbuminemia. The gelatin solution in artificial colloid has a relatively small molecular mass and a less impact on blood clotting function, but its duration of action on expanding blood volume is shorter. At the same time, it has a higher risk for occurrence of allergic reaction. The dextran solution has a relatively large molecular mass, and the duration of its action on expanding blood volume has been extended to some extent compared with the gelatin solution, but it also has an increased impact on blood clotting function. The effect of expanding blood volume of hydroxyethyl starch is best, and the old-generation hydroxyethyl starch with higher relative molecular mass, degree of hydroxyethylation, and C2/C6 ratio has a longer duration of action on expanding blood volume, but it has a greater impact on blood coagulation and renal function; while the new-generation hydroxyethyl starch with middle molecular mass (HES, Voluven) not only retains the effectiveness of expanding blood volume of the old-generation hydroxyethyl starch, it also greatly reduces the impacts on blood coagulation and renal function. It can significantly improve visceral blood flow and oxygenation, prevent capillary leakage, reduce capillary permeability, reduce the endothelial cell activation after ischemia-reperfusion, reduce endothelial injury, and maintain the stability of endothelium, thereby reducing the inflammatory response. Its allergic reaction incidence rate is the lowest in all colloidal solution used in clinic; thus, it becomes a more ideal colloidal solution.

8.5 Blood Conservation

Blood conservation refers to carefully protecting and preserving the patient's own blood to prevent its loss, destruction, and contamination and managing and using well the precious natural resources in a planned way, thus preventing the occurrence of the transfusion transmitted diseases and complications. In addition to strictly controlling the indications for blood transfusion and avoiding unnecessary allogeneic transfusions, the blood conservation measures which can be selectively used in the perioperative period of the tumor operation include preoperative autologous blood storage and the use of erythropoietin, intraoperative acute normovolemic hemodilution, intraoperative acute hypervolemic hemodilution, use of antifibrinolytic drugs, and controlled hypotension. The anesthesiologists should make a choice based on the specific condition of the patient, the operating room facilities, and the personal experience, and two or more types of blood conservation methods can usually be used.

8.5.1 Preoperative Autologous Blood Donation and the Use of Erythropoietin

Preoperative autologous blood donation (PABD) refers to that a certain amount of autologous blood are collected several times from the patient at 2–4 weeks before surgery and then

are stored, and these autologous blood will be infused back into the patient on the day of surgery to meet the need of surgical blood. In the process of preoperative blood storage, the patient can take oral iron supplements and be treated with erythropoietin to promote erythropoiesis. PABD requires that the patient is in generally good condition, with no anemia (Hb > 110 g / L, Hct > 33%) and no serious heart and lung disease. Its main advantage is that it causes no antigen-antibody reaction and is relatively safe, and it can economize the source of blood and has no infectious diseases. It is mostly suitable for patients with a rare blood type and the allergy to foreign proteins; its main drawback is that the blood may be contaminated in the process of collecting blood, and the hemolytic reaction may occur in the stored blood, and thus the length of stay of the patient is longer. Walther-Wenke et al. made a statistics on related reactions to 22,630 autologous blood transfusions in 21,553 patients which were reported in the relevant literatures and found that the incidence of sepsis was markedly lower than that in patients receiving allogeneic blood transfusion, and the incidence of blood transfusion reaction was also very low, which was about 1/4500. The main problem is that sometimes the operational errors may appear.

8.5.2 Intraoperative Acute Normovolemic Hemodilution

The acute normovolemic hemodilution (ANH) refers to the blood conservation method that the anesthesiologist collects a certain amount of blood from the artery or deep vein of the patient and stores it for a while after anesthesia induction and before the start of surgery; meanwhile, the circulating blood volume of the patient is supplemented with colloidal solution (1:2), and the diluted blood is used to maintain the function of circulation during surgery, minimize the hematocrit, and thus reduce the absolute loss amount of red blood cells in the blood; then the collected blood is reinfused into the patient before the end of surgery. ANH is simple and operable, and it costs less compared with preoperative autologous blood storage or application of recombinant erythropoietin and the intraoperative or postoperative autologous blood recovery. The collected blood is stored at room temperature in the operating room, it is less error-prone, and the blood will not be contaminated.

1. Major indications: (1) The expected amount of surgical bleeding > 800 ml, (2) the patients with rare blood type who need to undergo major surgery, (3) the patients with religious beliefs who refuse allogeneic blood infusion, and (4) polycythemia, including the polycythemia vera and the polycythemia caused by chronic hypoxia
2. Major contraindications: (1) Anemia, Hct <30%; (2) hypoalbuminemia, serum albumin <25 g/L; (3) coagulation disorders; (4) the elderly or the children; (5) increased intracranial pressure; and (6) vital organ dysfunction, such as myocardial infarction, pulmonary hypertension, respiratory insufficiency, and renal insufficiency

The acute normovolemic hemodilution is a relatively safe measure for effective blood conservation. According to some basic researches, ANH, combining with controlled hypotension, can cause hypoxia-ischemia brain injury when Hct ≤ 20%, which demonstrates as the mitochondrial degeneration in the hippocampal CA1 region, nuclear enrichment, aggregation, and nuclear membrane deformation. Furthermore, the expressions of NF-$_{\kappa}$B and tumor necrosis factor-α (TNF-α) in the cerebral cortex are increased; thus, it is recommended that ANH combined with controlled hypotension should be avoided when Hct ≤ 20%.

8.5.3 Intraoperative Acute Hypervolemic Hemodilution

The acute hypervolemic hemodilution (AHH) refers to that the patent is rapidly infused with a certain amount of crystalloid solution or colloidal solution (20–25 ml/kg) after anesthesia induction and within 25–30 min before surgery, while the autologous blood is not collected, so that the hematocrit is reduced into the physiological limits. The patient is supplemented with the same amount of colloidal solution for the intraoperative bleeding and with the same amount of crystalloid solution for the urine and evaporated water in surgical field, so that the blood volume remains in the hypervolemic state during surgery. AHH is simple and operable, and it has good timeliness and causes little damage to the blood components.

1. Major indications: (1) Complicated noncardiac surgery, such as oncoplastic surgery, esophageal cancer surgery, colon cancer surgery, hepatobiliary surgery, and orthopedic surgery; (2) the heart, lung, liver, kidney, and blood coagulation functions are normal before surgery; (3) Hct > 35% and Hb > 120 g/L; (4) the estimated blood loss is about 800 ml; (5) the patients cannot (or would not) receive allogeneic blood transfusions
2. Major contraindications: (1) Anemia (Hb <100 g/L), (2) demonstrable clinical cardiopulmonary dysfunction, (3) untreated hypertension, and (4) coagulation dysfunction

Mielke et al. observed the effects of ANH and AHH on parameters such as the intraoperative and postoperative blood loss, the proportion of allogeneic blood transfusion, postoperative hemoglobin, hematocrit, platelets, and blood clotting function and found that there are no significant differences between ANH and AHH, but the ANH is more time-consuming, and it costs more. Therefore, it is considered that the patient with about 1000 ml of estimated blood loss can be treated with AHH instead of ANH.

8.5.4 Application of Antifibrinolytic Drugs

Before resection of the primary lesion in the oncoplastic surgery, it is considered to use some antifibrinolytic drugs with short half-life to reduce the blood loss and allogeneic blood transfusion caused by the resection of the primary lesion.

1. Aprotinin. Aprotinin is natural polypeptide-serine protease inhibitor. It can inhibit plasmin, kallikrein, trypsin, and chymotrypsin and slow down the activation of the complements. It not only blocks the endogenous coagulation pathway, but it also protects the extrinsic coagulation pathway; it not only has a protective effect on platelets, but it also has a systemic anti-inflammatory effect. Therefore, it may prevent the patient from massive blood loss induced by the activation of fibrinolysis. It is noted that the patient is prone to allergic reaction when using aprotinin.
2. Hemocoagulase. The action target of hemocoagulase (sulindac) is clear, and the hemocoagulase plays an effect only on fibrinogen. It does not contain prothrombin activators and does not activate the coagulation factor VIII. Therefore, from the mechanism level, this avoids the potential risk of the blood hypercoagulable state and the thrombogenesis within the normal blood vessel wall which may occur after the use of blood clotting enzyme drugs. Pharmacokinetic studies showed that the half-life period of hemocoagulase is 2.5 h. The hemocoagulase is mainly distributed in the blood, and it can be removed quickly from the body, and thus there is no drug accumulation.

But it is not advocated that the antifibrinolytic drugs are applied after the primary lesion is resected and the bleeding is stopped, in order to avoid the effect of the blocking of the anastomosed blood vessel on the blood supply of the skin flap.

8.5.5 Controlled Hypotension

The intraoperative blood loss can be reduced through performing controlled hypotension when the primary lesion is resected.

8.6 Allogeneic Blood Transfusion

In 1998, China formally promulgated the Blood Donation Law of the People's Republic of China. In 2000, the Ministry of Health developed the Technical Specification of Clinical Transfusion, which has promoted the great progress of blood conservation and saving the usage of blood. The Hb value which is controlled as an indication for blood transfusion gradually decreases from less than or equal to 100 g/L to 80–90 g/L, and it has been decreased to 70 g/L in some operations. But no matter what kind of blood conservation measures are adopted, and no matter how the blood transfusion indication is controlled strictly, some patients undergoing oncoplastic surgery still need to receive allogeneic blood transfusion, and the anesthesiologists and the surgeons should master the following principles.

8.6.1 Implementation of Blood Component Transfusion

In order to save blood resource, it is mostly advocated that the principle of supplementing what the patient lacks should be abided by. The red blood cells can be infused to maintain a certain degree of hematocrit and carry oxygen for tissue cells to use, and the patient with blood loss of more than 20% of blood volume should be supplemented with red blood cells. The plasma is mainly infused to expand the blood volume, and the fresh frozen plasma contains some fibrinogens and blood coagulation factors. The patient with massive blood loss (more than 50% of blood volume) should be supplemented with plasma according to 10 ml/kg, and this can play a certain role in preventing secondary hyperfibrinolysis at the same time of expanding the blood volume. Because the blood platelets and cryoprecipitate must reach a certain concentration to play a better hemostatic effect, and it is more difficult to stop bleeding after large volume hemodilution, it is considered that the patient with a blood loss exceeding 50% of the blood volume should be supplemented with blood platelets according to 0.1 U/kg; the patient with a blood loss exceeding 100% of the blood volume should be supplemented with coagulation factors (i.e., cryoprecipitate) according to 0.1 U/kg, and the patient with a blood loss exceeding 100% of the blood volume had better be infused with fresh whole blood. With improvements in surgical techniques, the patients can safely pass through the perioperative period basically through blood component transfusion.

8.6.2 Paying Attention to the Warming of Banked Blood

The infusion of a lot of blood at 4 °C will cause the temperature to decrease in the patient, and sometimes it can be decreased to 34 °C, and thus this leads to a series of biochemical metabolic disorders and the inhibition of cardiac function. Therefore, the banked blood must be pre-warmed; the warming methods include that the blood is warmed by the blood warmers or the blood bag is placed into warm water at 30–40 °C.

8.6.3 Selecting the Blood Products with Shorter Storage Time

When large quantity blood transfusion is needed, it is supposed to use the blood with shorter storage time as far as

possible, and the storage time is preferably within 5 days. In fact, in the banked blood which has been stored for 24 h, the activities of platelets have been basically lost; in the banked blood which has been stored for 3 weeks, from 85% up to 90% of the coagulation factors II and III have been destroyed.

8.6.4 Treatment of Transfusion-Related Complications

The blood transfusion can cause many acute and chronic phase reactions, especially the acute phase reactions; thus, the anesthesiologist should take an active prevention and treatment.

1. Acute urticaria, hypotension, and purpura. These are mostly the antigen-antibody reaction caused by allogeneic transfusion. It should be noted to strictly check blood type, control the blood transfusion speed, and follow the principle that the blood should be infused slowly at first and then faster; it is noted that the infusion tube should be rinsed clean as far as possible when the blood is replaced and the patient is intravenously injected with 5–10 mg dexamethasone before transfusion. Once the severe transfusion reactions occur, the blood infusion should be immediately stopped, and the patient is treated with corticosteroids. The patient with severe shock will be treated directly in accordance with the method for treating the anaphylactic shock, including intravenous or subcutaneous injection of adrenaline, the symptomatic and supportive treatment such as speeding up the infusion speed. The acute hemolytic reactions may lead to acute renal failure; thus, the patient should be supplemented with a lot of fresh whole blood and treated with blood purification immediately.
2. Bleeding tendency. This is a serious complication caused by massive transfusion, and it should be noted that the supplements of platelets and coagulation factors are carried out synchronously. In addition, because it is needed to consume the calcium ions in the blood clotting process, while a large number of potassium citrate in the banked blood can replace in vivo free calcium, the free calcium is reduced to affect the blood clotting and myocardial activities. It should be noted that 10–20 ml of 10% calcium gluconate or calcium chloride is used simultaneously every 1000 ml banked blood transfusion.
3. Hyperkalemia. If two to three venous pathways are developed simultaneously for massive transfusion of banked blood, this can cause acute hyperkalemia. Then it is supposed that the patient is immediately infused with the glucose and insulin to promote the potassium ions to enter into the cells, which are given according to the ratio of 1 U insulin versus 3–4 g glucose, or 10% calcium gluconate or 10–20 ml calcium chloride is infused to replace the potassium ion. The patients with severe acidosis are given simultaneously with 5% sodium bicarbonate for intravenous drip.
4. Respiratory distress syndrome. The banked blood contains tiny polymers which are composed of the fibrin network with platelets and the white blood cells, and they can clog the pulmonary capillaries, and thus causes respiratory distress syndrome. The shorter the storage time of the banked blood is, the less the formation of this substance is. 20–40 μm Millipore filters are selectively used, and they have certain preventive effect.

8.7 Application of Antibiotics

Most of oncoplastic surgeries which involve maxillofacial and oral areas are type IV operations with type II incisions, and it is needed to routinely use the broad-spectrum antibiotics during operation. The antibiotics are administered generally at 30 min before skin incision for the first time, which is repeated every 4 h, and the patient still needs to be treated additionally with anti-anaerobic bacteria drugs to prevent wound infection.

8.8 Management After Anesthesia

8.8.1 Postoperative Recovery

The vast majority of patients undergoing oncoplastic surgery can successfully regain consciousness in postanesthesia care unit (PACU) after surgery. In individual patients, since the anesthesia time is too long, the trauma is large, the basic condition is poor, or the age is too big, all of these would lead to that the anesthetics accumulate in body, the recovery is delayed, and the breathing recovery is dissatisfied; thereby, the patients need to be transferred into the intensive care unit (ICU) for continuous observation and treatment. The life-threatening phenomenon that the airway is obstructed again after extubation frequently occurs in the patients who have undergone head and neck surgery, and the anesthesiologist should pay particular attention to subtle changes in the patient's condition and strictly control the extubation indications to prevent the occurrence of accidents. The indications for extubation include:

(1) Consciousness recovery: The patient fully recovers consciousness and can answer questions (instructions) correctly.
(2) Respiratory recovery: The patient's respiration is recovered. The patient can maintain spontaneous breathing after the ventilator is deactivated; the respiratory rate is more than 10 to 12 beats/min; the oxygen saturation is maintained at around 95%; the patient has no significant

symptom of airway obstruction; the results of blood gas analysis is normal for 30 min.

(3) Reflex recovery: The laryngeal reflex, pharyngeal reflex, and muscular tension are fully recovered, and the patient can open eyes, look up, and shake hands.

For the patients who achieve the above conditions, the endotracheal extubation is performed in the presence of a surgeon and with tools to reestablish the airway. If all indicators are normal after extubation, the patient can take a sitting position, and the patient can be sent back to the ward after no symptom of airway obstruction is observed for 30 min.

8.8.2 Problems in Indwelling Endotracheal Tube

When the oncoplastic surgery involves the oral, maxillofacial, and cervical areas, the acute upper respiratory tract obstruction may occur due to muscle relaxation, glossocoma, throat or neck swelling, oozing or bleeding, and hematoma compression; the airway obstruction may occur after maxillofacial and cervical surgery due to the commonly used dressing bandage, transarticular flap, elastic fixation in bilateral zygomatic arches, and fixation with steel wire between the two jaws and the missing teeth. If the patient cannot undergo extubation after fully regaining consciousness in PACU, the patient can take the tube back to the ward and is continuously observed for 24–48 h, and the tube is retained maximally for 72 h. The tip of the steel wire flexible tube which is currently used has a small stimulation on airway wall. Under the condition of mild analgesia and sedation, the patient can generally retain the transnasal endotracheal tube for 24–48 h, and the extubation can be performed after the edema subsides. There must be a condition for carrying out tracheotomy when the extubation is performed, in order to establish the airway at any time. If the possibility that the airway will be obstructed again is very large, and there are still a lot of secretions and the edema is obvious after the tube is retained for 24–48 h, it is best to carry out the tracheotomy immediately to ensure patient safety and facilitate expectoration.

8.8.3 Postoperative Analgesia, Sedation, and Anti-vomiting

The postoperative nausea, vomiting, and restlessness may lead to a contaminated wound and damage the organs and tissues which have been repaired. The restlessness may be due to pain or intravesical catheter stimulation. The nausea and vomiting may be due to that the pharyngeal area is stimulated by the secretions or effused blood, or the stomach is stimulated by swallowed secretions or blood; the nausea and vomiting may also be the adverse reactions of the anesthetic drugs. It should be noted that the fentanyl plus a small dose of anti-inflammatory analgesics is used postoperatively in patient-controlled analgesia to alleviate the pain and also play a mild sedating effect, and this facilitates the patient to have a good rest. At the same time, the 5-HT3 receptor antagonists are routinely used to stop vomiting and prevent the occurrence of nausea and vomiting, and the secretions of the oropharyngeal cavity are cleaned timely by suction to reduce throat irritation.

8.8.4 Prevention of Complications

Statistics show that the complication rate in ICU patients after oncoplastic surgery with an average duration of 9 h reaches 57.4%; the hospital stay in patients older than 60 years is obviously prolonged, and the smokers are more prone to developing short-term complications. According to the American Society of Anesthesiologists (ASA) classification, the survival rate especially the long-term survival rate is lower in patients with grade 3–4 tumors. Another analysis on the complications of 469 cases of head and neck surgery showed that after such surgery, the cardiovascular complication rate is 12%, the respiratory complication rate is 11%, and the incidence of the heart failure is higher than that of the pneumonia. The high-risk period for cardiovascular complications is the first day after surgery, and the high-risk period for respiratory complications is the second day after surgery. The risk factors for cardiovascular complications include age, lung disease, alcoholism, and improper tumor site; the risk factors for respiratory complications include lung disease, pre-existing myocardial infarction, and higher ASA classification. Therefore, for the elderly, weak, and smoking patients after surgery, attention should be paid to preventing the occurrence of lung infections and cardiocerebral events, correcting water and electrolyte disturbances, acid-base balance disorders, and hypoproteinemia and preventing the poor blood supply to the skin flap due to that the blood is too concentrated [25].

9 Effect of Preoperative Radiotherapy on Skin Flap Graft in Oncoplastic Surgery

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The integrated treatment of the tumor refers to that the existing treatment means are used purposefully, designedly, and reasonably based on the body condition of the patient and the pathological type, invasion range, and development trend of the tumor to significantly increase the cure rate and improve the patient's quality of life. The integrated application of surgery and chemoradiotherapy brings to the malignant tumor patients a more satisfactory therapeutic effect compared with before. The integrated treatment cannot only cure the early stage tumors, but it can also protect the function and appearance; it can increase the chance of cure for patients with

middle-stage tumors, expand the surgery resection rate for patients with middle-late-stage tumors, and try hard to win a better curative effect for patients with recurrent malignant tumors. The integrated treatment of the tumor needs to be completed through multidisciplinary collaboration of oncology surgery, radiation therapy, and chemotherapy.

However, the concept of integrated treatment of the tumor brings out another question to the medical experts in clinical oncology: What kind of impacts will the inevitable radioactive damages caused by radiation therapy bring on the post-surgical incision healing, the skin flap graft in oncoplastic surgery, and the repair and reconstruction of postoperative defects? This is the problem the medical workers have to study and solve; this section will make a preliminary discussion on this problem.

9.1 The Healing Process of the Normal Tissues

The tissue healing is a complex and orderly biological process of the response of tissues to trauma and repair. Theoretically, the tissue healing can be divided into three phases: the inflammatory phase, the fibrous proliferative phase, and the scar formation and reparative phase.

9.1.1 The Inflammatory Phase

The inflammatory phase starts from the tissue damage and lasts for 3–6 days under the physiological conditions. The physiological process is divided into the following stages: The damaged tissue cells release the vascular active substances to cause local vasoconstriction; at the same time, the platelets aggregate to activate the coagulation system, and the fibrinogen is converted into an insoluble fibrin network to produce blood clots to seal off the damaged blood vessels and protect the wound.

At 2–4 h after skin tissue damage occurs, the phagocytic cells begin to move into the wound and swallow the debris, foreign bodies, and microorganisms within the wound. In the early phase of inflammation, the neutrophils are seen mostly, and they secrete a variety of inflammatory mediators, namely, cytokines such as tumor necrosis factor-α and interleukin in the wound. Meanwhile, the neutrophils engulf bacteria and release the proteolytic enzymes to remove the damaged and deactivated components in extracellular matrix. After swallowing the tissue and cell debris, the phagocytic cells will be decomposed, and then the decomposed phagocytic cells together with the lysed tissues form into pus, which needs to be cleared away from the wound through changing dressings and local drainage. The accumulation of pus in the wound will also affect the healing of the wound.

The macrophages are attracted by chemotaxis-stimulating substance such as bacterial toxins and are further activated by the neutrophils, and they enter into the wound from the blood in large quantities and secrete the cytokines (such as interleukin-1, interleukin-2, tumor necrosis factor-α) which promote the inflammatory reaction and a variety of growth factors (such as basic fibroblast growth factor, epidermal growth factor, platelet-derived growth factor). These growth factors are polypeptides, and they can attract and promote cells to enter into the inside of the wound, stimulate cell proliferation, and precisely control the wound healing by means of complex interactions.

The inflammatory reaction is a complex defense reaction of the body, and its purpose is to remove or inactivate harmful substances, remove the necrotic tissue, and create favorable conditions for the subsequent proliferation. The inflammatory reaction exists in any process of wound healing and has four typical symptoms such as red, swelling, fever, and pain in suffered area.

9.1.2 The Fibrous Proliferative Phase

The fibrous proliferative phase is also known as granulomatous phase. In this phase, the angiogenesis and vascularization are the basis for the growth of granulation tissue. The granulation tissue consists of tissue connecting cells, small blood vessels, and collagen.

Under the stimulation of growth factors, the endothelial cells of the vessel wall break through the basement membrane to move into the area around the wound and form into vascular buds through cell division. The single vascular bud grows into another vascular bud, and two vascular buds are integrated and formed into vascular access and then are further integrated and formed into vascular branch, vascular net, and capillary loop. This process is also known as a process of the reconstruction of capillary vessels, and it takes 1–4 days to complete the entire process. The angiogenesis is the basis to ensure an adequate supply of oxygen and nutrition to the wound. If there is no vascular angiogenesis and reconstruction, there will be no growth of the granulation, and the wound also cannot heal.

When the neovascularization occurs, each granulation has a corresponding vascular branch and is accompanied by a large number of capillary loops. The collagens are produced initially by fibroblasts, and the fibers are formed in the cells to support the granulation tissue. The granulation tissue fills the basal layer of the wound, and it can seal the wound and is taken as the basis for epithelialization. The formation degree of granulation tissue is directly related to the extent of blood coagulation and inflammatory reaction, including the debridement process of the body under the assistance of the phagocytosis.

The fibroblasts are the main functional cells in the process of wound healing. After the trauma occurs, the fibroblasts enter into the local area to proliferate, differentiate, synthesize, and secrete the collagens. If there is hematoma, necrotic

tissue, foreign body, or bacteria in the wound, the transition of the fibroblasts and the formation of new blood vessels will be delayed.

Modern researches have shown that there are fibroblasts in different stages in the wound. Their secretory activities are different, and their responses to growth factors are also different. These characteristics are extremely important for wound healing.

9.1.3 The Scar Formation and Reparative Phase

The scar formation and reparative phase is also known as maturation phase or epithelial formation phase. After the secretory activities of the fibroblasts in the wound are finished, some are turned into the stationary fibroblasts, namely, fibrocytes, and some are turned into myofibroblasts. The morphology of the myofibroblast is just like that of the smooth muscle cell, and it contains the contractile actins, which can tighten the edges of the wound and make them shrink. This process begins at 2 weeks after the injury, and the wound will continuously shrink and get smaller at a speed of 0.6–0.7 mm a day regardless of the size of the wound area.

The cells in the skin basal layer with metabolic activity have an unlimited potential in mitosis, and its physiological process is as follows: After the epidermis is damaged, the wound area is short of a large number of cells that secrete the chalones; thereby, the "epidermal chalone" level is significantly decreased in cells, and the mitotic activity is increased in the basal cells. This process initiates cell proliferation required to fill the defect. The cells migrate from the basal layer to the surface of the skin, and the repair is carried out in the linear and opposite direction to the wound edge through cell maturation, repair, and cell replacement. The formation of epithelia in the wound edges starts from where the epithelial integrity is broken, and the divided epithelial cells creep and grow to the other side through amoeba-like movement, which is similar to the activity of the unicellular organism. The wound is covered by new epithelial cells formed through mitosis and cell migration, which marks the completion of the wound healing process.

9.2 The Wound Healing of Radioactive Injury

9.2.1 The Characteristics of Wound Healing of Radioactive Injury

1. The early inflammatory reaction in the wound healing of radioactive injury is significantly inhibited, and the wound effusion is decreased, especially the leakage of leukocyte is decreased mostly. The tissue necrosis is increased, and the bleeding is extensive.
2. The growth and maturation of granulation tissue in the wound of radioactive injury are slowed down. The fibroblasts are severely damaged, and the radiation fibroblasts appear. The synthesis and secretion of the collagens in the wound are inhibited, and the wound contraction is also affected.
3. The process of the epithelial cells covering the wound of radioactive injury is lagged, and the wound healing process is delayed [26].

9.2.2 Effect of Radioactive Rays on Wound Healing

1. Diminished inflammatory reaction. The radioactive rays lead to early inflammatory reaction in wound healing, and the wound effusion is decreased, especially the leakages of monocytes and neutrophils are decreased, which is very unfavorable for the initiation and development of wound healing process and the removal of necrotic tissue. The causes for diminished inflammatory reaction may include: (1) The numbers of white blood cells and platelets are decreased in the peripheral blood of the patients with the wound of radioactive injury at the early phase; (2) the radioactive rays destroy the vascular structure in the bottom of the wound and the surrounding tissue, which leads to degeneration, necrosis, and falling off of the endothelial cells and affects the attachment of leukocytes to the vessel walls and their adhesion and emigration; (3) the tissues surrounding the wound of radioactive injury slow down the migration of leukocytes.
2. The injury of tissue cells around the wound. The lethal or sublethal damages to the tissue cells around the wound of radioactive injury, especially the poorly differentiated mesenchymal cells and fibroblasts, can cause an obstacle in the proliferation and differentiation of a variety of cell components. Rudolph et al. reported that the fibroblasts in the edges of the radiation skin ulcer were cultured in vitro, and then the ability to attach to the substrate and form colonies was significantly reduced compared with the control group, and the growth rate of the skin fibroblasts affected by radiation damage in logarithmic growth phase was reduced compared with the control group, which indicates that the proliferation ability of skin fibroblasts is low or the radioactive rays selectively eliminate the fibroblast population with stronger proliferation ability. The experimental results of Rudolph et al. confirmed the direct damage effect of the radioactive rays on fibroblasts, including reducing the proliferation ability of fibroblasts and delaying the appearance of myofibroblasts and finally resulting in delayed wound healing or nonunion. The result of the experiment showed that the fibroblasts after radiation damage have a serious degeneration, and the large and abnormal radioactive fibroblasts appear, and their proliferation and differentiation will inevitably be

affected. Gorodetsky et al. [27] also noted that the wound tension was measured at 2 weeks after the homologous fibroblasts were injected into the radioactive compound wound, and it was increased significantly compared with that in the control group. Rubin et al. considered that the damage effect of the radioactive rays on skin tissue is caused by the microvascular occlusion and tissue hypoxia.

3. The destruction of the vascular structure in the surrounding tissue. The radioactive rays destroy the vascular structure in the surrounding tissue, cause local blood circulation, and thus affect the healing process. The radioactive rays can also affect the formation of the capillary network in granulation tissues, and the reason for this is mainly related to the direct damage effect of the radioactive rays on undifferentiated mesenchymal cells, vascular endothelial cells, and smooth muscle cells.
4. Fibroblast injury. The radioactive rays cause delayed wound healing, and each development phase is lagged, of which the fibroblast injury is one of the key points. The fibroblast is one of the major repair cells, and it participates in the whole process of wound healing. Since the radioactive rays cause a sharp drop in the number of fibroblasts, structural damage, and morphological changes in fibroblasts, their proliferation abilities and the functions of secreting a variety of growth factors and type I and III collagens are weakened. The growth factors play important roles in the process of wound healing, and the abnormal expressions of a variety of growth factors in each development phase of radioactive compound trauma are the significant cause for inhibited fibroblast proliferation and weakened functions in the synthesis and secretion of collagens and extracellular matrix. In the early phase after irradiation with radioactive rays, the type I and type III collagen mRNA transcription as well as the protein synthesis and secretion are decreased, and thus the formation of granulation tissue and its transformation into normal tissue are affected. This firstly leads to reduction in the number of fibroblasts and secondly leads to reduced abilities to synthesize fibroblasts and secrete collagens.
5. The deteriorated general condition of the body. The radioactive rays deteriorate the general condition of the body, which may also be part of the reason for the delayed wound healing.

9.3 Advantages of Preoperative Radiotherapy

The preoperative radiotherapy refers to that the patient is irradiated with radioactive rays before surgery. In general, the advantages of preoperative radiotherapy are: (1) It can eliminate subclinical lesions (i.e., the small lesions which can't be detected by current imaging methods). Meanwhile, it can reduce the size of the tumor and release the adhesions; (2) it can increase the surgical resection rate, so that the patients who have been not suitable for surgery or who are inoperable can undergo surgeries; (3) it can reduce the range of surgery and better maintain the physiological and living abilities of the patients after surgery; (4) it can block the small blood vessels and lymphatic vessels around the tumor and reduce the opportunity of metastases through the blood and lymph vessels; (5) it can reduce the viabilities of tumor cells and reduce the chance of intraoperative iatrogenic spread, thereby improving the cure rate.

9.4 Study on the Underlying Mechanisms of the Effects of the Preoperative Radiation Damage on Tissue Healing

Approximately 70% of patients with tumors will receive radiotherapy at some stage in the course of disease. Therefore, most oncology surgeons may have the experience of performing the operation on the patients with a history of radiotherapy. The timing of surgery relative to the radiotherapy and the effect of radiotherapy on wound healing and postoperative complications are worth careful consideration.

The radiotherapy can cause the skin and connective tissues to produce the early and late phase reactions. The main cause for the early phase reactions is cytotoxic effect of the radioactive rays on the epithelial cells. The potential mechanisms for the late phase reactions are complex. All lamellar layers of the skin will be involved, and its main feature is the vascular injury and fibrosis. The implement of the operation in tissues which have been treated with radiotherapy can increase the postoperative complications. Therefore, it needs adequate preoperative preparation, attentive perioperative management, and precise surgical technique at the moment. It is also necessary to forewarn patients about the increased likelihood of the postoperative complications.

9.4.1 Radiotherapy-Induced Early Phase Reactions in the Skin and Connective Tissues

The early phase reactions occur in the process of radiotherapy or within a few weeks after radiotherapy. The single radiation dose is 3–8Gy. It can induce a transient skin erythema at 1–2 days after radiotherapy, and this is caused by the congestion and expansion of the blood capillaries in the top layer of the dermis. The depilation occurs at the second week after radiotherapy, and the erythema reappears at the third week and is accompanied by redness and dry or moist desquamation.

The radiotherapy-induced early phase reactions in the skin and connective tissues are mainly due to the effect of

radioactive rays on the epithelial cells in dermis base layer and stratified dermal layer. The signs or symptoms of early phase skin reactions usually develop along with the treatment process, but due to the accelerated epithelial proliferation, they will begin to subside at the end of treatment after reaching a peak. In addition to the effect of the radioactive rays on the epithelial proliferation, the important changes will also occur in small blood vessels (such as capillaries, arterioles) and lymphatic system, and it is usually possible to observe the capillary dilatation and congestion, plasma leakage in the dermal papilla layer, and inflammatory cell infiltration.

9.4.2 Radiotherapy-Induced Late Phase Reactions in the Skin and Connective Tissues

The late radiation damage occurs usually at 4–6 months after radiotherapy [28]. These late changes occur in all lamellar layers of the skin, including the epidermis, dermis, and subcutaneous tissue. The epidermis atrophy is often the most significant, then the skin becomes thin, smooth, and hard and loses its elasticity, and its resistance to injury is reduced. The sweat glands, sebaceous glands, and hair follicles will usually also shrink and thus lead to dry skin and hair removal. The heavier pigmentation and telangiectasia can also be observed. After receiving high doses of radiation, the skin ulcers or necrosis may occur.

The changes in blood vessels and connective tissue play an important role in radiotherapy-induced late phase reactions in skin and connective tissues. The study is carried out from the histological level, and it is possible to observe the progressive capillary occlusion and thrombosis, while the remaining capillaries are typically dilated; thus, this leads to telangiectasia. The arterioles and small arteries show a progressive hardening and thus cause a significant stenosis and occlusion of the vessel lumen. The vascular injury may lead to inadequate tissue perfusion and oxygen supply. The study also found that the densities of the collagen fiber network and irregular elastic fibers in the irradiated sites will be greater compared with the normal skin. After receiving the high dose (60–70Gy) of radiation, the dermis and subcutaneous tissue will gradually be replaced by a very dense and inelastic fibrous tissue. It is worth attention that, although the skin and subcutaneous tissue fibrosis and its reduced blood supply may be stable at last, the reaction to stress may be the ulcer or necrosis, for example, which may occur when there is an infection or operation. Therefore, when an operation is performed in the radiation area, the late phase reactions and chronic vascular injury in the irradiated skin may disrupt the skin wound healing process and increase the risk of postoperative complications.

9.5 Effect of Preoperative Radiotherapy on Skin Flap in Oncoplastic Surgery

9.5.1 Head and Neck Tumors

Wang Zhonghe et al. in The Ninth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine have made related clinical studies on the radiotherapy resistance of the skin flap graft after resection of oral and maxillofacial tumors. Wang et al. reported that after 82 patients underwent oral and maxillofacial tumor resection, 88 tissue flaps were used for immediate repair. Sixty-eight patients (74 flaps) started to receive radiotherapy at 2–6 weeks after surgery, and the remaining 14 patients (14 flaps) had received 50–70Gy of radiotherapy within 10 years which started from 2 months before surgery. The successful rates of skin flap transplantations in the preoperative radiotherapy and postoperative radiotherapy groups were 85% and 98.6%, respectively. The incidence of acute radiation reaction of the skin flap in the postoperative radiotherapy group was significantly lower than that of the surrounding normal tissue (35.1% and 83.8%, $P < 0.01$). Follow-up was carried out for 12 to 36 months. Three patients had fibrosis changes in skin flap, and two patients had atrophic changes.

When the skin flap graft is to be carried out in patients who have received radiotherapy, full consideration should be given to the effects which may be caused by the radiotherapy. The blood vessels in receptor site may be damaged by radiotherapy, and a certain degree of barrier will happen when the revascularization is performed between tissue flap and the tissues in receptor site. Therefore, the tissue flap is prone to necrosis and poor healing. The blood circulations in receptor sites of the patients undergoing postoperative radiotherapy are normal. The radiotherapy is carried out after tissue flap heals, which will not produce significant effect on the recent healing of the tissue flap. Most scholars believe that the survival rate of tissue flap and the good healing rate in the patients undergoing preoperative radiotherapy are significantly lower than those in the patients undergoing postoperative radiotherapy.

In order to increase the successful rate and the good healing rate of the immediate reconstruction with tissue flaps in the patients undergoing preoperative radiotherapy, Wang Zhonghe proposed: When the repair with tissue flap is to be performed after the recurrent tumor or the second primary tumor is resected, the vascular anastomosis is performed as far as possible in the area outside the original radiotherapy area. The blood vessels with thicker diameters are selected for anastomosis, and the blood vessels must be strong and unobstructed after anastomosis; the length-to-width ratio of the skin flap is appropriate, and it cannot be too long and narrow; if there is fibrosis in the receptor site of the tissue flap, the tissues in the receptor site should be cut to the area with active oozing of the blood, and then the reconstructive suture

can be performed. If such patients want to undergo postoperative radiotherapy, the range and the dose of preoperative radiotherapy must be taken into account to avoid the serious consequences. It should be noted that the newly repaired tissue flap has not been treated with radiation, and it also has a good tolerability to the postoperative radiotherapy. If most of the tissues in the lesion area with preoperative radiotherapy are resected together with the tumor, it is not necessary to totally exclude the postoperative radiotherapy.

9.5.2 Breast Cancer

The radiotherapy is commonly seen in the two situations before repair and reconstruction of the breast defect: (1) The patients undergo total mastectomy plus breast reconstruction when the breast cancer recurs after breast-conserving surgery plus radiotherapy; (2) the patients undergo secondary repair.

Compared with the primary autologous repair, the difficulty of the secondary repair after mastectomy surgery is relatively small. The delayed repair leads to postoperative exposure of some surgical areas of the tumor to facilitate early detection of cancer local recurrence. After the primary repair of breast defect, the breast contour makes it difficult to achieve the uniformity of radiotherapy dose, while the secondary repair can reduce the adverse effect of the radiotherapy on breast cosmetic effect and the effect of the breast contour on radiation dose distribution. However, the patients need to receive two operations, which will aggravate the trauma and pain. After mastectomy, the patients must bear the psychological pressure induced by breast deformity within a certain period of time. If the patients undergo postoperative radiotherapy, this will increase the difficulty of repairing the chest wall injury.

US MD Anderson Cancer Center reported the surgical complications in a group of 102 patients undergoing breast reconstruction after mastectomy and made comparisons of the incidences of early and late complications between the patients undergoing primary repair ($n = 32$) and the patients undergoing secondary repair ($n = 70$). The study found that the incidence of complications in the patients undergoing radiotherapy before secondary breast repair is significantly lower than that in patients undergoing radiotherapy after primary repair.

Disa et al. believed that the autologous tissue breast reconstruction is an ideal way for breast reconstruction in patients after undergoing chest wall radiotherapy. This is due to the fact that the autologous tissue has overcome some difficulties involved in allograft tissue reconstruction, and it is not need to perform tissue expansion. Furthermore, the autogenous healthy tissues have replaced the tissues after radiotherapy. The shape and texture of the reconstructed breast are close to those of the normal breast, and the long-term cosmetic result is good, and thus it is less likely to require surgical repair.

In the principles to be followed for selection of repair and reconstruction of defects after tumor surgery, Zhou Xiao indicated that:

1. If the simple surgery can achieve the same effect, the complex plastic surgery or microsurgery will not be performed.
2. Only the secondarily important area of the body can be taken as the donor site of the tissues used for the repair of the important receptor site.
3. It is necessary to not only consider the good recovery in function and appearance of the receptor site but also minimize the loss of function and appearance of the donor site, thereby avoiding the secondary deformity or dysfunction of the donor site.
4. The surgical plan for primary repair of tissues and organs is selected as far as possible.
5. It is inappropriate to select the area after radical radiotherapy as the donor site of skin flap.

It is required that the oncology surgeons should fully communicate with the radiation therapists before developing a therapeutic regimen and reasonably arrange the timing of reconstruction and repair combined with the radiotherapy and thus develop a comprehensive therapeutic regimen which cannot only make the patients restore near-normal function and appearance as far as possible but also ensure the effective treatment.

9.6 The Timing of the Preoperative Radiotherapy and Dose

There are still debates on preoperative or postoperative application of adjuvant radiotherapy and what kind of radiation treatment is best. But the surgeons are more willing to perform postoperative radiotherapy, because what they are worried about is that the preoperative radiotherapy will affect the wound healing and increase surgical complications, and furthermore, it may also increase the risk of tumor recurrence due to the fact that the preoperative radiotherapy narrows the scope of surgical resection.

The clinical studies have shown that the more hypoxic cells exist within the tumor entity, the less sensitive to radiotherapy the tumor is, and the worse the therapeutic effect is. The nourish blood vessels around the tumor before the implementation of preoperative radiotherapy have not been destroyed by surgery. The blood supply to the tumor bed is good, and the tumor cells contain rich oxygen, while the quantity of hypoxic cells is less. Therefore, the tumor is sensitive to radiotherapy. At this moment, the application of radiotherapy has a significant killing effect on tumor cells, and this is very beneficial to reducing the size of the whole

tumor and eliminating subclinical lesions to perform organ preservation surgery for tumor patients. The analysis on 229 patients with oral cancers treated in the Cancer Hospital of Chinese Academy of Medical Sciences showed that for patients with T_1 and T_2 lesions, the 5-year survival rate in the preoperative radiotherapy group was the same as that in the simple surgical group; but for patients with T_3 and T_4 lesions, the 5-year survival rate in the preoperative radiotherapy group (40–50Gy) was 60%, and the 5-year survival rate in the simple surgical group was 29.4%. Therefore, the patients with early cancers can undergo simple surgery, but the patients with advanced cancers should be treated otherwise with preoperative radiotherapy [29].

It is not so much that the preoperative radiotherapy has no effect on surgical healing, but if the dose of preoperative radiotherapy is controlled well (i.e., 40–50Gy), this will not cause a significant effect on the surgery in practice. Tupchong compared the data of two groups, namely, the preoperative radiotherapy group (50Gy, 136 patients) and the postoperative radiotherapy group (60Gy, 141 patients), and the results showed that the surgical complication rates in the two groups were 43% and 42%, respectively, of which the serious complication rates were 18% and 14%, respectively. There was no statistically significant difference between two groups. The study of Cancer Hospital of Chinese Academy of Medical Sciences showed that 209 patients with laryngeal cancers were randomly divided into two groups. One group (91 patients) was treated with preoperative radiotherapy (40Gy), and another group (118 patients) was treated with simple surgery. The postoperative complication rate was 25.4% in the preoperative radiotherapy group and was 26.4% in the simple surgery group, and this indicates that the preoperative radiotherapy (40Gy) does not increase the surgical complication rate.

At present, another reason for the surgeons to select less preoperative radiotherapies is that the tumor after radiotherapy is ill-defined and the tumor-free resection margin cannot be guaranteed. But in order to recognize the problem on tumor boundary after radiotherapy, there exist the following two situations: One situation is that the tumor boundary is reduced by the planned preoperative radiotherapy (planned comprehensive treatment), and the surgery is performed at 2–4 weeks after radiotherapy; the other situation is that the tumor recurs after radiotherapy failure. The squamous cell carcinoma is taken as an example. In the formal situation, the boundary is reduced in the vast majority of the tumors, and the peripheral lesions of the tumor are controlled better than the central lesions; thus, the surgical border is guaranteed; while the tumor which recurs after radiotherapy failure often grows under the mucosa, its boundaries are indeed difficult to determine. In addition, the local circumstance is quite different from that before preoperative radiotherapy; thus, it is required to carry out extensive surgery rather than simply reducing the tumor boundary. These two situations should be treated differently.

Sauer et al. conducted a randomized study to determine which was better between preoperative synchronous chemoradiation and postoperative synchronous chemoradiation in the treatment of the rectal cancers (CAO/ARO-094). CAO/ARO-094 randomized controlled study included 823 patients. Through the pelvic CT scan and transrectal ultrasound examination, the patients were diagnosed with T3-T4 or N + rectal cancers without distant metastases. The ages were less than or equal to 75 years and the tumor was within 16 cm from the anus. The patients underwent no prior chemotherapy or radiotherapy. The patients received fluorouracil at a dose of 1000 mg/m^2 daily during synchronous chemoradiation, and the intravenous infusion was continuously carried out for 1–5 days. At the first week and the fifth week after the start of radiotherapy, the consolidation chemotherapy regimen was that the fluorouracil was administered at a dose of 500 mg/m^2 daily, and the intravenous infusion was continuously carried out for 1–5 days, with 4 weeks as a period, and there were a total of four periods. The radiotherapy was the whole pelvic irradiation. The total dose was 50.4Gy (1.8Gy each time, a total of 28 times), and the local supplement dose in the postoperative radiotherapy group was 5.4Gy. Finally, 799 patients were randomly divided into two groups: the preoperative chemoradiotherapy group and the postoperative chemoradiation group. The local recurrence rate was significantly reduced in the preoperative chemoradiation group (6%, 13%; $P = 0.006$); after examination by the surgeon, it was considered that a total of 194 patients needed to undergo abdominal perineal resection (the anal sphincter cannot be preserved) before surgery. The actual anal sphincter preservation rates in two groups were 39% and 19%, respectively ($P = 0.004$), and the anal sphincter preservation rate in the preoperative synchronous chemoradiation group was significantly increased. It was important that the acute and long-term side effects of the preoperative synchronous chemoradiation group were significantly lower than that of the postoperative synchronous chemoradiation group, and the incidences of anastomotic leakage, bleeding, and intestinal obstruction were not increased in the preoperative synchronous chemoradiation group. Although its delayed wound healing rate was higher than that of the postoperative synchronous chemoradiation group, the difference did not reach statistical significance.

The best timing for preoperative radiotherapy is an issue of concern to clinical oncologists, who can get tips from the abovementioned laboratory studies on the mechanism under-

lying the effect of radioactive damage on tissue healing. The radiotherapy given at a 3–6-week interval is safe, because early phase reaction of the radiotherapy has subsided at this moment and the late phase microvascular injury and fibrosis have not occurred. By this time, the incidence of postoperative complications caused by radiotherapy is lower, which has been verified in our long-term clinical practice.

Tu Guiyi and Xu Guozhen considered that the preoperative radiotherapy should be applied at a dose of 50Gy, and the surgery should be performed at 2–4 weeks after radiotherapy; the postoperative radiotherapy should begin within 6 weeks after surgery at a dose of 60–70Gy. The dose used for preoperative radiotherapy in the past was 40Gy. Zhang Zongmin et al. in Cancer Hospital of Chinese Academy of Medical Sciences applied the radiotherapy at a dose of 50Gy in the treatment of hypopharyngeal squamous cancer (5 weeks), and the case analysis showed that its overall treatment effect was better than that of 40Gy radiotherapy (4 weeks). Wang Zhonghe et al. advocated that preoperative radiotherapy dose should not exceed 50Gy; otherwise, the incidence of serious complications such as postoperative delayed wound healing, fistula formation, and the rupture and bleeding of carotid artery will be increased. Therefore, that the preoperative radiotherapy is applied at a dose of 50Gy (5 weeks) has basically become the consensus.

9.7 The Oncoplastic Surgery Treatment After Radical Radiotherapy

If the patients still have residual tumors after radical radiotherapy which reaches the designed radiation dose, and the residual tumors still don't disappear after 3 months of follow-up observation or recur after subsiding, the local resection or lymph node dissection can be used to save lives in clinic. At present, the radical cure dose of radiotherapy for the cancer is usually 60–75Gy in clinic. At the same time of the tumors being treated, the normal tissues can also have scarring and capillary degeneration accompanied with varying degrees of tissue necrosis due to the radiation damage. Most frequently, these injuries cannot be completely recovered to normal in several months or even years after radiotherapy. If a surgery is performed in the tissues after radical radiotherapy, the healing ability of the tissues after surgery is significantly decreased. Therefore, the oncoplastic surgical treatment after radical radiotherapy remains controversial.

With the continuous development of plastic surgery techniques, the means for repair with autologous skin flap are increasing, and this provides repair methods for some patients after radical radiotherapy. At present, the methods mostly adopted in the hospital where the author works in include reconstruction using myocutaneous flap with vascular pedicle, such as the latissimus dorsi muscle flap and double-pedicle trapezius myocutaneous flap (see Chap. 6, Defect Repair After Tongue Cancer Surgery), and free flap reconstruction, such as radial forearm flap, vastus lateralis flap, and rectus abdominis myocutaneous flap pedicled with inferior epigastric artery (see Chap. 7, Repair and Reconstruction of Oral-Maxillofacial Region Penetrating Defect).

It is still needed to carry out the comprehensive treatment after breast cancer radical surgery. The anterior chest wall skin is prone to radioactive ulcers after radiotherapy. Due to local skin and soft tissue fibrosis and poor blood supply, the ulcers are gradually enlarged and accompanied by infection and deep bone tissue exposure, and the ulcer wound cannot heal through change of dressing. The wound after ulcer resection cannot be repaired with skin graft method, while it needs to be repaired with pedicle flap graft and free grafting by vascular anastomosis. The radical radiotherapy causes the radiation damage to blood vessels within the radiation field, and other tissue injuries related to radical radiation such as endovasculitis, endometrial shedding, and vascular constriction will occur; therefore, the tissues in the field of radical radiotherapy are generally not selected as the donor site of skin flap and the blood vessels used to anastomose the free skin flap in receptor site. In order to improve the success rate of free flap, it is supposed to take the following measures:

1. The necrotic tissue is removed completely to avoid postoperative infection.
2. The free flaps with large-diameter blood vessels are selected and used, because the anastomotic stomas of the large blood vessels are not prone to thromboses.
3. The free flaps with long vascular pedicles are selected and used, and the need to carry out vein transplantation due to insufficient vascular pedicle length is avoided as far as possible.
4. The thick and large blood vessels are used as far as possible.
5. The arterial intima after radiotherapy is easy to be separated and detached from the vessel wall. Therefore, it is supposed to adopt the visualized vascular anastomosis technique.
6. Attention is paid to monitoring of blood supply after free tissue flap transplantation, and the vascular anastomosis should be performed again when necessary.

The indication and contraindication of the surgical treatment after radical radiotherapy remain to be further studied and discussed in the future.

10 Effect of Postoperative Radiotherapy on Skin Flap Graft in Oncoplastic Surgery

Bingqiang Hu, Xuping Xi, and Hui Wang

10.1 Advantages of Postoperative Radiotherapy

The postoperative radiotherapy is performed in patients with residual lesions due to incomplete resection, patients with possible existence of cancer according to the rules of tumor development, or patients with sensitive tumors and high-grade malignant tumors. The suspected residual area should be marked with metal clip during surgery to provide reference for easy positioning of postoperative radiotherapy. The postoperative radiotherapy is generally performed after surgical wound healing and physical rehabilitation. The patients with confirmed postoperative residual lesions should be treated with radical radiotherapy, which can achieve the purpose of curing or controlling the tumors and delaying tumor recurrences. The postoperative radiotherapy has great significances in increasing the local control ratio after oncoplastic surgery, especially in preventing the recurrence of tumors in patients with insufficient safe surgical margin.

Advantages of postoperative radiotherapy: The postoperative radiotherapy will not delay the operation time; the target area of radiotherapy can be more accurately formulated according to specific intraoperative findings, the situation of surgical resection, and the results of postoperative pathological examination; the target area and dose of radiotherapy can be determined according to subclinical tumor lesions within the scope of the operation, including metastatic lesions in regional lymph nodes; the known residual lesions or high-risk areas are treated with a large dose of radiotherapy, so as to effectively control the tumor.

Disadvantages of postoperative radiotherapy: The postoperative radiotherapy must be performed after wound healing; because the surgery has changed the vascular distribution of the tumor bed, the local blood supply may be affected, so that the hypoxic cells in residual lesions or subclinical lesions of tumor bed are increased; thereby, the radiotherapy effect is affected.

10.2 Study on the Underlying Mechanisms of the Effects of the Postoperative Radiation Damage on Tissue Healing

The effects of the postoperative radiation damage on tissue healing include the following aspects.

10.2.1 Changes in the Extracellular Matrix

The speed and quality of wound healing have an important relation with extracellular matrix components. The extracellular matrixes in the wound mainly are synthesized and secreted mainly by macrophages, fibroblasts, endothelial cells, and epidermal cells. The extracellular matrixes not only play connection and supporting effect on cells but also control the cell growth and differentiation, regulate the gene expression in cells, and affect the cell metabolism and movement. The content of collagen determines the wound tension strength. The main function of the elastic fibers is to determine the elasticities of tissues and wounds; in addition, the elastic fibers can also affect the stereoscopic morphology of fibroblasts.

The study of Midwood et al. showed that other studies have shown that after radiation damage, the abundant expressions of type I and II collagen and the abnormal collagen cross-link can be observed in normal tissue fibrosis, and there is a deposition of extracellular matrix components.

10.2.2 The Change of Cytokines

The phagocytic function of macrophage in the wound macrophage is decreased obviously after radiotherapy, and the cytokines such as tumor necrosis factor-α (TNF-α) and interleukin-1 (IL-1) released by macrophages are decreased. Cytokines have an important role in the wound healing process; particularly the transforming growth factor (TGF), fibroblast growth factor (FGF), platelet-derived growth factor (PDGF), and vascular endothelial growth factor (VEGF) are closely related to wound healing, while the radiotherapy may lead to changes in the cytokine levels of the local wound, thus affecting wound healing.

The transforming growth factor-β (TGF-β) is a multifunctional basic anti-inflammatory cytokine, and it is produced by platelets, fibroblasts, macrophages, and leukocytes. The content of TGF-β has a certain correlation with collagen synthesis, wound healing time, tension in wound healing tissue, and scar density. The TGF-β level is decreased and the collagen deposition is reduced; these are the factors that lead to wound dehiscence. All fibroblasts, endothelial cells, smooth muscle cells, and chondrocytes produce FGF. The function of FGF is to promote the proliferation of microvascular endothelial cells, thus accelerating the growth of new blood vessels. FGF plays a role through paracrine effect, which provides a necessary stimulation on early growth factor, IL-1, which plays an important role in endothelial repair. The myofibroblast is a special fibroblast, and the cytoplasm contains muscle filaments, which have systolic function, and their main role in the process of wound healing is to cause wound contraction so as to reduce the wound as soon as possible and accelerate healing; the lack of the myofibroblasts also makes it difficult to reduce the wound, thus delaying healing.

The macrophage is an important source of cytokines such as PDGF, epidermal growth factor (EGF), IL-1, prostaglandin (PG), and tumor necrosis factor (TNF); the lack of macrophages will seriously affect wound healing.

10.2.3 Traumatic Environmental Changes

The radiotherapy can cause degradation of microvascular basement membrane around the wound and increase its permeability, resulting in the loss of plasma components and the thrombosis, so that the local blood supply is poor. After further irradiation, the proliferation of endothelial cells is inhibited, and the blood vessels are further damaged, thus causing ischemia and hypoxia in the wound area and decreasing peripheral white blood cell count; therefore, the local area is prone to infection after trauma. These traumatic environmental changes are not conducive to wound healing.

10.3 Effect of Postoperative Radiotherapy on Skin Flaps in Oncoplastic Surgery

10.3.1 The Radiotherapy After Breast Reconstruction Surgery

The radiotherapy after breast reconstruction surgery is commonly performed in patients who need postoperative radiotherapy after primary repair of defects which is pathologically confirmed.

For patients who decide to undergo postoperative radiotherapy before surgery, the secondary repair can avoid delay in radiotherapy and refrain from achieving a possible imperfect cosmetic effect. Some patients who have had negative lymph nodes confirmed by preoperative clinical examination have undergone primary repair of breast defect, but it is only known after surgery that the patients need radiotherapy. Whether there is a presence of micrometastases in these patients with negative lymph nodes in the preoperative clinical examination cannot be accurately assessed during surgery, and the final pathology report is usually obtained in a few days after surgery. If the patients have undergone primary repair during surgery, and it is confirmed postoperatively that the patients need radiotherapy, there is no doubt that the patients have to face the possibility of occurrence of complications and imperfect cosmetic effects; in addition, after primary repair, the outer contour of the breast will increase the technical complexity of the radiotherapy.

Most scholars reported that the radiotherapy after primary repair causes some complications in patients. Rogers et al. reported the incidence rate of complications in patients who underwent mastectomy combined with primary autologous repair of breast defects: There were a total of 60 patients, of which 30 patients underwent postoperative radiotherapy and another 30 patients were taken as controls; the follow-up time was calculated from the start of surgery; it was 19.9 months in the radiotherapy group and was 17.4 months in the control group. The results showed that there were no significant differences in the incidence of infection, the need for skin repair, and the proportion of contralateral mastopexy between two groups, but the fat necrosis rate, the incidence of breast fibrosis (shrinkage), and the incidence of flap contracture in the radiotherapy group were higher than those in the control group, and the cosmetic result in the radiotherapy group was also inferior to that in patients who did not receive radiotherapy.

The most suitable time for breast repair after breast cancer resection is determined by whether it is needed to carry out postoperative radiotherapy. If the patients need postoperative radiotherapy, the radiotherapy after primary repair will not only greatly affect the cosmetic effect but can also lead to a higher incidence of complications. Only under the premise that the patients don't need postoperative radiotherapy can the primary repair be the best option.

10.3.2 Tolerances of a Variety of Tissue Flaps Used in Oral and Maxillofacial Repair on Postoperative Radiotherapy

The postoperative radiotherapy can increase the local tumor control rate and can't produce significant adverse effects on the cosmetic results of the repaired tissues and organs. Hidalgo and Pusic [30] retrospectively analyzed the clinical outcomes of 20 patients with mandibular tumors who underwent the primary microsurgical repair of mandibular bone and radiotherapy after mandible resection, of which 12 patients were given radiotherapy after repair surgery at a total dose of 60–65Gy. 10-year follow-up results showed that the radiotherapy did not delay the healing of the tissues in the area where the bone was incised or affect the survivability of the bone graft. Over time, the volume of free bone flap used in repair was reduced, but there was no statistically significant difference in the loss of volume in free bone flap between patients with and without radiotherapy.

Wang Zhonghe et al. reported that 82 patients who underwent repair with tissue flap after oral and maxillofacial tumor resection received 40–72Gy radiotherapy. The acute response of the tissue flap was significantly lower than that of the adjacent oral mucosa ($P < 0.01$–0.05). Two years of follow-up showed that the late side effects of the flap were rare. The results of mid- and long-term observation on oral and maxillofacial tissue flap after postoperative radiotherapy confirmed that various tissue flaps have a good tolerance on postoperative conventional radiotherapy, and the specific manifestations include: All acute radiation reactions may be dissipated and healed within 6 weeks after surgery, and the long-term follow-up showed no serious adverse consequences. This provides a reliable basis for that the patients

who have undergone immediate reconstruction with tissue flap after the eradicative resection of head and neck malignant tumor safely receive the postoperative radiotherapy to improve the outcome. The tolerance of the intraoral tissue flap on the radiotherapy was superior to that of the surrounding normal mucosa within the radiation field, and the grades II, III, and IV radiotherapy reaction rates were significantly lower than those in normal mucosa ($P < 0.01$). In addition to that, the causes are related to the thicker epithelial and cuticular layers in the skin structure of the tissue flap (a better tolerance on radiotherapy) compared with the oral mucosa, but also may be associated with the protective effect of hypoxia (strong radioresistance) due to the slightly inadequate new blood supply to the tissue flap. There was no significant difference in tolerance on radiotherapy among different types of tissue flaps.

The blood circulation of the receptor site in tissue transplantation is normal in patients undergoing postoperative radiotherapy, and the radiotherapy is performed after tissue flap healing, which does not have a significant impact on the healing of the tissue flap; therefore, the tissue flap survival rate and the good healing rate in patients with preoperative radiotherapy are significantly lower than those in patients with postoperative radiotherapy.

It is not convenient to directly observe and early detect the recurrent lesions in some areas after one-stage repair and reconstruction, especially in the deeply hidden areas. Therefore, it should be noted the regular reexamination and dynamic observation are carried out for these patients, in order to detect recurrent lesions.

10.4 The Timing and Dose of Postoperative Radiotherapy

10.4.1 The Timing of Postoperative Radiotherapy

The same as the preoperative radiotherapy, the timing of postoperative radiotherapy will also affect the wound healing process. The most sensitive period to radiotherapy for the wound healing is the first 2 days of postoperative inflammation reaction period and subsequent cell proliferation period. Therefore, if the radiotherapy is performed immediately after surgery, the inflammation will be suppressed, while the neutrophils, monocytes, and macrophages are significantly decreased. In cellular proliferative phase, the quickly differentiated fibroblasts in the wound are extremely sensitive to radiation at this phase, which can lead to decreased contents of type I and III collagen fiber; therefore, it is not normally advocated that the immediate radiotherapy is performed after surgery. In the clinical application, the timing of postoperative radiotherapy is slightly delayed, which will significantly reduce the potential complications of the wound.

However, from the perspective of oncology, the postoperative residual tumor cells are in a more active growth phase, and the tumor doubling time is relatively shorter. If the radiotherapy or chemotherapy is carried out as early as possible at this time, the tumors may be more sensitive to the therapy. Therefore, the postoperative radiotherapy becomes even more important; and because the local blood supply is affected after surgery, the longer the interval time between the postoperative radiotherapy and the surgery is, the poorer the local blood supply is, and the worse the sensitivity to radiotherapy will be, which leads to reduced radiotherapy efficacy. Therefore, it is often recommended that the postoperative radiotherapy should not be performed later than 6 weeks after surgery, and the postoperative radiotherapy should better be started in patients at high risk of recurrence within 4 weeks after surgery; if the interval time between the start of postoperative radiotherapy and the day of surgery is longer, it is not conducive to controlling the residual tumor and will increase the chance of tumor recurrence.

It is surely important to establish an effective blood supply through performing vascular anastomosis for free tissue flap and receptor site during surgery, but it is also indispensable to gradually establish abundant collateral circulation (revascularization) between free tissue flap and receptor site. Zhang Chenping et al. reported that the time needed for fully establishing the tissue flap revascularization is about 3 weeks; therefore, it is safer to carry out postoperative radiotherapy at 3 weeks after surgery.

Therefore, in clinical practice, the timing of the postoperative radiotherapy can be determined specifically according to the clinical needs and the healing status of tissue flaps. If the length-to-width ratio is proper, and the vascular anastomosis is unobstructed, the postoperative radiotherapy can be started in advance at 2 weeks after surgery, which is extremely important for improving the curative effect in tumor patients among whom the tumor is cut broken during surgery, the incisal margin of the tumor margin is too close, the incisal margin is positive, or there is residual tumor. The postoperative radiotherapy should be appropriately delayed in patients with poor tissue flap healing.

10.4.2 The Dose of Postoperative Radiotherapy

The postoperative radiotherapy is applied locally in patients with advanced tumors, in whom the large lesions have been removed surgically and the surgical margins may be negative or positive. The surgical field needs to be treated with radiotherapy to strengthen the control of local or regional lesions. There are certain requirements for the time and dose of postoperative radiotherapy, and the dose is usually 60Gy; if the incisal margin is positive, and the local recurrence risk is high, the dose should be increased to 70Gy.

Wang Zhonghe made an immediate and long-term observation on the reaction of postoperative radiotherapy in

114 repair tissue flaps for oral and maxillofacial repair (4000–7200 cGy, 4–7.5 weeks), and the adjacent normal oral mucosa or skin for self-control within the radiation field was taken as self-controls. The results showed that the acute radiation reaction rate in tissue flaps (including swelling, erosions, or ulcers) was significantly lower than that in the adjacent normal tissues ($P < 0.05$), and the acute radiation reaction appeared late with a lighter degree, which could be completely subsided after radiotherapy; the long-term reaction was not common. There were no significant differences in tolerance on radiotherapy among different types of tissue flap prosthesis. Among 114 tissue flaps, 112 whole tissue flaps (98.2%) survived after radiotherapy. Conclusion: The tissue flaps for oral and maxillofacial repair have good tolerances on radiotherapy and can safely receive the whole course of postoperative radiotherapy at a conventional dose.

10.5 Measures to Reduce Radiation Damage

In view of the above characteristics of radiation damage, the radiation induced necrotic ulcers are rather intractable, and the prolonged unhealed ulcers may even have local canceration. Therefore, in the process of radiotherapy, attention should be paid to the individualization of radiation dose and the selection of radiotherapy plan; at the same time, it is particularly important to strengthen the radiological protection and the skin protection in patients with radiotherapy. In order to control, improve, or prevent radiation damage, many scholars are trying to find the methods for prevention and treatment of radiation damage.

10.5.1 Strengthen the Symptomatic Treatment

The radiation damage can cause disorders in normal metabolism of tissue cells and inhibit the regenerative capacity, which are often accompanied by severe infection and tissue necrosis. It is particularly important to strengthen local skin care and change the bandage several times to prevent local pollution. The necrotic fibrous tissues can be removed with chymotrypsin or elastase ointment, which is more conducive to infection control; the bacterial culture is carried out for infected wounds, and the sensitive antibiotics is selected for topical application or intravenous drip to promote granulation tissue growth and healing; it is supposed to strengthen symptomatic and supportive treatment, enhance nutrition, and provide immunotherapy, and the healing can be promoted by improving human body immunity.

10.5.2 Surgical Treatment

If the chronic radiation dermatitis causes repeated ulceration with obvious signs of deterioration, the efficacy of drug therapy for radiation-induced ulceration is not obvious, or in order to shorten the course of treatment and prevent the malignant transformation, the patients are often treated by surgery. The surgery aims to remove skin lesions and select different repair methods for covering the wound according to local wound conditions.

The resection range of the chronic ulcer should be large enough to have a free margin of 1 cm of the normal skin. The skin lesions around the ulcer such as atrophy, attenuation, and pigment changes are removed together with the ulcer, and thus the ideal depth is: The normal tissues with active bleeding are exposed in wound base after wound debridement. Some degenerated cartilages or bone tissues should be removed.

The different methods should be selected and used for wound repair according to the nature of the wound, the range and depth of the resection, as well as the wound base condition and location. The more common methods are skin transplantation including skin graft, local random flaps, and axial flaps and the omentum transplantation, and the good therapeutic effects can be obtained.

10.5.3 Application of High-Precision Radiotherapy to Minimize the Normal Tissue Damage

At the end of the twentieth century and the beginning of the twenty-first century, due to the rapid development of molecular biology and radiophysics and the active involvement of advanced computer technology and imaging techniques, the radiation oncology has already achieved great-leap-forward development. The high-precision radiotherapies mainly consisting of three-dimensional conformal intensity-modulated radiotherapy (IMRT) are quite different from the two-dimensional conventional radiotherapy in the past, and they can greatly improve the conformity between the shapes of the high-dose region and the target region and further reduce the treatment volume and can minimize radiation dose to normal tissues.

The three-dimensional reverse conformal IMRT plan greatly improves the conformity between the three-dimensional shapes of the high-dose region and the target region compared with conventional treatment plan, further reducing the range of the surrounding normal tissues and organs involved in the radiation field; because of the improvement of the target dose distribution and the reduced irradiation range of the normal tissues around the target, the prescription dose is further increased, and the dose of the surrounding normal tissue is decreased, thereby reducing the complications of radiotherapy. It is especially suitable for local treatment of tumors which are located in complex anatomical structures and have special shapes and multiple target points, significantly reducing the complications of preoperative and postoperative radiotherapies and thus improving the qualities of life of the patients.

10.5.4 The Use of Healing Promoting Effect of Stem Cells on Radiation Injury Impaired Wound

In recent years, with the development of stem cell engineering technology, it has been frequently reported that the stem cells are used to repair the bones, cartilages, tendons, muscles, etc. Aiming at solving the fundamental problem that the fewer repairing cells and the proliferation inhibition in local area lead to difficulty in curing the systemic or local radiation injury impaired wound, Majumdar et al. used the mesenchymal stem cells (MSCs) which have the ability to differentiate into repairing cells in the local radiation injury impaired wound. After the implantation of autologous MSCs in the local wound, a comparison was made between the wounds with transplanted MSCs and the wounds in the control group. The speed of wound healing in the MSC-implanted group was faster than that in the control group, the formation and growth of the granulation tissues were more vigorous and fresh than those in the control group, and the granulation tissues contained rich blood capillaries and fibroblasts; the content of the primary substance for synthesizing collagens, hydroxyproline, was significantly higher than that in the control group, and the formation of type I and III collagens also was increased compared with the control group, suggesting that MSCs have obvious healing promoting effect on the wound.

The MSC transplantation has an obvious healing promoting effect on the local radiation injury impaired wound. Its healing promoting effect is due to the fact that, on the one hand, the implanted MSCs or the cytokines secreted by them can promote the migration and proliferation of the inflammatory cells and repairing cells around the wound into the wound surface, initiate the repair as early as possible, and increase the number of local repairing cells; on the other hand, the local wound microenvironments may also affect the expressions of the proteins and genes in implanted MSCs, and they can induce MSCs to evolve into repairing cells and (or) secrete the extracellular matrix to participate in tissue repair; MSCs are likely to evolve into the main repairing cells, fibroblasts, to participate in tissue repair under the action of the local microenvironment of the wound. The interaction between stem cells and local wound microenvironment may affect wound healing.

10.5.5 Improvement of Local Oxygen Supply

Improving the oxygen supply to the local wound can enhance the bactericidal ability of the white blood cells and promote angiogenesis and epithelialization, which is of great benefit to the wound healing process.

The hyperbaric oxygen therapy (HBOT) can promote angiogenesis and enhance healing of tissues damaged by radiation and also has a therapeutic effect on soft tissue damages that occurred in a few months or a few years after radiotherapy. HBOT can promote blood supply to these tissues, thereby accelerating tissue healing.

10.5.6 Cytokine Therapy

The radiation-induced skin damage can significantly decrease the expressions of a variety of cytokines and their receptors, and a better curative effect has been achieved through the use of growth factors to treat radiation-induced ulceration.

After the body is damaged, the platelets will aggregate and degranulate in the local wound and release all kinds of growth factors, including PDGF, TGF-β, EGF, and insulin-like growth factor-1 (IGF-1). TGF-β1 has a positive effect in improving surgical incision healing and skin flap survival in rats after radiotherapy, and it can increase the tensile strength of the postoperative incision and promote flap survival. The systemic application of hematopoietic growth factor, interleukin-3 (IL-3), colony-stimulating factor (CSF), and interleukin-1 (IL-1) can accelerate the recovery of the function of hematopoietic system, so that the whole body condition can be improved, which is conducive to local wound healing.

Now, the externally used finished product recombinant bovine FGF basic (Beifuji) is available in the market, and it can be externally used to repair the chronic wound. Its main mechanism is to increase collagen content in the wound, thereby improving the mechanical strength for tissue repair. In short, FGF participates in the whole process of regulating the tissue repair, including regulating the inflammatory response, inducing capillary proliferation, accelerating the growth of epithelium and granulation tissue, and playing a significant role in wound healing.

Because the macrophages can produce a variety of cytokines to promote tissue healing, Zuloff-Shani studied a new method for the treatment of refractory ulcers. Under sterile conditions, the macrophages are extracted from the blood of healthy donors. In the process of preparation, the macrophages are activated in hypotonic environment to enhance their various functions in wound repair. These cells can play roles after being locally injected or directly instilled into the wounds.

11 Effect of Chemical Treatments on Biological Tissues

Wei Wang, Yi Luo, and Zhaoyan Wang

The radical surgical resections are currently the most important method for the treatments of most tumors, but they often cause serious functional defects or appearance defects at the same time of curing the tumors, which greatly affects the quality of life of patients, and therefore, more and more tumor patients ask for postoperative repair and reconstruction. Different from the patients with ordinary

plastic surgery, the patients undergoing oncoplastic surgery operations often have received multiple courses of preoperative chemotherapy, and most of them will be required to receive a certain course of postoperative adjuvant chemotherapy after plastic surgery. The chemotherapy may have impacts on the aspects such as skin flap design, skin flap donor site selection, skin flap survival, and blood supply reconstruction in these patients, but there is still a lack of systematic research on this.

11.1 Preoperative Induction Chemotherapy and Postoperative Adjuvant Chemotherapy

The preoperative induction chemotherapy and postoperative adjuvant chemotherapy have put forward new challenges to the theory and technique of oncoplastic surgery. Due to the presence of the risk of tumor recurrence or metastasis, the oncoplastic surgery operations often require a certain course of preoperative induction chemotherapy. Drawing lessons from existing research results, the preoperative induction chemotherapy has the following advantages: (1) It can shrink the tumor, improve the surgical resection rate, reduce the difficulty of plastic surgery, and even avoid the need to perform plastic surgery, thus reducing the shape defects and the loss of function as much as possible; (2) it can eradicate the micrometastases, avoid the postoperative rapid proliferation of micrometastases which lurk in the body, and reduce the vitality of tumor cells, so that the tumor cells are not easy to spread during surgery; (3) it may kill the tumor cells which are sensitive to chemotherapy and eliminate the subclinical metastases, control and reduce the tumor recurrence after plastic surgery, and prolong the postoperative disease-free survival of the patients, thus indirectly ensuring the quality and efficacy of plastic surgery operations and improving the success rate and the value of the plastic surgery operations.

The postoperative chemotherapy is an important means for controlling and destroying the remaining micrometastases and has played a positive role in the prevention of local recurrence and distant metastasis. A large number of tests or studies have shown that the residual tumor cells after surgery can enter into proliferation cycle in quantity, which accelerates the tumor growth, increases the proliferation ratio, and promotes the sensitivity to chemotherapy; at the moment, the effective chemotherapy should be applied as early as possible to achieve the best therapeutic effect. Therefore, the chemotherapy after plastic surgery cannot only control the local tumor recurrence and ensure the efficacy of the plastic surgery but also is an important means for eliminating the distant metastasis, prolonging the lives of patients, and improving the qualities of life of the patients after surgery.

Different from general surgery and oncology surgery, the oncoplastic surgery has its own peculiarities. In general, the patients undergoing plastic surgery have relatively early stage tumors or some local advanced tumors which are not expected to recur within a long time after comprehensive treatment, and it is possible to implement more successful radical surgery and plastic surgery only in these patients; if the patients cannot achieve a longer survival after surgery, the repair and reconstruction also cannot be considered. For the patients with local advanced tumors, it is not difficult to receive appropriate preoperative chemotherapy, but for the patients with relatively early stage tumors, is it necessary to carry out preoperative and postoperative chemotherapy?

In another situation, the clinicians have no room for choice. Many patients have advanced disease conditions or tumor recurrences, and they have undergone multiple courses of comprehensive treatment such as radical surgery, radiotherapy, and chemotherapy before plastic surgery. For these patients with relatively late-stage tumors and the indications for plastic surgery, whether it is needed to carry out chemotherapy in the end and how to select the best time of chemotherapy need to be studied further.

For those tumors which are sensitive to chemotherapy, the preoperative chemotherapy before plastic surgery is generally beneficial; and for those tumors which are relatively insensitive to chemotherapy, in the course of preoperative chemotherapy, a few patients inevitably have disease progression or the appearance of new lesions or metastases, so that the purposes of using the preoperative chemotherapy to achieve the downstaging of the disease and make it easy to perform the surgical resection and control the metastasis are not achieved completely. Some patients with tumors which can be resected by surgery have missed the timing of surgery due to disease progression and the emergence of new metastatic lesions; it is not known whether it is beneficial to carry out preoperative chemotherapy in these patients. Should the patients who are insensitive to chemotherapy be given chemotherapy before surgery? How to predict and avoid deterioration during preoperative chemotherapy? Should the decision on whether carrying out chemotherapy be determined according to the tumor stage? These are the problems needing to be solved by the preoperative chemotherapy in oncoplastic surgery.

Along with the progress of life science and biochemistry, a lot of chemotherapy drugs with small side effects and good efficacy spring up; with the development of evidence-based medicine and the advent of joint multicenter study, more and more chemotherapy regimens are gradually becoming perfect. The use of multidisciplinary-integrated treatment mode enables us to get a new understanding on the role of chemotherapy in tumor treatment, even for some tumors which are relatively insensitive to chemotherapy; people also begin to

pay attention to studies on their postoperative chemotherapies. It should be mentioned that the postoperative chemotherapies have made a great contribution to curbing the growth of tumor cells and prolonging the survival of patients. Out of fear of tumor recurrence and metastasis, the patients are often willing to receive a certain course of postoperative chemotherapy, and those with oncoplastic surgery are no exception, because even after highly successful radical surgery and plastic surgery, there may be tumor recurrence. But there are still several issues worth noting: (1) Is it needed to carry out chemotherapy after plastic surgery for patients with early stage tumors? (2) Is it needed to carry out chemotherapy after plastic surgery for patients with tumors which are insensitive to chemotherapy? (3) How to carry out the sequential chemotherapy and radiotherapy in the treatment of tumors? There is a lack of systematic-related researches on these problems, and no unified standard is available to guide the treatment standardization, all of which are expected to be further studied.

11.2 Effect of Chemotherapy on Biological Tissues

It is undoubted that the chemotherapy drugs have certain influences on biological tissues, which has also proposed new requirements to the theories and techniques of the oncoplastic surgery; for example, it is found in clinic that the blood vessels after injection of chemotherapy drugs are often damaged, which is manifested as endovasculitis, vascular occlusion, vascular stiffness, etc. Is the direct intravenous injection site still suitable for use as the skin flap donor site? What are the differences in histology and ultrastructure between the blood vessels at the non-intravenous injection sites and the blood vessels at the direct intravenous injection sites? All these problems remain to be further studied.

Even the nonneoplastic general plastic surgery also needs to have a longer time to heal the wound; the special nature of the tumor often requires that the chemotherapy is timely carried out after oncoplastic surgery to reduce tumor recurrence. For the cancer patients whose general conditions are far worse than those in healthy people, would chemotherapy have a delay the tissue repairment and wound healing process after plastic surgery? In some studies on the use of neoadjuvant chemotherapy and radical surgery, it is generally believed that the neoadjuvant chemotherapy will increase the difficulty of surgical procedure and the postoperative complications; for instance, the intraoperative blood loss is increased significantly, the difficulty in dissecting the free blood vessel is increased, the operative time is relatively prolonged, the incidence of postoperative arrhythmia is increased significantly, and the wound healing is delayed. But some studies also suggest that the neoadjuvant chemotherapy does not increase the postoperative complications and mortality, and the chemotherapy has no effect on the tissue healing in patients with oncoplastic surgery. The oncoplastic surgery often involves transplantation of various tissue flaps, multisite operation, and even allotransplantation, and it is a complex and delicate surgery. The keys to the success of oncoplastic surgery are that, in the one hand, the tumors are completely removed without recurrence; on the other hand, the growth of the repairing tissue is good, and its morphology and function are normal or similar to normal. If the tissue repair is affected by the preoperative or postoperative chemotherapy, the purpose of appearance recovery and functional reconstruction cannot be achieved through plastic surgery; in fact, it is the failure of plastic surgery. Therefore, the study on the effect of chemotherapy on tissue repair will provide the basis for oncology surgeon to design appropriate repair and reconstruction scheme and formulate reasonable chemotherapy treatment course.

At the same time of recovering the functions of the human body, the plastic surgery can cause trauma in the body and reduce the tolerance on chemotherapy in patients, so that the patients are even unable to complete the established systemic chemotherapy; if there is a concurrence of postoperative local necrosis, infection, and depigmentation in tissue flaps, it will further delay the starting time of chemotherapy and affect the dose intensity of chemotherapy. Carrying out timely and active postoperative chemotherapy in patients with tumors is often the key to cure tumor. If the delivery of chemotherapy is delayed, or the systematic chemotherapy cannot be completed, it may even cause negative effects such as tumor recurrence and shortened survival. Therefore, when the plastic surgery program is formulated, the effects of the surgery itself on postoperative chemotherapy and other comprehensive treatments should be taken into account [31–33].

11.2.1 Effect of Chemical Treatment on Skin Flap

The autologous skin flap transplantation is an effective method for repair and reconstruction. The skin flaps can be divided into the random pattern skin flap (no blood supply from direct cutaneous artery) and the axial pattern skin flap (including the well-known nutrient vessels) according to blood supply mode; they can be divided into pure skin flap, fasciocutaneous flap, and myocutaneous flap according to the tissue contained in the skin flap; they can also be divided into the pedicled skin flap and the skin flap with vascular anastomosis according to the mode of skin flap transplantation.

Currently, there are rare basic researches on skin flap and chemotherapy. Zhou Xiao et al. [34, 35] conducted a research on the effect of combined chemotherapy of cisplatin and fluorouracil on abdominal skin flap and found that there was no obvious difference in the growth of skin flap after carrying out the in situ skin flap repair at the site where the chemotherapy drug was injected directly. Wang Wei et al. conducted a research on the effect of preoperative induction

chemotherapy on saphenous flaps in experimental dogs and found that there were more inflammatory cell infiltrations and thrombogeneses in direct injection site than those in non-direct injection site, but the effect of short-term chemotherapy on skin flap healing was not obvious. There is still no relevant research on whether the sites after a long-term repeated stimulation of chemotherapy drugs are suitably used as flap donor sites. Ge Zixin et al. have observed the effects of early chemotherapy after breast cancer surgery on wound healing of skin flap necrosis of the chest wall. One hundred four breast cancer patients after Halsted mastectomy were divided into the chemotherapy group (56 patients) and the control group (48 patients).The chemotherapy group was treated by the CMF regimen consisting of cyclophosphamide, methotrexate, and fluorouracil, while the control group received no chemotherapy. There were no significant differences in granulation generation time, the healing time of the dressing wound, and the time for establishing blood circulation in free skin flap between the two groups. Another report on local skin flap repair of skin ulcer caused by the chemotherapy drug leakage showed that 26 patients with chemotherapy-induced persistent skin ulcers underwent skin flap repair and achieved satisfactory results.

The study on skin flap and chemotherapy started earlier at abroad. In 1993, Vaden SL et al. carried out a study on the use of cisplatin and carboplatin in the tumor skin flap and the normal skin flap and found that there was a difference in platinum distribution between the two. However, the report mainly investigated the distribution of the platinum drugs and the establishment of research model of platinum-related skin flap from the perspective of pharmacology, failed to carry out in vivo study of the skin flap, and also didn't link it to oncoplastic surgery. The study on the application of skin flap in the repair of tumor mainly focuses on aspects of head and neck surgery and breast cancer; currently many cases are reported each year. Rapidis AD has studied 48 patients with orbital tumors, of which only 10 patients underwent surgery alone and the other 38 patients underwent radiotherapy or chemotherapy alone. In all patients, 19 underwent radical surgery combined with split-skin graft transplantation, 16 patients underwent eye socket removal and forehead flap transplantation, and 7 patients underwent maxillectomy plus repair of forehead and temporalis muscle flaps. Unfortunately, this study failed to observe the effect of chemotherapy on the growth and repair of skin flap. The same situation occurred in the relevant literatures on breast cancers and oral cancers, although all these studies mentioned that the chemotherapy or chemoradiotherapy was used before and after the implementation of plastic surgery and also put forward that the adjuvant chemotherapy could not be delayed because of plastic surgery; all studies failed to analyze the effects of chemotherapy on the risk of plastic surgery, wound healing, and skin flap survival.

11.2.2 Chemotherapy and Fascial Flap

The fascial flap refers to the tissue flap containing superficial fascia and deep fascia; since it doesn't contain the skin, the donor site won't have loss in appearance after harvesting of fascial flap, and it is the new tissue flap which has been gradually developed in recent years. The fascial flap can be divided into the pedicled fascial flap and free fascial flap according to the blood supply, simple fascial flap and composite fascial flap according to the components of the transplanted tissues, and temporal fascial flap, the fascial flap behind the ear, deltopectoral flap, and calf fascial flap according to anatomic sites.

The repair of tumor-associated scalp defect needs to use a variety of tissue flaps such as skin flap, fascial flap, and muscle flap; it also involves facial nerve repair and ectropion correction and is a relatively complex surgery. Lutz BS reported 11 patients with tumor-associated scalp defects in 2002, including eight patients after undergoing surgery and radiotherapy or with recurrent tumors after radiotherapy; the average defect area was 169.5cm^2 (30–600cm^2). This article didn't analyze the effect of chemotherapy on the surgery and didn't explain whether the adjuvant chemotherapy was performed after plastic surgery, but judging from the conclusion that all patients have achieved good cosmetic results and functional recoveries, it seems that the chemotherapy does not increase the risk of plastic surgery.

Rath T et al. have studied the defect repair after radical resection of tumors in the mouth; they used the mucous membrane to wrap the fascia which was mixed with gastrocnemius nerve transplantation and then covered it with a silicone sheet to make the mucous membrane spread within the fascia, so that the fascial flap finally complied with the requirements for transplantation. This process requires 8–10 weeks, during which the patient must receive radiotherapy or chemotherapy. Such intraoral defects repaired by reinnervation surgery can produce mucus, which is a more successful approach. Although the authors still did not observe the effect of chemotherapy on tissue flaps, the chemotherapy in this study apparently did not hamper the transplantation and survival of the tissue flap.

11.2.3 Chemotherapy and Muscle Flap

The muscle flap refers to the muscular tissue which doesn't contain skin, and it can be divided into the pedicled muscle flap and the muscle flap with blood vessel anastomosis according to the transfer mode.

There was a research on chemotherapy and muscle flap in the fifth issue of Shanxi Medical Journal in 1997. The author transplanted the pedicled temporalis muscle flap into the tumor cavity to increase local blood flow in the tumor cavity and used teniposide in the chemical treatment of brain glioma, so that the residual tumor could get a double dose of chemotherapeutic drug. The clinical observation confirmed

that the efficacy was satisfactory, according to the evaluation criteria of David Barba; it was excellently effective in three cases, effective in two cases, and invalid in five cases. The patients with excellent effect were followed up for 30 months, and no tumor recurrence was observed. The study was not designed for the purpose of repair and reconstruction.

The skin invasion and lymph node metastasis of the penile cancer often cause damages to the groin and perineum, and the defects must be repaired with tissue flaps containing skins, fascias, muscles, and nutrient blood vessels. In a prospective study based on the use of CMB regimen consisting of cisplatin, methotrexate, and bleomycin as a neoadjuvant chemotherapy regimen, 15 patients with penile squamous cell carcinomas underwent tumor resection plus immediate myocutaneous flap repair after treated with CMB regimen for an average of 2.4 period and antibiotic treatment. Twenty-nine of 31 myocutaneous flaps achieved primary healing.

The neoadjuvant chemotherapy has been considered likely to increase the complications of breast cancer surgery and delay the postoperative treatment. Deutsch MF et al. carried out plastic surgery with transverse rectus abdominis myocutaneous flap (TRAM flap) in 31 patients undergoing neoadjuvant chemotherapy immediately after mastectomy and made evaluations on the surgical complications and whether the postoperative adjuvant chemotherapy was delayed. The results showed that 17 patients had postoperative complications, but the postoperative chemotherapy was delayed in only two patients; therefore, it is considered that the breast cancer patients after neoadjuvant chemotherapy can safely undergo radical surgery and plastic surgery. The study also found an interesting phenomenon: The smokers may have increased surgical complications and delayed postoperative chemotherapy. Allweis TM et al. also believed that the immediate plastic surgery after mastectomy of breast cancer will not delay the starting time of postoperative adjuvant chemotherapy.

Chang DW et al. carried out a follow-up study on 77 patients undergoing skull base reconstruction surgery after tumor resection, of whom 52 patients underwent repair with free flap, 14 patients underwent repair with temporalis muscle flap, 8 patients underwent repair with pericranium flap, and 3 patients underwent repair with other local tissue flaps. Twenty-one patients had complications, including falling off of the full skin flap in three patients, partial falling off of the skin flap in three patients, cerebrospinal fluid leakage in two patients, meningitis in two patients, abscesses in two patients, hematoma in two patients, delayed wound healing in five patients, wound infections in one patient, and cerebral vascular accident in one patient; Seventy-seven percent of the patients had a survival time of 2 years, and 58% of the patients had a survival time of 4 years. The author believes that the types of reconstructive surgery, the defect site, the dural repair mode, and whether to receive preoperative chemoradiotherapy have no effects on the occurrence of complications.

The comprehensive treatments of soft tissue tumors include artery intubation chemotherapy, tumor resection, and defect reconstruction. Sadrian R et al. carried out a retrospective analysis on some patients receiving the above treatments. All patients underwent systematic artery intubation chemotherapy before surgery, and the repair and reconstruction of the defect were carried out mostly with latissimus dorsi and rectus abdominis free flaps. Among whom, a patient still received a vascular graft and had no sign of falling off or infection of tissue flaps. The total transplantation success rate of tissue flaps was 100%. Twelve patients had good functional recovery, four patients had ordinary functional recovery, and seven patients had tumor recurrence. The average survival time after surgery was 20.6 months. These studies showed that preoperative artery intubation chemotherapy does not increase the complications of immediate tissue flap transplantation.

The free flap reconstruction and adjuvant chemotherapy after surgical resection have been used in a growing number of sarcoma patients. Peter FW carried out a study in mouse models and found that the chemotherapy and the granulocyte colony-stimulating factor (GCSF) will enhance the endothelial function of the leukocytes and thus are considered to affect the microvascular blood flow and cause flap failure. Goldschmidt D repaired the defects with serratus anterior and latissimus dorsi muscle flap in two patients after resection of stage I malignant melanoma, and the patients were treated with melphalan after surgery. In addition to moderate swelling of the tissue flaps, it was not observed that the chemotherapy had other side effects on transplanted flaps.

11.2.4 Chemotherapy and Bones

Most of domestic scholars have a positive attitude toward the preoperative neoadjuvant chemotherapy before bone tumor surgery. Fu Qin et al. selectively performed the limb-salvage surgery using metal prosthesis in 22 patients with osteosarcoma in four limbs on the basis of neoadjuvant chemotherapy and the curative effects of which were good. The Bone Tumor Research Center of The First Affiliated Hospital of Sun Yat-sen University carried out a retrospective analysis on complete clinical and follow-up data of 52 patients with bone tumor around the knee who underwent limb-salvage surgery through artificial prosthesis replacement from 1990 to 1999, including 33 patients with osteosarcoma and 19 patients with osteoclastoma; twenty-four patients were treated with preoperative chemoembolization, and 28 patients were not treated with chemoembolization at the same period. All 33 patients with osteosarcoma and 12

patients with grades II and III osteoclastoma underwent postoperative regular chemotherapy. The knee joint function was evaluated according to Enneking standard. The longest follow-up time was 118 months, and the shortest follow-up time was 12 months, with an average follow-up of 38 months. Results: Within 12 months after surgery and at the last follow-up, the function scores in the intervention group were superior to those in the nonintervention group; the early and recent complication rates and the repair rate in the intervention group were lower than those in the nonintervention group.

There are many studies on chemotherapy and bone abroad. Bertermann O et al. observed effects of the preoperative and postoperative strengthened chemotherapies on wound healing in 110 patients with lower limb osteogenic sarcoma and the chemotherapy regimen of which included bleomycin, cyclophosphamide, actinomycin D (BCD), adriamycin (ADR), and high-dose methotrexate (HD-MTX). All patients underwent en bloc resection and artificial limb surgery, and some patients received debridement and skin grafting. The antibiotics were routinely used before and after surgery, the wound healed well in 80% of patients, and no patients died of wound infection. Morello E et al. observed 13 dogs with osteosarcoma of the distal radius. These dogs without distant metastases received preoperative adjuvant chemotherapy (cisplatin plus doxorubicin) and then received the limb-salvage treatment and autologous transplantation. The average survival time and median survival time were 531 days and 324 days, respectively. The 6-month survival rate was 100%. Therefore, the author thought that it was an effective method. Gravel CA et al. [31] observed the effect of neoadjuvant chemotherapy on distraction osteogenesis technique in goat models. The results showed that whether carrying out chemotherapy or not had no significant inhibition on bone formation; therefore, it was considered that the chemotherapy was not a contraindication for limb-lengthening surgery after osteosarcoma resection. But some studies have also found that the chemotherapy indeed has some adverse effects on bones. In order to observe the effects of three kinds of commonly used chemotherapy drugs such as methotrexate, cisplatin, and doxorubicin on bone tumors in children, Van Leeuwen BL used the male Wistar rats as the study objects and found that the abovementioned three drugs reduced the intensity of the epiphysis and increased the risk of fracture. Another study suggests that the doxorubicin reduces the thickness of the growth plate, the methotrexate increases the thickness of the growth plate, and the cisplatin does not affect the thickness of the growth plate. All three chemotherapy drugs decrease the metaphysis bone trabecula in the proximal tibia, and some adverse effects are related to malnutrition caused by chemotherapy.

11.2.5 Chemotherapy and Blood Vessels

At present, most domestic studies on chemotherapy and blood vessels start from the aspects of the treatment of tumor drug extravasation and are limited to the study of chemotherapeutic phlebitis. Some abroad scholars carried out treatments and observations which lasted for 7 years in 20 patients with soft tissue sarcoma involving the limb vascular plexus, of whom six patients underwent limb perfusion treatment, four patients received systemic chemotherapy, two patients received systemic chemotherapy plus local hyperthermia, and one patient received radiotherapy; all patients underwent resection of sarcoma and invaded nerves and blood vessels, and the blood vessels were repaired by autologous or allogeneic veins; six patients underwent repair of soft tissue defects with myocutaneous flaps or skin flaps. Among 20 patients, 19 patients had successful limb salvage, and the average survival time was 30 months, and then 11 patients had distant metastases. The author believed that the preoperative combination therapy, extended resection, and vascular repair had longer-term effects of local control and limb salvage in these patients.

Valentino J observed the effect of intra-arterially administrated cisplatin on the neck arteries; the results showed that there were no differences in histology and ultrastructure between the blood vessels with and without injection of cisplatin, both of which showed intimal thickening and depositions of collagens and elastins in vascular intima. The intimal smooth muscle hyperplasia occasionally occurred, and a small number of smooth muscles had vacuolization, elastic fiber degradation, and calcinosis.

11.3 Summary

The clinical literature reports on oncological surgery have been summarized. Some studies suggest that the tumor tissue fragility after chemotherapy is increased, the difficulty to dissect the free blood vessels is increased, the surgical complications are increased, and the vascular intima damage caused by the preoperative induction chemotherapy may affect the survival of the skin flap; but others argue that the preoperative induction chemotherapy does not increase the incidence of complications after immediate tissue flap transplantation and also does not affect the recovery time after oncoplastic surgery. So far, there are rare basic researches on the effect of chemotherapy on tissues at home and abroad, when the clinical patients are taken as research objects, due to the unmanageable differences in aspects of test conditions, patient compliance, surgical procedure selection, and economical affordability; the conclusions are not always reliable. All of these are worthy of further exploration.

12 Applications of Biological Materials in Oncoplastic Surgery

Yong Zeng, Bo Zhou, and Lijian Zou

12.1 Overview of Biological Materials

The previous radical tumor surgery can achieve complete excision of the lesions; at the same time, the patients often have a damaged appearance and loss of organ function. Some radical tumor surgeries involving important sites can't be carried out because of the lack of appropriate alternative materials used to repair and even have been listed as forbidden surgeries. Therefore, a large number of cancer patients have lost the chance of surgical treatment, and some patients are also unwilling to accept radical surgery due to the low quality of life after surgery. The emergence and development of oncoplastic surgery provide new ideas and patterns for solving these problems; in particular, the progresses in biological materials science and applied technology in recent years provide a strong support for the design of operation plan in oncology surgery, the repair and reconstruction, as well as the aesthetic reproduction after surgical resection [36].

Currently, the use of tissue grafts from different sources to carry out local defect repair and aesthetic reproduction has become a more mature treatment means, and different transplantation methods have their respective advantages and disadvantages. The autologous tissue transplantation is the most commonly used treatment means in plastic surgery; even the use of autologous tissue is recognized as the "gold standard" in the field of most tissue repairs, but the acquisition of autologous tissue is limited, often leading to secondary damage in donor site; there exist some problems such as mismatching of tissue shapes, long postoperative recovery time, and poor aesthetic effect. For the patients who can't provide the required amount of tissue due to lack of tissues in donor site or are unwilling to accept donor site damage, it is needed to carry out repair using allogeneic and xenogeneic tissues or tissue substitutes [37–40].

Different from simple cosmetic and plastic surgery, the defect repair after tumor resection will make more stringent requirements for biological materials, particularly after radical resection of malignant tumor; the range of tissue defect may be larger, and some tissues surrounding the lesion have concurrent inflammation, infection, tissue degeneration, and even potential tumor cell infiltration; the patients need to be treated with systemic chemotherapy or local radiotherapy after surgery, all of which are negative factors affecting the efficacy of implanted biological materials. In turn, the implanted biological materials will also seriously affect the efficacy of local chemoradiotherapy; as an allogeneic biological material, the implant will increase the degree of local inflammation and infection. All these factors lead to a high incidence of complications after the use of biological materials to repair the defects after radical resection of malignant tumor and even eventually lead to the failure of the operation; and certain types of implanted materials may also cause interference to imageological examination after tumor surgery and affect the postoperative reexamination. Therefore, within the scope permitted by the conditions, the soft tissue and bone defects after tumor surgery should be repaired as far as possible using autologous tissues, which is still the currently preferred scheme for oncoplastic surgery; the biological materials can be used as a supplement or alternative means for oncoplastic surgeons to choose, and their indications also need to be controlled more strictly.

12.2 Classification of Biological Materials

The biomedical material is briefly called as biological material, referring to the material used in the human body or indirectly contacting with the human body; therefore, it is the general name for in vivo implant material, medical material, and prosthetic material and is a non-drug material in clinical medicine. In 1987, the International Organization for Standardization (ISO) described the definition of biological material as: It is an inanimate material which is used to contact with living tissue to reconstruct the function, including biocompatible or biodegradable material. At present, a wide variety of biological materials can be used in clinics; there are different classification methods according to different standards; under normal conditions, the classification can be carried out according to the properties, functions, sources, application sites, and use requirements of the biomedical materials. It is more common to perform classification according to the properties of biological materials [41].

12.2.1 Medical Metallic Materials

The metal materials are the biological materials earlier used in the medical field, mainly including titanium, tantalum, niobium, zirconium, stainless steel, cobalt alloys, titanium alloy, and tantalum alloy, and they are widely used in internal fixation, artificial joints, and prostheses.

12.2.2 Medical Inorganic Nonmetallic Materials

The inorganic nonmetallic materials mainly refer to a variety of biological ceramics, glass, carbon, etc., including oxide ceramics, phosphate ceramics, and bioglass. The biological ceramics can also be divided into bioinert ceramics, surface-active ceramics, and biodegradable ceramics according to their tissue reaction characteristics.

12.2.3 Medical Polymer Biological Materials

Various types of polymer biological materials develop rapidly and are gradually applied in clinics. The materials sources could be natural polymer such as polysaccharides and proteins, and synthetic polymer such as polyethylene, polytetrafluoroethylene, and polyethylene methyl methacrylate. These materials are widely used in human tissue repair and drug carrier.

12.2.4 Medical Composite Materials

The composite material refers to a new material which is made from two or more biological materials, and it can obtain more excellent material properties to make up for the shortcomings of a single material and is widely used in the replacement and repair of human tissue and organs.

12.3 Requirements for Commonly Used Biological Materials

According to different sources, the biological materials can be divided into two kinds of materials such as natural materials and synthetic materials. In order to ensure the safety and effectiveness of clinical application, there are certain requirements for biological materials from various sources.

12.3.1 Good Biocompatibility

The biological materials will not cause toxic reaction, inflammatory reaction, foreign body reaction, and allergic reaction. They have no antigenicity and carcinogenicity and are unlikely to cause thrombosis and other security issues.

12.3.2 Appropriate Intensity

The biological materials applied in repair of the force bearing parts in the human body are required to have certain intensity, tolerate a certain degree of tension and pressure, and withstand a certain load. For example, the elastic modulus of bone repair material should be close to that of the bone, have a high wear-resistant degree, and have to be resistant to aging. The requirements for the biomechanical properties of the materials used in different parts of the body are different, and the good biomechanical conditions can promote strong bonding strength at the interface between material and human body tissue.

12.3.3 Good Stability

Since the biological materials implanted into the body will have various forms of material, energy, and signal exchanges with the adjacent parts, thus it is required that the materials should have chemical stability, with no structural change after long-term implantation, and should also have good anticorrosion performance, with resistance to corrosion and abrasion and without producing soluble toxic substances.

12.3.4 Other Requirements

The requirements are that the biological materials should be nonmagnetic, conducive to processing and shaping, and easy to disinfect and sterilize.

The abovementioned are some basic requirements for biological materials proposed just from the point of view of clinical medicine and biology. Because of different characteristics of different materials, the corresponding reactions of the body are also different; even for the same material used by the same method, the reactions of the body to the materials may be different due to individual differences. The reactions of the body to the materials are closely related to the types, characteristics, surface structures, morphologies, implantation methods, implantation sites, and functional statuses of the biological materials.

12.4 The Characteristics of Commonly Used Biological Materials

With the rapid development of biological material science, there is a wide variety of biological materials which can be currently used in clinics, and different materials have different clinical use. This article will make a brief introduction on various types of materials mostly used in oncoplastic surgery and will focus on metal materials, inorganic nonmetallic materials, high molecular polymers, and biocomposite materials which are widely used in oncoplastic surgery.

12.4.1 Metal Materials

The metal materials have characteristics such as high strength, fatigue resistance, and easy processing. They are currently used in sites such as bones and teeth which need to withstand the higher loads, and the most important applications include fracture fixation plates, screws, artificial joints, and dental implants. It is important to note that the use of metallic materials in the process of repair and reconstruction of bone tissues and bone joints in oncoplastic surgery may produce un-negligible effects on local radiotherapy after surgery, different metal materials can have scattering and blocking effects on high-energy particles, so that the bone and soft tissue in front of the metal material receive an increased radiation dose, while the bone and soft tissue in the rear of the metal material receive a decreased radiation dose. Therefore, before carrying out radiotherapy on the site where the metal material is implanted, it is supposed to comprehensively consider the shape and thickness of the metal material and make corresponding adjustments to radiation dose and radiation angle. In addition, some metal materials can block the penetration of the X-ray beam, or they can be magnetized

or interfere with the accuracies of imaging examination results under the strong magnetic field, which will bring effects on reexamination and treatment.

1. Medical stainless steel. The medical stainless steel is one of the earliest developed medical alloys, and it has achieved a very wide range of clinical applications due to its low prices and easy processing, such as artificial joints, fracture fixation devices, cortical and cancellous bone compression screws, skeletal traction wire, artificial vertebrae, and skull plate. After long-term implantation, the stability of the medical stainless steel will be poorer. There are large differences in density and elastic modulus between the medical stainless steel and the human hard tissue, and the mechanical compatibility between medical stainless steel and bone is poor, the metal ions dissolved from which can induce inflammatory response of the body, and its utilization rate has declined in recent years, especially the built-in products that have gradually been replaced by other better biocompatible metals or alloys.
2. Medical titanium alloys. The titanium and titanium alloy have been widely applied in clinics due to its good biocompatibilities and excellent mechanical properties. Titanium is the metal with the best biological affinity in currently known metals, and it will cause a minor tissue reaction after implanted into the body. It has a certain biological activity and the ability to bind to the bone and especially is suitable for being embedded within the bone. Its disadvantages include low hardness and poor wear resistance, and its biocompatibility and comprehensive mechanical properties can be further improved through adding other metal elements into titanium to produce the titanium alloy and implementing special surface treatment. Its clinical applications include that it can be used in productions of bone fixation devices, artificial joints, various brackets, and cranial prosthesis and it can also be used for reconstruction of jaw bone defects during oral and maxillofacial surgery.
3. Medical precious metals. The precious metals for medical use include gold, silver, platinum, and their alloys. These metals have relatively more stable chemical properties and biocompatibility, especially the alloys containing multiple metals that can improve the mechanical strength, and are mainly used for oral and maxillofacial surgery and skull repair.
4. Medical rare metal materials. Medical rare metal materials include rare metals such as tantalum, niobium, and zirconium. Such materials have good chemical stability, corrosion resistance, and biocompatibility, and they can be processed into surgical implant materials such as bone fracture plate, cranial prosthesis, and screws according to clinical use. Most of these materials are more expensive, so that their applications are limited in a certain extent.

12.4.2 Inorganic Nonmetal Materials

The inorganic nonmetal materials mainly refer to all types of biological ceramics, including hydroxyapatite, tricalcium phosphate, hydroxyapatite cement, and bioactive glass. The repairing bone tissue with bioceramic materials has a long history of clinical applications, and new materials have always been developed for clinical application. Application of these materials has become an important means for repair of bone defects and defects after benign bone tumor curettage, but the effects of local radiotherapy and systemic chemotherapy on the biological activity of these materials still need further study.

1. Hydroxyapatite. The molecular structure of hydroxyapatite (HA) is very similar to that of the human bone and tooth enamel and has a good biocompatibility. A strong chemical bond can be formed between hydroxyapatite and the human bone, but the hydroxyapatite cannot be dissolved and absorbed by the body. Synthetic HA [$Ca_{10}(PO_4)_4(OH)_2$] is the crystal structure formed by calcium and phosphate under high-temperature reaction. The ratio of calcium and phosphorus is 1.67, and its biggest feature is that its chemical composition and properties are very similar to those of the mineralized natural bone, so that it has a good osteoconduction and biocompatibility, and thus it has been widely used as a bone substitute in clinics. The osteoconduction refers to the process by which the implant materials after contacting with bone or periosteum can guide new bone regeneration in sites with the presence of osteoblasts, while the osteoinduction refers to the process by which the implant materials can also guide the new bone regeneration in the soft tissue in the absence of osteoblasts. Although the implanted hydroxyapatite structure or the scaffold composed of hydroxyapatite closely contacts with the neighboring natural bone, it is not suitable for load-bearing bone repair and also has no osteoinduction due to its high brittleness. In recent years, the hydroxyapatite has also been used as the bone induction growth factor and the biologically active carrier of osteoblasts, and it is used for promoting repair and reconstruction of damaged bone.

   HA such as porous the type and granular type is more commonly used in clinics, especially the structure of bulk porous material that is similar to that of the natural bone, and is mainly used in the nonweight-bearing area; for example, it is used for repair of bone defects in mandible, cheekbones, and orbital bone. Since pure HA material has a high brittleness, the composite material which is developed in recent years and is made from HA and other materials has the characteristics of two or more biological materials, having a wider prospect of clinical application. Common HA composite materials can be roughly divided into five types, and they are defined as follows,

respectively: (1) the composite consisting of HA and biological material, such as bone morphogenetic protein (BMP), collagen, and fibrous protein; (2) the composite consisting of HA and organic biological material, such as polyester; (3) the composite consisting of HA and inorganic biological material, such as metal material; (4) the composite consisting of HA and autologous material, such as autologous bone marrow or desalinated bone; and (5) the composite consisting of HA and multiple materials.

2. Tricalcium phosphate (TCP) is a resorbable bioceramic material; after being implanted into the bone tissue, it is dissolved and absorbed by the body fluid and then is metabolized and excreted out of the body. The defect site is eventually replaced by new bone tissue, and the implanted material plays a supporting role within a period of time. TCP has a good biocompatibility and osteoconduction, whose chemical composition and microstructure are similar to those of natural bone and tooth at calcification stage, and the constitute formula is $Ca_3(PO_4)_2$. It can be divided into two types such as type α and type β according to the crystal structure. β-Tricalcium phosphate (β-TCP) is more commonly used in clinics; compared with the HA, its biggest advantage is that it can be absorbed and degraded by the body and has a higher strength.

   The application of TCP as a synthetic bone defect filler has a history of more than 20 years; its smaller particle diameter and cavernous interconnecting microporous structure make it have a good osteoconduction and at the same time also make it have a high degradation and absorption rate in the process of bone remodeling. The in vivo degradation and absorption of TCP can stimulate the growth of the surrounding new bone and thus can better guide new bone regeneration and play a physiological supportive role in the bone repair process. Now there are three main types of finished TCP: (1) granular TCP for filling various bone defects, (2) porous TCP, and (3) dense TCP. Its usage and indications are similar to those of HA, mostly applying to repair skull, orbital floor, and jawbone, as well as repair the bone defects after resection of benign bone tumor and tumor-like lesions.
3. Hydroxyapatite cement. The hydroxyapatite cement is also known as hydroxyapatite bone cement or calcium phosphate cement (CPC). It has a clinical application history of more than 30 years, and it is also a good bone substitute with biological activity. Compared to other bioceramic bone substitutes, it has a good plasticity; therefore, it can contact more closely with the bone. Such materials have a good osteoblastic activity while not affecting the imaging examination and being easy to obtain. The hydroxyapatite bone cement powder is generated through reaction between four-calcium phosphate and dicalcium phosphate in the presence of water, and it has a certain biological absorptivity after solidification. Compared with the hydroxyapatite ceramics, the biggest advantage of the hydroxyapatite bone cement is that it can easily be shaped into any desired forms in the surgical procedure. The disadvantage of the hydroxyapatite bone cement is that it has an osteoconduction only after contacting closely with the natural bone, and because it does not have an osteoinduction, the growth of the new bone after its implantation is often limited. To overcome this disadvantage of the bone cement, various growth factors to promote bone formation are used simultaneously, and it has been confirmed that they can accelerate collagen synthesis and bone defect healing, thereby enhancing the clinical effect of bone cement.
4. Bioactive glass. The bioactive glass was originally reported by Hench et al.; its main components include silicon dioxide, sodium oxide, calcium oxide, and phosphate. At present, such materials can be used alone or used in combination with autologous or allogeneic transplantation, being widely used to fill and repair the bone defects. The binding reaction between the natural bone and bioactive glass is the result of the interreaction between the bone and bioactive glass surface, and the hydroxyapatite surface of bioactive glass bone during a long time after implantation can be replaced by bone, whose biological activity is affected by its compositions, pH of the surrounding area after implantation, the temperature, and the glass surface treatment. The micropores of the bioactive glass also provide a scaffold for the new bone to facilitate the differentiation of blood vessels and osteoblasts. Histological studies have showed that after being implanted into the body, the bioactive glass will cause no or only a relatively minor inflammation in the surrounding tissue, and the glass fiber scaffold is absorbed more completely at 6 months after implantation. The bioactive glass is mostly used for the ear drum reconstruction, filling after bone tumor surgery, reconstruction of facial bone defect, and repair of alveolar bone defect.

12.4.3 High Molecular Polymer

Most soft tissue-filling materials belong to the polymer biological materials, and the ideal soft tissue-filling materials need to have excellent biological properties, such as the stability in aqueous solution, the chemical resistance in the surroundings, easiness of shaping, and no toxicity. Today, all kinds of polymer biological materials have some shortcomings more or less; for example, they have different degrees of degradation in the physiological environment, and the long-term implanted materials have poor in vivo stability, tissue toxic reaction, and potential carcinogenicity. The polymer biological materials which are more commonly used in clinic

include silicone, polymethyl methacrylate, polytetrafluoroethylene, high-density polyethylene, polylactic acid, polyglycolic acid, polyester, nylon, polyvinyl fluoride, polyacrylonitrile, etc.

1. Silicone. Silicone (silica gel) has a repeating unit structure wherein the skeleton is constituted by the monomers consisting of silicons and oxygens, and the branched chain is composed of methyl, phenyl, and vinyl. Silicone has characteristics such as high stability, good biocompatibility, no toxicity, and insoluble in body fluids. Although it is considered as an ideal in vivo implant, it will still cause some foreign body reactions, such as the formation of fibrous capsule. The silicone viscosity is determined by its degree of polymerization. The short-chain molecule polymer is in a liquid state, while the long-chain molecules turn into jellylike substance after polymerization, and the highly cross-linked polymer chains have a rubberlike appearance.

   Polyvinyl alcohol/poly(acrylamide-co-acrylic acid) hydrogel has been used for injection filling in the breast and face in the 1960s and 1970s of the twentieth century, with increasing reports of serious complications, such as inflammatory reaction, injection site induration, discoloration, tissue ulceration, migration in the tissue, and granuloma formation; the US Food and Drug Administration (FDA) has listed it as one of the materials which are prohibited for use. Currently, the elastic solid silicone with a higher degree of polymerization is more commonly used in clinic, which can be made into tissue expanders, breast implants containing saline water or semisolid silicone, and orthopedic prosthesis used for filling the soft tissue in the skull, jaw, cheekbones, nose, and chest, and can also be used for joint replacement and tendon reconstruction.

   The most common complications after implantation of silicone prosthesis include the formation of fibrous capsule and the capsule contracture, especially in the process of breast aesthetic surgery and reconstruction; there may be the occurrence of the shape change and induration in the implant site. The surface treatment for silicone prosthesis can reduce the capsular contracture, but the effect has still not been proved conclusively. The use of the silicone prosthesis in joint reconstruction can cause synovitis. Once the synovitis occurs, it is often needed to perform surgery to remove the prosthesis.
2. High-density polyethylene. This product is also known as porous high-density polyethylene, and the trade name is MEDPOR (Porex Surgical Inc., USA). It has a nearly 20-year history of surgical application, and different shapes and thickness of materials are available for surgical repair of different purposes. Its porous structure contributes to implant vascularization, thereby reducing the formation of fibrous capsule and the rejection reaction.

   In 1993, Romano et al. firstly reported the use of polyethylene (PE) materials for repair of facial fractures, which can be made into the right shape according to the needs of surgery, while not preventing the growth of the soft tissue after implantation, and it generally does not cause the rejection reaction; in addition to that, it is necessary to remove the implant because of the infection. Dougherty and Wellisz observed in vivo differences between animal models after implantation of porous PE material and silicone prosthesis; at 1 week after implantation, it can be found that a fibrous capsule is formed around the silicone prosthesis, while the growth of blood vessels and soft tissue will appear in the surrounding area of the PE prosthesis; the recent research by Jordan et al. has found that the microvascular growth is observed at 12 weeks after implantation of porous PE prosthesis into the human body, and these findings suggest that PE material is an ideal material for synthesizing prosthesis. The clinical application of PE is also more widespread; for example, PE can be used in all repairs of defects in the head and facial areas such as the cheek, orbital arch, orbital floor, upper and lower jaw, cheekbones, temporal region, and aural region. Lupi et al. have achieved fairly good results in the use of PE materials to repair the orbital bone damage and reconstruct the orbit after tumor surgery. The research by Ram et al. has shown that PE prosthesis is an ideal material for repairing a wide range of orbital defects. Although PE implants can achieve more excellent repairing efficacy in clinics, their related complications also need to cause enough attention. Some studies suggest that PE materials have a higher infection rate compared with other implanted prostheses; therefore, it is needed to pay attention to strict sterilization in the process of clinical application. The aseptic principle should be strictly abided during surgery, and the antibiotics must be used systemically after surgery. In addition, PE materials cannot be used in the stress concentration area; otherwise, it may cause wear and tear, thus resulting in chronic inflammative reaction of the tissues.
3. Polytetrafluoroethylene. The polytetrafluoroethylene (PTFE) has characteristics such as stable chemical properties and biological activity, no antigenicity, suitableness for high-temperature and high-pressure sterilization, and easy shaping, and it is an ideal biological implant material. Due to its smaller compression and tension, its application in bone repair is limited, but it is widely used for filling the soft tissue. The product Gore-Tex which is more commonly used in clinic is an expanded polytetrafluoroethylene polymer sheet, with a high purity, no hypersusceptibility

and immunological activity, small foreign body reaction, and low incidence of inflammation. It can be used to make suture lines and artificial blood vessels and can also be used for soft tissue augmentation.

4. Polymethyl methacrylate. The polymethyl methacrylate is an acrylic polymer mainly used for bone fixation, craniofacial bone substitute, joint replacement, and chest wall repair. It has good biocompatibility, easiness of shaping during surgery, higher density, and good X-ray penetration. The reaction of the body shows a low foreign body reaction against the implanted polymethyl methacrylate, may have fibrous tissue encapsulation, and have a risk of concurrence of infection and leakage after long-term implantation. The recently developed hard tissue replacement (HTR) is a poly(methyl methacrylate) composite, which is porous and rich in anion, and can stimulate bone growth.
5. Biodegradable materials. The biodegradable materials include purified extracts of natural materials and synthetic biodegradable materials, such as collagen, chitin, cellulose, and polylactose. After these materials are implanted into the body, they can be degraded biologically and absorbed and then are metabolized and excreted out of the body. Its applications include (1) tissue engineering scaffolds, (2) bone fixation materials, (3) surgical suture lines, and (4) soft tissue filling.

12.4.4 Biocomposites

The biocomposite is a medical material consisting of two or more different biological materials. Since the conventional single kind of medical material has the advantages in one aspect but has some shortcomings in other aspects, the new materials constituted by materials with different properties not only have the properties of constituent materials but also achieve the new properties which are not possessed by one-component material; therefore, the multicomponent composite materials have the widest development prospect in the field of medical materials.

The composite materials are divided into three categories according to the types of matrix materials, namely, metal matrix composite, inorganic nonmetallic matrix composite, and polymer matrix composite.

1. Metal matrix composite. The metal matrix composite has a unique set of properties, such as excellent metal wear resistance, corrosion resistance, and biocompatibility. Its categories include titanium matrix ceramic composite materials and magnesium alloy matrix composite biological materials, and they are used extensively for hard tissue replacement and repair in surgical implant materials.
2. Inorganic nonmetallic matrix composites. The inorganic nonmetallic matrix composites mainly use the oxide ceramics, bioactive glass, hydroxyapatite, and calcium phosphate as the matrix; it is added to other reinforcement materials to improve or adjust the performance of the raw material. Its categories include:
   (1) Inert inorganic nonmetallic and active inorganic nonmetal composite materials such as zirconia (ZrO2)-HA composites, carbon fiber-TCP composites, carbon nanotube-HA composites, and nano-silicon carbide (SiC)-HA composites
   (2) Active inorganic nonmetal and active inorganic nonmetal composite materials such as bioactive ceramics-bioactive ceramic composites and bioactive ceramics-bioglass composite
   (3) Metal and inorganic nonmetallic composite materials such as various types of alloys-HA composites
3. Polymer matrix composites. The more widely used polymer matrix composites mainly include three kinds of polymer-based composite materials such as inert inorganic nonmetallic-polymer composites, active inorganic nonmetallic-polymer composites, and polymer composites-polymer composites. All kinds of materials have their unique biological characteristics, the biocompatibility and mechanical characteristics of the product have been significantly improved through integration of materials, and they are widely used to repair and replace the bone tissue and soft tissue.

12.5 Clinical Application of Biological Materials in Oncoplastic Surgery

The use of autologous tissue to repair defects in the process of repair and reconstruction of tissues and organs in oncoplastic surgery will still face many problems, such as limited donor site, secondary damage, postoperative secondary plastic surgery, and chronic pain, although inactivated allogeneic tissue transplantation can partly solve these problems, but may cause adverse effects such as infectious disease and rejection reaction. Further developments of biological materials and tissue engineering offer more options for oncoplastic surgeons. Against the operation situation of different tumor patients, all factors are considered to develop an individualized rehabilitation plan and further improve the qualities of life of patients on the basis of ensuring the effectiveness of tumor treatment, which is also the general guidelines for oncoplastic surgery. In recent years, great achievements have been made in the use of biological materials and tissue engineering technology in the fields of bone and cartilage defect repair after tumor surgery, joint

replacement, artificial blood vessels, and soft tissue reconstruction, so that the surgical treatment of tumors has reached a higher level. Here are some examples of clinical application of used biological materials in oncoplastic surgery and its new progresses [42–45].

12.5.1 Defect Repair After Bone Tumor Surgery

The bones support the body and mainly play roles in sports, for support and protection. The bone tumor surgery often causes severe appearance deformity or motor dysfunction, and the qualities of life of patients are greatly affected. The excellent results have been achieved in the use of the autologous bone grafts to repair the small defects, but a wider range of defects must be repaired with biological materials. Good bone repair materials are required to have the following characteristics: (1) having a good biocompatibility; (2) not affecting the imaging examination results of the body; (3) being easily molded according to the characteristics of the defect sites; (4) having osteoconduction, the speed of biodegradation and absorption is matched with the speed of bone substitution; and (5) being readily available.

The biological materials have a widespread application particularly after the removal of benign bone tumors. The benign bone tumors refer to the abnormal bone neoplasms with slow growth and no metastasis, and a few benign tumors (e.g., osteoclastoma) potentially have malignant characteristics. According to the definition formulated by World Health Organization (WHO), the benign bone tumors can be divided into tumors originated, respectively, from the bone, cartilage, connective tissue, and blood vessels according to the histological origins of the tissues. Once the benign bone tumors are definitely diagnosed, they need to be removed by curettage, and the remaining bone defect site can be repaired by using a variety of biological materials, such as hydroxyapatite (HA), β-tricalcium phosphate (β-TCP), and TCP composites consisting of HA and α-BCP. Various types of bone cements with excellent biocompatibility, osteoconductive properties, and sufficient mechanical strength have become the most promising materials for repairing the defects after curettage of benign bone tumor.

So far, the repair of defects after resection of malignant bone tumors in maxillofacial area, load-bearing area, or areas surrounding the movable joints is the surgery which is still quite challenging, such as repair and reconstruction of function and appearance after radical surgeries for primary or nonprimary malignant tumors in cranial and maxillofacial area and the primary or secondary malignant tumors in the hip. The appearances of the patients may be affected greatly after surgery due to the complex anatomy and the large surgical difficulty; there may exist a postoperative need for withstanding the greater stress and the wear and tear; the use of biological materials in these sites for repair or reconstruction often results in poor postoperative efficacy due to worse postoperative healing and more complications. Therefore, the performers are required to have a comprehensive and in-depth understanding of the performances of all kinds of biological materials, so as to increase the success rate of surgery and practically improve the qualities of life of patients after surgery.

The materials for repair of defects after cranial and maxillofacial tumor surgery have a wide range of varieties, including autologous bone, bone cement, polybutylene methyl, titanium stent, polyethylene, and various composite materials. Various types of materials have their own characteristics, but also inevitably have some disadvantages; for example, the poly(methyl methacrylate) can release heat to lead to degeneration and necrosis of local cells during the application process; although the titanium stent has a good biocompatibility, its small deformation range and easiness to compress the tissue eventually result in the exposure of the titanium plate; all kinds of bioceramics have good biocompatibility and mechanical strength, but it is difficult to mold them according to the specific circumstances during surgery. The conventional repair method only uses the scaffold-like materials. The recent progress in tissue engineering leads to innovation in repair of craniofacial defects. Warnke et al. [43] made the titanium metal cage by means of computer-aided design and filled the recombinant human bone morphogenetic protein (rBMP-7) within the titanium metal cage, which was embedded into the latissimus dorsi during primary surgery and then was transferred to repair the mandibular defects in the maxillofacial area after good vascularization was completed, and the good results were achieved. Hernandez et al. used the titanium metal stent in combination with rBMP-7 and autologous bone marrow transplantation to induce new bone formation to repair the defects after resection of adamantoblastoma in mandibular angle, which also obtained good results. In these cases, the application of autologous tissue, biological materials, tissue engineering techniques, and growth factor-induced osteogenesis in combination with the application of vascular surgical techniques and computer-aided design and other technologies has showed a broad prospect for the clinical application of biological materials and tissue engineering. In addition to all types of metal and composite materials, the bone resected during tumor surgery after appropriate treatment can also be used as biological material scaffold for in situ repair of bone defects. The high-pressure steam method can completely inactivate the tumor cells in bone tumors and retain the good bone scaffold. This method does not cause the donor site defect, and the bone scaffold has good biocompatibility and exact match with the donor site defect in shape; therefore, in theory it will not cause local tumor recurrence. However, the tumor cells in the bone are inactivated, and at the same time the bone scaffold has also lost the osteoinduction. Von Wilmowsky et al. conducted a prospective study on the use of autologous bone marrow-derived cells which are implanted

and amplified in the inactivated bone to repair bone defect, and it was found the inactivated bone where bone marrow cells were implanted and amplified had excellent osteoinduction. In addition, the platelet-rich plasma and bone morphogenetic protein had certain effects in promoting the osteogenesis characteristics of the inactivated bone.

The radical surgery for the malignant tumor of the hip joint has a high disability rate; the repair of pelvic bone and hip joint is one of the major challenges in oncoplastic surgery. The repair and reconstruction of pelvic bone and hip joint have higher complication rate and failure rate, and the nature of the pelvic tumor, the invasion range, and the occurrence site are still the most important factors to determine the surgical difficulty. The classic repair method for the hip joints such as Harrington repair method can better reconstruct the support and movement functions of the hip joints by the use of bone cement and metal screws to fix the artificial acetabulum on the healthy hip after tumor resection. The improvements of this method including the combined use of inactivated allogeneic bone and artificial hip joint reconstruction are also successful, which is suitable for most patients with pelvic tumors including children, but it still has a higher incidence of complications such as infection, bone nonunion, and postoperative fracture, and it is not recommended to be used for patients requiring postoperative radiotherapy.

12.5.2 The Cartilage Reconstruction After Tumor Surgery

The cartilages can be divided into three types such as hyaline cartilage, elastic cartilage, and fibrous cartilage. Of which, the hyaline cartilage covers the articular surface to play a buffer effect, while it can also provide the bone support for the pharynx, trachea, nose wing, and nasal septum; the elastic cartilage is located in sites which are pliable and soft, such as the outer ear, epiglottis, and pharynx, and plays a supporting role. The cartilage itself has no vascular structure, surviving only based on the nutrition in the surrounding tissue fluid, whose regenerative capacity is extremely weak, and therefore, the reconstruction of cartilage structure is also one of the difficulties in oncoplastic surgery. Especially for the trachea reconstruction after throat tumor surgery, it is not only needed to reconstruct the support function of the trachea but also needed to resolve the problems such as the tracheal intima regeneration and the prevention of postoperative contracture, so that such surgery is very challenging.

Reconstruction of the trachea needs to meet at least the following two conditions: (1) The respiratory tract has the dynamic cartilage structure; (2) the respiratory tract is covered by mucous membrane. This type of structure in the trachea is unique, and thus it is difficult to obtain the composite tissue possessing these two kinds of structures at the same time in other sites of the body, which makes it very difficult to repair and reconstruct the trachea. Although some progresses have been made in the researches on repair and reconstruction of tracheal cartilage and mucous membranes in recent years, many researches still remain in the preliminary experimental research stage. For example, in animal experiment, Delaere et al. used and transferred the autogenous ear cartilage and oral mucosa graft after prevascularization into the pharyngeal area to repair the trachea defect, and the initial success had been achieved. This method has a certain clinical value, but it also has some more serious disadvantages, because the vascularization process of the cartilage is very slow and is not suitable for mucosal graft, the cartilage vascularization and the tracheal intima reconstruction take a long time, and the success rate is low. Given the limitations of the use of autologous cartilage graft for tracheal reconstruction, people began to explore the use of biological materials to reconstruct the trachea, such as titanium stent, MEDPOR, hydroxyapatite, and the tissue engineering tracheal stent for planting the mucosal cells. All these materials can recover the appearance and the support function of the trachea better in the experimental process, but their common problem is that the tracheal intima reconstruction is not ideal. For smaller defects, the process of mucosal coverage in the inner wall of the prosthesis can be better completed through the crawl of the normal mucosa tissues, while for a wide range of defects, it is difficult to complete the repair through the crawl of mucous membrane, and the most important reason is the low vascularization degree of the inner surface of the stent. In animal experiments, Janssen et al. implemented the mucous membrane transplantation using the porous titanium stent and then buried them under the skin to carry out pre-vascularization for the repair of the tracheal defects, which achieved success, suggesting that the porous stent has a very important significance for the survival of mucous membrane in the inner wall of the trachea.

12.5.3 Soft Tissue Reconstruction After Tumor Surgery

Depending on whether directly contacting with the blood circulatory system, the biological materials for soft tissue repair can be divided into the biological materials which contact with the blood flow and the biological materials which don't contact with the blood flow. The former include artificial blood vessels, and the latter include breast prosthesis.

The artificial blood vessels can be used to repair and replace the diseased artery or vein. The vascular substitutes made of synthetic materials are widely used in clinics, so that the surgical range of oncology surgery also has been broadened continuously. For example, some tumors involving large blood vessels have almost been the restricted surgery zone before the appearance of suitable vascular replacement materials, but with the development of materials science, the artificial blood vessels have been widely applied; therefore,

these surgeries can be generally carried out, and the good postoperative results have been achieved. At present, most artificial blood vessels are made with polymer materials by means of knitting; there are also some experimental studies on the human umbilical vein and bovine carotid artery which have been chemically treated. After the large arteries are replaced with artificial materials, the long-term effects are good, but after the artificial blood vessels are used for some arteries with slow blood flow or veins, the effects are poor, whose causes include thrombosis in the vascular lumen in the healing process, the lack of vascular endothelial cells in the intima, and hemodynamic disorders, and these are urgent problems to be solved in the field of artificial blood vessel.

The breast reconstruction after breast cancer radical surgery needs to achieve at least two objectives, namely, to restore the shape of the breast and restore the texture of the breast. Similar to other tissue reconstructions, the breast can be repaired selectively using the autologous tissue or prosthesis, and both methods can achieve satisfactory reconstruction results, because the autologous tissue reconstruction can achieve better long-term results and thus get the recognition of plastic surgeons. However, not all patients are suitable for autologous tissue reconstruction, such as some patients with more slender shape or patients with excessive fat, as well as patients with diabetes, and the autologous tissue breast reconstruction will inevitably cause donor site defect and affect the appearance. The prosthetic breast reconstruction also has been widely used due to its advantages such as simple operation, short operation process, small trauma, good postoperative aesthetic effect, and no donor site defect.

The breast prosthesis usually consists of two or three main parts: silicone outer capsule and filling material within the capsule, and some prostheses also have valves used for injection of filler material. The silicone outer capsule has a certain strength and plays a barrier effect, and the surface after special treatment may also improve tissue reaction of the body after implantation of the prosthesis; the filling materials within the capsule are mostly liquid or gel-like materials, such as liquid silicone and saline water. Previous prosthetic breast reconstruction is generally divided into two steps: The dilator is placed under the pectoralis major muscle during the primary surgery. After being injected with water for some time, the dilator is removed during two-stage surgery, and then the appropriate size of silicone prosthesis is implanted to reconstruct the breast. In recent years, with the extensive development of nipple-, areola-, and skin-sparing radical mastectomy, the surgical method of immediate breast reconstruction by which the silicone prosthesis is implanted during the primary stage after the removal of glandular tissue began to increase year by year. But breast reconstruction by implanting silicone prosthesis has its inherent drawbacks, and enough attention should be paid to possible postoperative complications. The complications of the prosthetic breast reconstruction generally can be divided into short-term complication and long-term complication. The complications which may occur within a relatively short time after surgery include infection, hematoma, seroma, dilator exposure, and skin flap necrosis. Once the prosthesis is exposed and the serious infection appears, the prosthesis must be removed, the second-stage reconstruction infection will be considered after the infection is completely controlled, and the recovery is achieved for 3–6 months. All long-term complications of the prosthetic breast reconstruction include fibrous capsule formation and contracture, prosthesis displacement, deformation, hardening, leakage, and chronic pain which will seriously affect the qualities of life of the patients, of which the incidence of fibrous capsule formation and contracture is higher, especially for some patients requiring postoperative radiotherapy or with a history of preoperative radiotherapy, and its incidence reaches from 38% up to 60%. The measures to prevent capsular contracture include improving the prosthetic material and surface treatment processes; for example, the silicone outer capsule with better biocompatibility is selected and used, and the grind arenaceous processing for its outer surface is carried out. The acellular allogenic dermis combined with prosthetic breast reconstruction is applied in recent years. This method cannot only reconstruct the natural shape of the breast but also reduce the displacement of the prosthesis and the fibrous capsule formation and contracture, thus achieving a better long-term effect.

12.6 Conclusion

The abovementioned examples are only the application of some biological materials and technology in oncoplastic surgery, which also include some experimental researches or progresses with forward-looking significance. The effects of innovative materials and technology on oncoplastic surgery are undoubtedly significant and far-reaching, while the related doctors and researchers are required to pay close attention to new progresses in all kinds of new materials and technologies. It is still needed to conduct in-depth basic and clinical researches on the interaction between radiotherapy, chemotherapy, and biological materials and its mechanism, and the relevant research results will guide us to further select the appropriate biological materials to be used in tumor patients [46].

13 Exploration on Oncoplastic Surgery and Mode of Comprehensive and Sequential Treatment

Wei Wang, Zhaoyan Wang, and Xiao Zhou

The clinical oncology is in a period of multidisciplinary cooperation of surgery, radiotherapy, and chemotherapy

during which the best treatment plan is summarized by means of evidence-based medicine, and multiple tumor treatment centers are required to collaborate to complete the study of the best treatment plan. In recent years, there are great progresses in prevention, diagnosis, and treatment concept of the tumors; attaching great importance to the comprehensive treatment of the tumor and emphasizing the standardization of diagnosis and treatment and the individualization of treatment have become a trend recognized in the academic world.

13.1 Paying Attention to the Comprehensive Treatment Is the Basic Principle of the Clinical Oncology

In the treatment of malignant tumors, various existing treatments have their own advantages, but at the same time, they also have some disadvantages. It is very difficult to cure the advanced malignant tumors using a method, which often requires a comprehensive application of multiple treatment means. The comprehensive treatment is to develop the best treatment plan through comprehensively using the treatment means such as surgery, radiotherapy, and chemotherapy properly and in a planned way according to the body conditions of patients, tumor histological types and subtypes, scopes of tumor invasion (staging), and development trends, whose purpose is to improve the cure rate and substantially improve the qualities of life of patients. The malignant tumors are a kind of diseases whose clinical manifestations are very heterogeneous, and each patient's response to treatment is not exactly the same, and therefore, it is needed to carefully discuss the specific issues: what kind of comprehensive treatment plan is needed by each patient and how to select the sequential therapeutic scheme, namely, how to determine the order of priority and the best time of the therapeutic measures such as surgery, radiotherapy, and chemotherapy.

The existing effective means for tumor treatment are roughly divided into the following categories.

13.1.1 Surgical Treatment

The surgical treatments of tumors are divided into radical surgery, palliative surgery, prophylactic surgery, and reconstruction surgery. The surgical treatment is a kind of local treatment; it occupies an extremely important role in the comprehensive treatment of the tumor and is now the preferred method for the treatments of most solid tumors. Some early or localized malignant tumors can be cured by the surgery alone. Due to the biological characteristics of easy recurrence and metastasis of the tumors, the purpose of completely curing the most advanced malignant tumors with surgical indications cannot be achieved by the surgery alone, and it is necessary to apply methods such as preoperative or postoperative radiotherapy, chemotherapy, and biological therapy to assist in the treatment.

13.1.2 Radiotherapy

The tumor radiotherapies are divided into radical radiotherapy and palliative radiotherapy and are one of the important means of comprehensive tumor treatment. For some tumors which grow in vital organs or near vital organs and cannot undergo radical surgery, but are sensitive to radiation, the radiotherapy can be used alone to achieve the purpose of cure. However, the same as the surgery, the radiotherapy is a local treatment method, which is often restricted by the following factors in the course of treatment:

1. Limited by radiation tolerance dose of normal tissue and organ around the tumor, the radiation dose for the treatment of tumor cannot be increased indefinitely.
2. The epithelial-originated tumors show a moderate sensitivity to radiation or a radiation resistance; even in the radiosensitive tumor tissues, there also exist some tumor cells such as hypoxic cells which resist the radiation.
3. The radiotherapy can treat the local tumors, but cannot cure the multiple tumor lesions which spread to the whole body, and therefore, the radiotherapy must be used in combination with other treatments such as surgery and chemotherapy.

13.1.3 Chemotherapy

The chemotherapies are divided into radical chemotherapy, palliative chemotherapy, neoadjuvant chemotherapy, and adjuvant chemotherapy. Unlike surgery and radiotherapy, the chemotherapy belongs to the systemic therapy, focusing on the control of systemic metastasis and proliferation of the tumors. The chemotherapy can radically treat a few tumors in the blood and lymphatic and reproductive systems which are highly sensitive to chemotherapy, and most malignant tumors cannot be radically treated with chemotherapy alone. For the tumor patients who have undergone or will undergo surgery or radiotherapy, the chemotherapy can control or kill the possible micrometastases and residual lesions and reduce the primary lesion, which help to improve the efficacy of the surgery and (or) the radiation and delay or control the recurrence and metastasis of the tumor, thereby improving the qualities of life of tumor patients and prolonging the survival period.

13.1.4 Biotherapy

The biotherapy refers to a therapeutic method that the biological reactions of the body are regulated through the body's defense mechanisms and the action of biological agents, thereby inhibiting or eliminating the tumor growth. It includes therapeutic applications of any biological substances or biological agents such as cytokines, monoclonal or polyclonal antibodies and their cross-linked products, immunocompetent cells, tumor vaccines, and gene therapy. Thanks to the rapid development of modern molecular biology and genetic engineering techniques, the biotherapy has become a new way to treat tumors and has good development

prospect, which may lead to a revolutionary breakthrough in tumor treatment.

13.1.5 Other Treatments

The interventional therapy, Chinese medicine treatment, thermal therapy, microwave therapy, ultrasound therapy, and laser therapy are important parts of the comprehensive treatment of the tumor. From the therapeutic point of view, both the surgery and radiotherapy are local treatments that can eradicate some tumors. The chemotherapy belongs to the systemic therapy, focusing on the control of the local lesion and systemic metastasis, emphasizing the treatment method of multiple courses and sufficient doses. Only the integrated use of various means can achieve the best therapeutic effect, improving the long-term survival and the quality of life of the patients.

13.2 Advances in Molecular Biology Make the Individualized Treatment of the Tumor Become a Trend

Since the 1970s, the results of researches on the human genome and the disease genome provide the platform for accelerating the development of personalized cancer research. In particular, the basic researches such as cancer genomics, pharmacogenomics, RNA genomics, and proteomics expand into clinical practice, so that the treatment mode of traditional experience is gradually shifted to the individual treatment mode based on the background of the genetic information. The molecular diagnosis and molecular-targeted therapy of the tumors and the gradually popularization and application of chip technology in the process of tumor diagnosis and treatment indicate that the era of individualized diagnosis and treatment of the tumor is coming. A growing number of research reports have confirmed that the expression levels of gene and protein detected in biological samples from tumor patients can predict the drug therapeutic effect and evaluate the prognosis, guiding the clinical individualized treatment, thereby enhancing the efficacy, reducing the adverse reactions, and promoting the rational use of medical resources.

Currently some progresses have been made in the individualized treatment of tumor; for example, EGFR-targeted monoclonal antibody therapy is used to treat head and neck squamous cell carcinoma; the high expression of excision repair cross-complementing gene 1 (ERCC1) indicates the reduced sensitivity to platinum; the high expression of thymidylate synthase (TS) indicates the reduced efficacy of pemetrexed; the ribonucleotide reductase subunit M1 (RRM1) is negatively correlated with gemcitabine sensitivity; the class III β-tubulin is negatively correlated with paclitaxel sensitivity. It is generally recognized that there are hundreds of thousands of human proteins, while the corresponding gene number is less, and the extremely complicated accidental events will occur in the process of gene transcription regulation, posttranscriptional modification, and protein expression. So far, it has been confirmed in clinic that there are still rare indicators of response-related genes of important anticancer agents. The reactivity of the drug is rarely determined by single factor and is often effectively regulated by multiple determinative factors. Therefore, we should observe that the results of relevant clinical researches do not show a consistency with laboratory findings, and there is still a long way to guide the individualized treatment of the tumor according to the genetic background information.

13.3 Exploration on the Oncoplastic Surgery and the Sequential Treatment Mode of Comprehensive Tumor Treatment

The oncoplastic surgery involves the treatments and repairs of body surface tumors, head and neck tumors, breast tumors, thoracic and abdominal tumors, bone and soft tissue tumors, and genitourinary tumors. In the process of treatment, the oncoplastic surgeons need to cooperate mutually with doctors in oncological surgery department, radiotherapy department, medical oncology department, and rehabilitation department. The oncoplastic surgery aims not only at radically curing the tumor through more reconstruction means but also at restoring the functions and appearances of human tissues and organs and maximally extending the progression-free survival and overall survival of patients.

The ultimate purpose of the oncoplastic surgery is to radically cure the tumor, preserve the function, carry out the repair and reconstruction, and prevent the recurrence, and the comprehensive treatment measures such as surgery, radiotherapy, and chemotherapy are implemented for this purpose. There is still a lack of the basis for reasonably arranging the order of comprehensive treatments and its treatment process; although some achievements have been made in sequence treatments of some tumors (such as breast cancer), there are still many issues to be resolved. Different from the patients with ordinary plastic surgery, the patients undergoing oncoplastic surgery operations often have received multiple courses of preoperative chemotherapy or radiotherapy. The chemoradiotherapy may have impacts on the aspects such as skin flap design, skin flap donor site selection, skin flap survival, and blood supply reconstruction in these patients. In particular, currently there is a lack of systematic in-depth study on whether the direct injection site of chemotherapy drugs is still suitable for use as donor site of skin flap. The plastic surgery can cause trauma in the body

and reduce the tolerance to chemotherapy in patients, so that the patients are even unable to complete the established systemic treatment; if there is a concurrence of postoperative infection and tissue flap necrosis, this will further delay the starting time of chemoradiotherapy and affect the dose intensity of chemoradiotherapy. Carrying out timely and active postoperative chemoradiotherapy in patients with tumors is often the key to cure the tumors. If the delivery of chemotherapy is delayed, or the systematic chemotherapy cannot be completed, this may even cause negative effects such as tumor recurrence and shortened survival. Therefore, when formulating the plastic surgery program, we should take into account the effects of the surgery itself on postoperative chemotherapy and other comprehensive treatments.

The modes of comprehensive treatment in oncoplastic surgery are varied, and different modes should be adopted according to different tumors, different stages, and different individual conditions. The establishments of the modes must undergo a rigorous clinical research, and the continuous improvement on the basis of evidence-based medicine is carried out.

For example, the tumor resection plus one-stage and (or) second-stage plastic repair may be considered for patients with tumors in early stage or in a relatively limited site, and postoperative radiotherapy, chemotherapy, and biological therapy are appropriately considered according to the postoperative pathological findings. The patients with tumors located in important sites are not suitable to undergo radical surgery; when the patients are sensitive to radiotherapy and the clinical studies have proven that the radiotherapy and surgical treatment have the same radical effect, it may be considered firstly to carry out radiotherapy, and the patients with better efficacy can undergo radical radiotherapy; the patients who are insensitive to radiotherapy are promptly treated by surgery and chemotherapy. The preoperative radiotherapy and/or chemotherapy may be considered for the patients with advanced local tumors or large tumors who are not suitable to undergo immediate surgery, and then the comprehensive treatment including radical resection, plastic repair, and postoperative chemoradiotherapy is implemented according to the changes of the tumor.

It should be noted that the sequential treatment is not to do simple addition or patchwork, and it is needed to emphasize the individualized treatment. Different patients have different types of diseases and different tumor staging and classification; even the patients with the same disease, pathological pattern, and staging will have differences in age, mental condition, and other aspects of tumor cell heterogeneity; therefore, the oncologists should design the individualized treatment plan according to specific patient's age, gender identity, psychological characteristics, treatment tolerance, and the desired quality of life and combined with the general condition of the patient, pathological type of tumor, clinical stage, and genetic background information. During carrying out the diagnosis and treatment of tumor patients, special attention should be paid to emphasizing consultation and discussion before multidisciplinary treatment, so as to formulate a scientific and rational sequential treatment scheme.

14 Repair and Reconstruction and Aesthetic Reengineering After Tumor Resection

Zuoliang Qi, Xiao Zhou, and Xiaonan Yang

14.1 Overview

As an important branch of the plastic surgery, the oncoplastic surgery mainly studies the repair of organ and tissue defects and the reconstruction of function and appearance after tumor resection. However, the oncoplastic surgery has certain differences with the repair and reconstruction of traumas, burns, and congenital deformities and the plastic and aesthetic surgery, of which a relatively important difference is the need to face the problems of tumor spread and recurrence and the effects of chemoradiotherapy on tissue healing and postoperative aesthetic effect. Large tissue defects will often be caused after surgical resections of some tumors located on the body surface, which seriously affect the appearance and organ function of the patient. At the same time of repairing the wound, the surgeons should not only consider the recovery of function and appearance but also consider the subsequent treatment of tumors and the postoperative quality of life of the patients. In recent years, with the continuous improvement of medical technology and people's living standards, the simple resection has been difficult to meet people's requirements; therefore, both doctors and patients pay more and more attentions on how to more reasonably and beautifully carry out repair and reconstruction and at the same time of removing the tumors.

14.2 Classification of Tumors in the Body Surface

There are many methods for classification of tumors in the body surface, which can be divided into benign tumors, malignant tumors and borderline tumors according to their pathological features, the tumors originated from epithelia and the tumors originated from mesenchymal tissue according to the histological origin, and tumors in facial region, tumors in body trunk, and tumors in limbs according to the different sites. The most commonly used classification method is adopted in this

section; namely, the tumors in the body surface are divided into benign tumors, malignant tumors, and borderline tumors according to their pathological features.

The common benign tumors in the body surface include pigment nevus, hemangioma, lymphangioma, neurofibromas and neurofibromatosis, skin fibroma, lipoma, xanthoma, wart and sebaceous cyst, epidermoid cyst, and dermoid cyst. Common malignant tumors in the body surface include malignant melanoma, squamous cell carcinoma, and basal cell carcinoma. Some pigmented nevi have biological behaviors which are in a state between benign and malignant tumors and have a tendency of malignant transformation and are called the borderline lesions.

14.2.1 Common Benign Tumors in the Body Surface

1. Pigmented nevus is the most common benign tumor in the body surface. It usually consists of pigment nevus cells, and it is black due to the fact that the nevus cells contain melanin granules. At present, it is mainly considered that the pigmented nevus originates from the epidermal melanocytes. It can be divided into junctional nevus, intradermal nevus, and compound nevus according to its intradermal status.
2. Hemangioma. The hemangioma mostly appears in the head, face, and neck. It mainly consists of blood vessels which are expanded and proliferated or the clearance and sinus cavity which are filled with blood and have inner walls covered with endothelial cells, and the interval and support structures are constituted by fibrous tissue and adipose tissue. According to the clinical features, the hemangioma can be divided into capillary hemangioma, cavernous hemangioma, and racemose hemangioma.
3. Lymphangioma. The lymphangioma is a benign lymphatic hyperplasia, which consists of expanded lymphatic vessels with endothelial cell proliferation and the connective tissues. According to the pathological structure, lymphangioma fall into three types: capillary lymphangioma, cavernous hemolymphangioma and cystic lymphangioma.
4. Neurofibroma and neurofibromatosis. The neurofibroma is a benign tumor which originates from Schwann cells and perineurial cell in nerve fibers or peripheral nerve axon sheath, and it is more common in the skin tissue. The neurofibromatosis is a systemic disease with neurofibroma involving the skin, bones, central nervous system, and endocrine system.
5. Dermatofibroma. The dermatofibroma is a reactive hyperplastic lesion of the skin and is common in adults. It is more likely to appear in the places such as extremities, shoulder, and back. The lesion is mainly located in the corium layer, consisting of fibroblasts, histiocytes, and collagen fibers, and can be divided into fiber-type dermatofibroma and cell-type dermatofibroma according to their different contents.
6. Lipoma. The lipoma originates from the adipose tissue and is a common benign tumor consisting of mature adipocytes. It is mostly comprised of single or multiple flat clumps of varying sizes, and it is segmented into multiple fronds by partitions composed of fibrous tissue.
7. Xanthoma. The xanthoma is briefly called as yellow tumor, and it is a benign tumor consisting of lipid-filled tissue cells and giant cells containing foam in cytoplasm.
8. Skin cysts. The skin cysts include sebaceous cyst, dermoid cyst, and epidermoid cyst. The sebaceous cyst refers to the common cyst formed through aggregation of secretions in sebaceous gland after blocking of sebaceous glands duct and is also known as atheroma or steatoma, and it is more common in young people with their sebaceous glands secreting exuberantly. The dermoid cyst is a relatively rare cyst formed by epidermal cells; it is a congenital cyst formed in the process of embryonic development; when fused with the groove, the epidermal cells are drawn into the groove by mistake and then form into the dermoid cyst along the embryonic closure line deviating from the in situ position. It is also known as traumatic epidermal cyst, epidermal cyst, or epidermal inclusion cyst and is formed usually due to the fact that the posttraumatic foreign body pierces through the skin, and then the scurfs pass through the wound into the subcutaneous tissue and grow slowly.

14.2.2 Common Malignant Tumors in the Body Surface

1. Basal cell carcinoma. The basal cell carcinoma is also known as basal cell epithelioma. It is a low-grade malignant tumor of epidermal basal cells or skin attachment which often occurs in hairy parts of the body, and it mainly consists of interstitial-dependent pluripotent basal-like cells.

2. Squamous cell carcinoma. The squamous cell carcinoma is briefly called as squamous carcinoma and is also known as epidermoid carcinoma or prickle cell carcinoma. It is a malignant tumor originated from the epidermis or adnexal keratinocytes, and the cancer cells tend to have different levels of diversification.

3. Malignant melanoma. The malignant melanoma is a highly malignant tumor originated from skin melanoma cells. It can occur in sites such as the skin, eye, gastrointestinal tract, and reproductive system, but the cutaneous malignant melanoma is the most common.

14.3 Surgical Resection of Tumors in the Body Surface

14.3.1 The Aesthetic Requirements for Incision Design

After surgical resection of tumors in the body surface, the scars are inevitably caused in the process of wound healing.

Selecting the appropriate incision can minimize scar formation, so as to achieve a satisfactory aesthetic effect. The incision scar formation is mainly affected by the following factors: (1) the individual physical constitution of the patient, (2) the characteristics of the skin in different body parts, (3) the incision tension, (4) the incision direction, (5) other local or systemic conditions, and (6) the surgical operating technique.

If the incision designs in the same part of the body are different, the postoperative results will also be quite different, of which, the wound tension will be mostly affected; therefore, the design of the surface incision should follow the following principles:

1. Incision direction. The incision should go along the direction of skin cleavage lines or wrinkles, and the surgical incision should be parallel to the skin tension lines, namely, the direction of skin cleavage lines. The skin tension lines were first discovered by Dupuytren, and Langer described them; therefore, the skin cleavage lines are also called Langer's lines. The direction of facial wrinkles is often parallel to the skin tension lines while perpendicular to the direction of the expression muscle. Therefore, the tension of the incision going along the facial wrinkles is also smaller (Fig. 1.1).

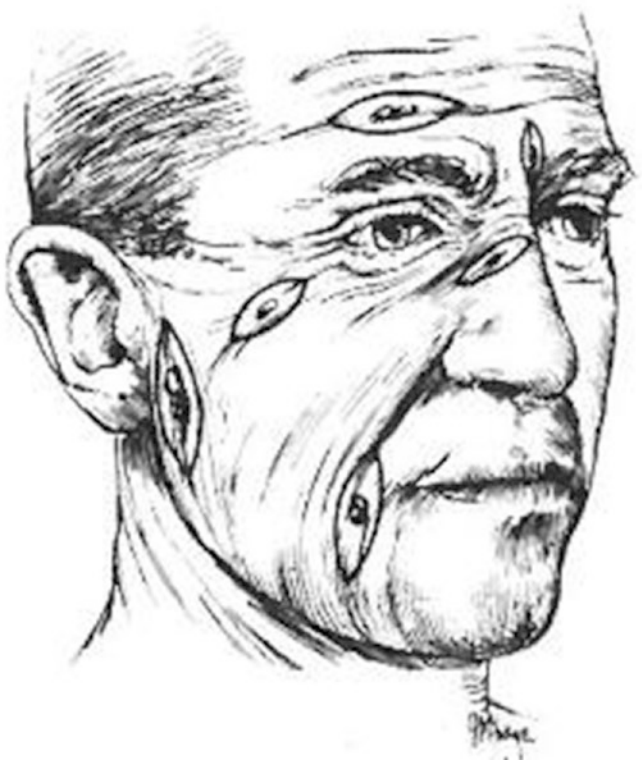

Fig. 1.1 Selected incision directions for lumpectomies in different parts of the face

2. Incision position. The incision is designedly placed in the hidden place as far as possible; thus, the postoperative scar can be well hidden. For example, the incision of the breast lump resection is placed in inframammary fold, beside the areola or armpit, and thus the postoperative scar is difficult to be found.
3. Incision shape. The incision shape also has an important impact on the postoperative appearance. The incision which can be drawn close and sutured is generally designed into the shape of long spindle, so as to avoid the formation of "cat ear" during suturing which affects the appearance.
4. Avoid the formation of linear incision across the joint. When the incision needs to cross the joint, it should be designed into Z-shape to avoid the formation of linear incision, in order to prevent the postoperative scar contracture which affects the joint function.

14.3.2 Resection Scope

For benign tumors in the body surface, such as pigmented nevus with a larger area, the fusiform excision can be first performed in a small area, and then the fractional resection will be performed every 3–6 months until the lesion is excised completely. For borderline tumors such as junctional nevus, the tumor excision should be completed at one time to avoid the canceration of the residual tumor due to surgical stimulation. The extended resection should be performed for malignant tumors in the body surface, and even the regional lymph node dissection may be carried out. The resection scopes are different according to different malignant degrees of the tumors. For example, the resection scope of the basal cell carcinoma with a low degree of malignancy is required to exceed 1.0–1.5 cm of normal tissue, and the resection depth should reach the deep fascia; the resection scope of skin squamous cell carcinoma should be limited to the area around the lesions at 0.5–2.0 cm within the normal tissue and the depth which can guarantee the extensive resection is appropriate; the melanoma with a high degree of malignancy and without lymph node metastasis should be resected to an area at 1.5–3.0 cm around the lesions, and the depth should reach to the deep fascia, while the malignant melanoma of the extremities often requires amputation.

14.3.3 Suture Method

The suture technique is another important factor in relation to the postoperative aesthetic effect. The subtle stitching and the good alignment of the tissues can effectively reduce the formation of postoperative incision scar. According to different needle inserting methods, the suture methods can be divided into simple interrupted suture, vertical mattress suture, horizontal mattress suture, continuous subcutaneous suture, half-buried horizontal mattress suture, continuous suture, skin stapling suture, and application of incision adhesive (Fig. 1.2).

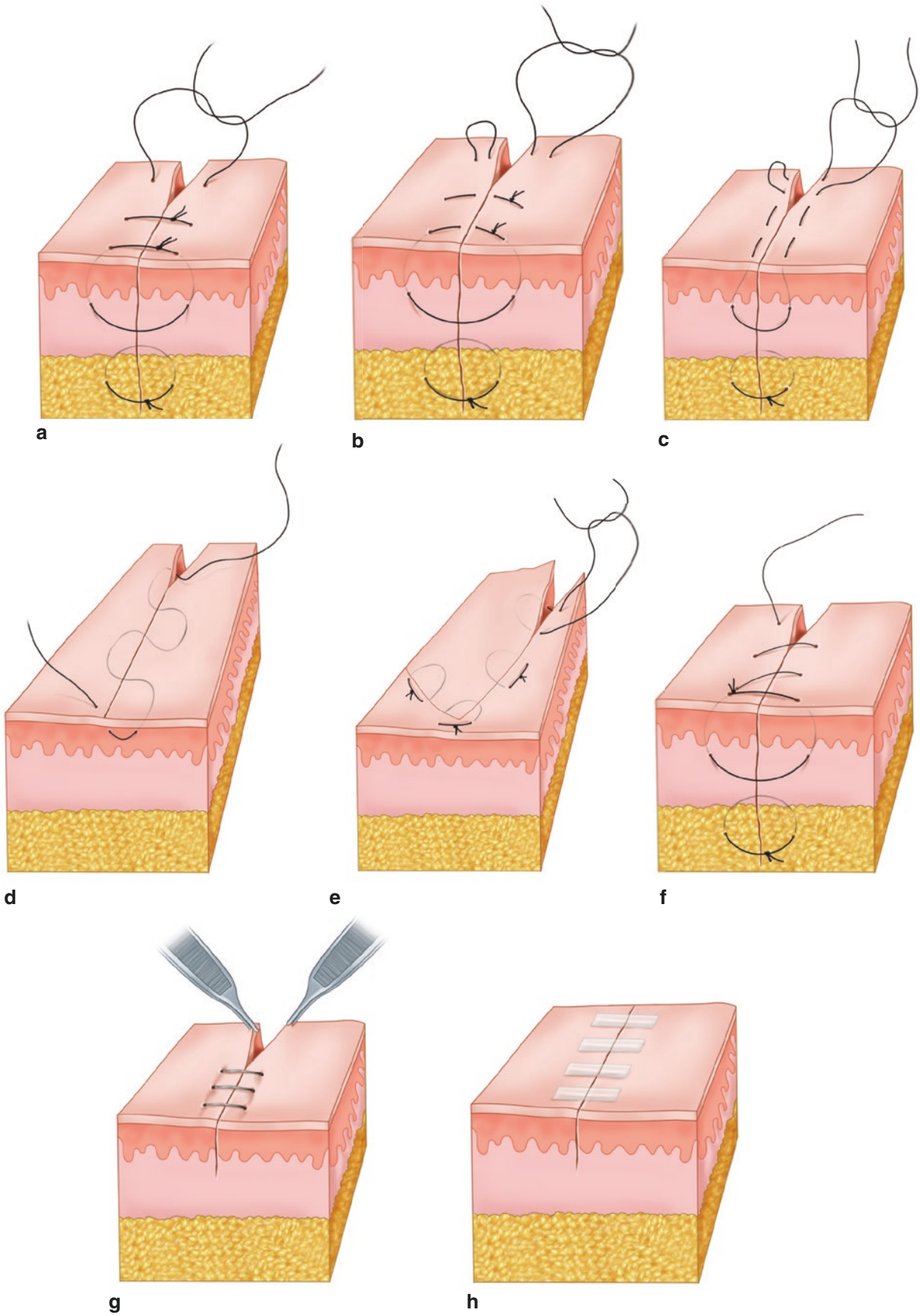

Fig. 1.2 Different surgical incision suture methods. (**a**) Simple interrupted suture. (**b**) Vertical mattress suture. (**c**) Horizontal mattress suture. (**d**) Continuous subcutaneous suture. (**e**) Half-buried horizontal mattress suture. (**f**) Continuous suture. (**g**) Skin stapling suture. (**h**) Application of incision adhesive

1. Simple interrupted suture. The simple interrupted suture is the most commonly used suture method in plastic surgery. The key point of the suture is that the needle should be inserted into the skin at a certain angle, so that the sutured tissue width in the base of the incisal margins is greater than the width between the needle entrance point and the needle exit point. The cross section of the sutured tissue generally has a trapezoid-like shape with narrow top and wide bottom, so that the incision after tying the knots is slightly valgus. The needle inserting depths should be the same on both sides of the incision to prevent the incisal margin varus. The needle distance is generally 5–7 mm, and the distance between the needle entrance point and the incisal margin is generally 3–5 mm, but it should be adjusted according to the tension at the suture site and the silk thread thickness.
2. Vertical mattress suture. The vertical mattress suture is most commonly used for incisions requiring skin edge eversion and incisions which cannot be sutured close with simple interrupted suture. It should be noted that if the stitches are not taken out early for vertical mattress suture, the obvious scars will remain.
3. Horizontal mattress suture. The horizontal mattress suture is commonly used for circumstances requiring skin edge eversion, especially for thicker smooth places (such as the foot and the palm side of the hand).
4. Subcutaneous suture. The subcutaneous suture may also be divided into continuous subcutaneous suture and intermittent subcutaneous suture. In the process of continuous subcutaneous suture, it should be noted that the needle is made to go horizontally through the dermis, and it is needed to ensure that both sides of the incision is sutured at the same level, which can make wound closed smoothly. Subcutaneous suture can avoid the scars caused by suture threads left on the skin surface, but it cannot be used for incisions with a larger tension force.
5. Half-buried horizontal mattress suture. This suture method can make thread knots only in one side of the incision to ensure that no scar is formed in the other side. For example, the incision beside the areola can be selected during breast lumpectomy, and the thread knots can be made in the areola area rather than in the side of the skin, which can make the postoperative scars well hidden.
6. Continuous suture. The advantage of this suture is to save time, but the alignment accuracy of the incision with this method is inferior to that with the interrupted suture. Sometimes, the continuous suture can be combined with locking stitch suture, which can produce a certain pressure on the incisal margin and play a role in hemostasis.
7. Skin stapling suture. The use of skin stapling suture can achieve good alignment of the wounds to avoid varus, while it can also save operation time. However, the skin stapling suture is commonly used for wounds in the surface layer of the skin, and it is still needed to use the interrupted suture method to reduce tension for wounds in the deep tissues. The skin stapling suture can also be used for the incision after the stitches have just been taken out newly to strengthen protection against wound dehiscence.
8. Application of incision adhesive. The incision adhesive and the incision paste can be used for incisions without tension or for incisions using the interrupted suture in deep tissues to fully reduce tension and have good alignment.

14.4 Repair and Reconstruction After Resection of Tumors in the Body Surface and Their Aesthetic Characteristics

Some tumor surgeries often require a wide range of resection, so that the postoperative residual wound cannot be directly drawn close and sutured, or even the wound is effectively closed, the destruction of the lesions and the surgical resection lead to serious damage or deformity of the local function and appearance, which will bring a heavy psychological burden to patients, and seriously affect the qualities of life of patients. Therefore, it is required that the oncoplastic surgeons must have a careful planning in the implementation of any tumor surgeries and fully consider the postoperative reconstruction of the local function and appearance, especially the anatomical reconstruction of the surface subunits, which is expected to achieve the purpose of radically curing the tumors and restoring the function and appearance.

14.4.1 The Selection Principles for Repair and Reconstruction Method

1. Prefer simple rather than complicated. Even for the same lesion, the repair and reconstruction methods are also varied. For example, a pigmented nevus with a small area in facial area can be treated by all methods such as serial partial excision, skin graft, and skin flap graft. Therefore, we need to develop a relatively simple therapeutic regimen with a lower degree of damage under the premise of comprehensively evaluating the treatment effects and surgical risks.
2. From near area to far area. It is often necessary to repair the wounds after resections of tumors in the body surface by the transfer of autologous tissue. Compared with the distal tissues, the adjacent tissues have a similar color and texture, while the repair by transfer of local adjacent tissues avoids the need of additional surgical site and reduces the risk of surgery in different degrees, so it is the preferred tissue transplantation.
3. Personalized design. The reasonable and effective surgical methods are designed according to different ages, genders, and local tissue structures of the lesions.
4. Pay attention to both function and appearance. At the same time of focusing on appearance repair, we should take into account the functional reconstruction. For example, after nasal tumor resection, it is not only needed to restore good nasal appearance but also needed to rebuild

the airway and restore the function of the external nose; after the resection of tumors in the bottom of the feet, the transplanted tissues should not only cover and close the wound but also have wear-resistant and good pressure-bearing capabilities.

14.4.2 Wound Closure

The appropriate surgical resection and repair plan should be developed before surgery according to the size and location of the lesion and the function and appearance requirements. The smaller lesion can be resected at one time or several times, and the wound is directly drawn close and sutured; the wounds which cannot be directly drawn close and sutured can be repaired by selection of methods such as skin soft tissue expansion, skin graft, skin flap graft, fascia flap graft, and myocutaneous flap graft. Each method has its advantages and disadvantages; the oncoplastic surgeons should select one or more methods according to the specific circumstances of the operation.

1. Simple resection and fractional resection. After it is confirmed that the surgical resection is taken as the therapeutic regimen of superficial tumors, the pinch-an-inch test of the skin can be performed to understand the elasticity and tightness of local skin of the tumor before surgery. If the scope of the lesion is smaller and the skin is loose, the fusiform or rhomboid incision can be designed to resect the lesion directly; if the resection scope is larger, a single direct resection may cause local tight skin and local tissue traction, thus affecting the appearance or function. Therefore, the fractional resection can be selected and performed at intervals of 3–6 months or even longer, so that the skin can achieve the result of external expansion under mechanical traction and ultimately only a small amount of linear scars are left. The fractional resection has the following advantages: The operation method is simple, it needs no special material and equipment, the skin has small changes after repair, the displacement of tissues and organs is small, and ultimately only the linear scars are left. But the fractional resection is not suitable for the following two situations: (1) The lesion scope is too large, the skin ductility is poor, and the wound after resection is difficult to be directly closed and repaired; (2) the tumor is malignant or because the repeated surgical stimulations are not conducive to the primary diseases.
2. Skin graft. The skin graft can be divided into blade-thickness skin graft, middle-thickness skin graft, full-thickness skin graft, and the skin graft with subdermal vascular network according to the thickness of the skin graft. The blade-thickness skin graft and middle-thickness skin graft are more commonly used in oncoplastic surgery, of which the blade-thickness skin graft is easy to cut and obtain, its survival rate is high, and the healing is faster; its advantages include that it lacks the flexibility, is prone to contracture after transplantation, and is not resistant to friction, the color is deep and dark, and the appearance is poor. The elasticity and toughness of the middle-thickness skin graft are stronger than those of the blade-thickness skin graft, and the middle-thickness skin is not prone to contracture and has a good appearance, but there are scars in its donor site, the requirement for wounds on the transplanted area is relatively high, and the survival rate is inferior to that of the blade-thickness skin graft. Comparing the two, the middle-thickness skin graft can achieve better wound healing and aesthetic effect, and it is more commonly applied in oncoplastic surgery.

Due to the racial and individual differences, the color shading and circular surgical scar will often appear in the local skin after transplantation of skin grafts, and the aesthetic effect of defect repair after lesion excision is greatly reduced. Therefore, it is currently not recommended as a first choice. However, it still has an application value in some clinical cases with large area surface defects who can't tolerate major surgical trauma. The aesthetic key points for skin graft donor site selection include: (1) Select the skin grafts from the local area to distal area; namely, the skin grafts to be transplanted should be selected preferably in the area near the lesion. For example, the area behind the ear can be selected as donor site for repair of head and face defects, and the groin area can be selected as donor site for repair of trunk defects, and the inside of the upper arm can be selected as donor site for repair of limb defects, so that not only does the transplanted skin graft have similar color and texture with the local skin in donor site but also is the location of the donor site secluded. (2) Select the thick skin graft first and then thin skin graft; namely, the full-thickness skin graft which has small color change and low degree of contracture after transplantation is selected preferably, if its sources are limited, and then the middle-thickness skin graft which is relatively thin will be selected, and the blade-thickness skin graft is often used as a last resort. The skin graft transplantation (especially in the head and face) should follow the principles of segmental skin graft (Fig. 1.3) in order to achieve better repair effect.

3. Skin soft tissue expansion. Since the American plastic surgeon Radovan et al. developed the first skin soft tissue expander in 1976, the skin soft tissue expansion began to be widely used in plastic surgery. Compared with skin graft transplantation and skin flap transfer, the biggest advantage of skin soft tissue expansion is that it can provide excessive skin with texture and color similar to the area around the site to be repaired within a short time and can perfectly repair the wound and cause no secondary damage in donor site. Especially in recent years with the development of prefabricated skin flap and the progress in the technique of flap prefabrication, the random pat-

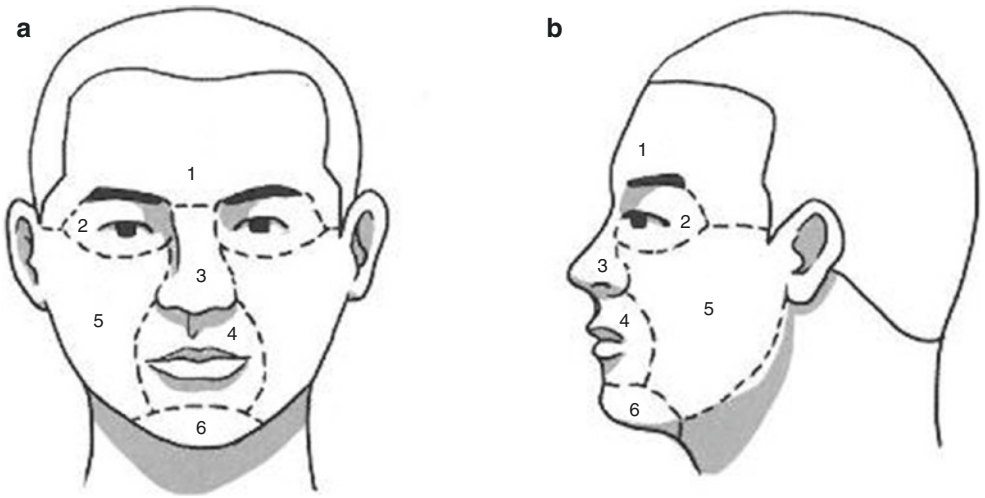

Fig. 1.3 Partition diagram of the facial area. *1*. Frontal area. *2*. Eyelid area. *3*. Nasal area. *4*. Lip area. *5*. Cheek area. *6*. Chin area. (**a**) Front view (**b**) Lateral view

tern skin flap is transformed into the axial pattern skin flap after expansion, which has greatly increased the survival rate of the skin flap and has also expanded the flexibility of skin flap design, so that the expansion technique has a wider application range in the clinical treatment. Because the skin soft tissue expansion requires a period for skin expansion, it is most commonly used for primary repair after resection of benign tumors in the body surface and the second-stage repair after radical resection and comprehensive treatment of malignant tumors. The specific application of skin soft tissue expansion is shown in Chap. 20.

4. Skin flap graft. The skin flap is composed of the skin and its attached subcutaneous tissue with blood supply. In the process of repair of skin and soft tissue defects, the free skin graft and the skin flap graft are the two kinds of methods which are most commonly used. Since the skin flap itself has a blood supply and also has a certain thickness, it has a greater application value in many areas. The skin flap is commonly used to repair the wounds with the exposure of important tissues such as bones, joints, blood vessels, and nerve trunks which cannot be directly drawn close and sutured or used in a situation without the exposure of deep tissue defects, which only aims to obtain a satisfactory therapeutic effect in appearance and function. The organ reconstruction requires the transplantation of support tissue on the basis of skin flap graft. The penetrating defects in areas such as the face, cheek, and upper jaw need to be covered by the skin flaps with a rich blood supply. The chronic ulcer wounds, especially the radiation-induced ulceration wounds, also need to be repaired by skip flap graft with blood supply flap. Therefore, the applications of skip flaps are the most basic repair means in oncoplastic surgery.

Similar to selection of the skin graft donor sites, the local skin flap near defects should be preferably selected and designed, and sewing up the incision after harvesting the skin flaps should follow the principles of the abovementioned incision design as far as possible. If the flap donor site wounds are difficult be closed at one stage, the skin soft tissue expansion can be jointly used to reduce secondary injury of the donor site. For more superficial tissue defects, the thickness of the skin flap should be trimmed at the same time of skin flap transplantation or at second stage to avoid the occurrence of bloated appearance, but it is needed to carefully protect the structures for blood supply such as accompanying vessels or subdermal vascular network.

According to their blood supply characteristics and transfer methods, the skip flaps are generally divided into two broad types: random pattern skin flap and axial pattern skin flap. The preparation and characteristics of all kinds of skip flaps and clinical indications are shown in Chap. 3 All Kinds of Commonly Used Tissue Flaps.

(1) Random pattern skin flap: The random pattern skin flap is also known as random flap. This type of skin flaps doesn't contain axial type vessels. Their blood supplies are provided by only dermal vascular network and subdermal vascular network, sometimes by subcutaneous vascular network (Fig. 1.4a). According to their transfer methods, the random pattern skin flaps can be divided into three categories such as local skin flap, ortho-position skin flap, and distant skin flap. The local skin flaps can be divided into three kinds of skin flaps including sliding skin flap, rotation skin flap, and transposition skin flap.

(2) Axial pattern skin flap. The axial pattern skin flap is also known as arterial skin flap; namely, the skin flap contains the well-known artery and accompanying venous system, and the blood vessels are used as the axis of the skin flap, so that it is parallel to the long axis of the skin flap. According to their blood supply and transfer mode, the following types are available

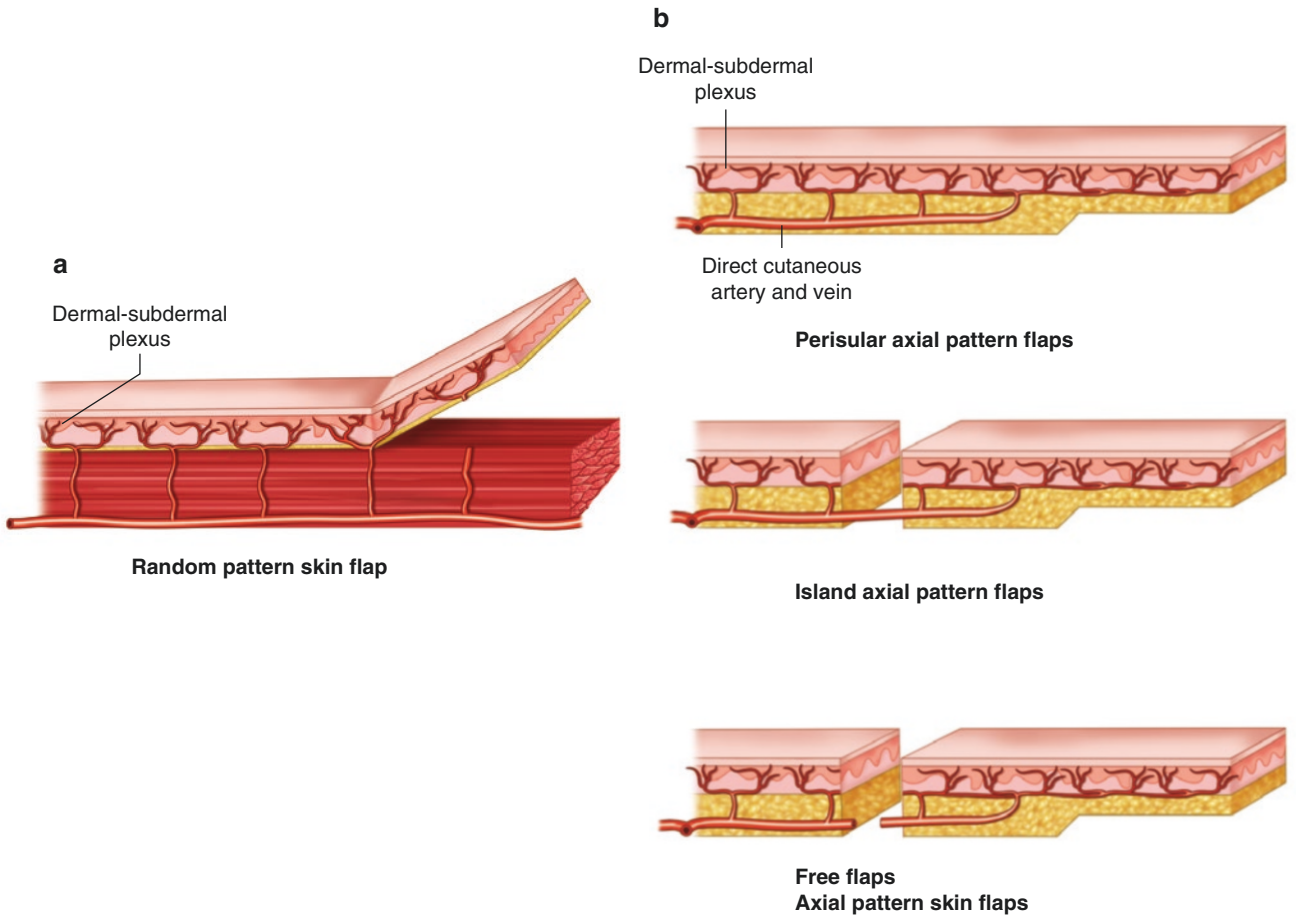

Fig. 1.4 The blood supply of the skin flap. (**a**) The blood supply of random pattern skin flap. (**b**) The blood supply of the axial pattern skin flap

for selection: arterial skin flap, island skin flap, reverse island skin flap, free skin flap, tandem skin flap, parallel skin flap, vascularized skin flap, and venous skin flap (Fig. 1.4b). Of which the free axial pattern skin flap needs to be prepared using microsurgical techniques, and the specific operations and requirements are detailed in Chap. 2 Microsurgical Techniques.

5. Fascial flap transplantation. The fascial flap transplantation is a new type of tissue flap transplantation developed on the basis of the fascia skin flap transplantation. Its main advantages are that the fascial flap has rich blood supply, the donor site can keep the skin, the appearance of the skin flap donor site is not affected, the fascial flap is thinner, and the receptive site will not be bloated with good function and appearance; its main disadvantage is that the defect area still needs skin grafting for wound closure. The surgical methods can be divided into two categories such as pedicled fascial flap transplantation and free fascial flap transplantation according to their transplantation methods. The preparation and characteristics of all kinds of fascial flaps are introduced in detail in Chap. 2 All Kinds of Commonly Used Tissue Flaps.
6. Myocutaneous flap transplantation. The myocutaneous flap is a composite tissue flap; namely, a piece of muscle or part of the muscle of the body with its superficial subcutaneous tissue and skin is harvested and transplanted. The myocutaneous flap has a rich blood supply and a strong resistance to infection, and it is suitably used for repair of larger wound defects because of its large volume and relatively great thickness. The myocutaneous flap with blood vessels and nerves can be used for functional reconstruction of local muscles due to its retention of muscle contraction function. According to its blood supply and transfer method, the myocutaneous flap can be divided into three categories such as pedicled myocutaneous flap, island myocutaneous flap, and free musculocutaneous flap with vascular anastomosis. The preparation and application of various myocutaneous flaps will not be repeatedly presented here.

14.4.3 Functional Reconstruction

The radical resection of tumors in the body surface cannot only lead to serious defect or deformity in the local appearance but also is more likely to directly affect the organ

function. The direct invasion of the tumors or the extended resection may lead to the injuries of the local bone, joints, muscles, nerves, and blood vessels, and the functional reconstructions of these important tissues are also the constituent parts in the process of aesthetic reconstruction of organs.

1. Bone and cartilage transplantation. After extended resection of some bone tumors, the local appearance and support function of the bone can be reconstructed through autologous or allogeneic bone and cartilage transplantation to achieve the purpose of restoring the aesthetic appearance and support function.
   (1) Cartilage transplantation: The cartilage can be divided into three types such as hyaline cartilage, elastic cartilage, and fibrous cartilage. The hyaline cartilages are mostly located on the joint surfaces and form into bony supports in the pharynx, trachea, nose wing, and nasal septum; the elastic cartilages are mostly located in soft sites with supporting role, such as the external ear, epiglottis, and pharynx. The hyaline cartilage and elastic cartilage are usually used for transplantation or used in sites requiring reconstruction in plastic surgery, such as auricular and tracheal reconstructions. There is no vascular structure inside the cartilage, and its cellular metabolic function is poor, but the cartilage can survive after transplantation through absorbing the nutrition in the surrounding tissues, and it will be integrated with the surrounding tissue to form into fibrous or fibrous bone healing about 2 months later. The commonly used donor sites of cartilage include the auricle, costicartilage, and nasal septum cartilage.
   (2) Autogenous bone transplantation: The bone defects can be repaired to reconstruct the appearance or support function through bone transplantation. The bone block without vascular pedicle can establish blood circulation to receptor site and survive within a period of time after transplantation, and it usually takes several months to reconstruct the blood supply to the dense bone after transplantation, while it is observed that the blood vessels grow into the cancellous bone at 2–3 days after transplantation. The most commonly used donor sites of autogenous bone transplantation including the ilium and ribs, fibula, tibia, and tabula externa ossis cranii can also be used as a bone graft material. The bone graft with vascular pedicle is also known as the bone flap graft, and because it has blood supply from inherent blood vessels, it can be combined with muscle and skin to form into composite tissue flap to repair the complex defects.
   (3) Allogeneic bone transplantation: The allogeneic bone transplantation after the removal of antigen can be used to repair a wide range of bone defects, and the transplanted allogeneic bone can be taken as a scaffold for mesenchymal stem cells and osteoblast to adhere and proliferate to form into new bones, which eventually replace the allogeneic bone through crawling and substituting method.
2. Muscle transplantation. The muscle transplantation generally refers to the transplantation of skeletal muscle and can be used to reconstruct the contraction function of local muscles. The muscle transplantation can be divided into three types according to its blood supply and transplantation mode: free muscle transplantation, pedicled muscle transplantation, and muscle transplantation with vascular and neural anastomosis. Of which, the free muscle transplantation has no inherent blood supply within the transplanted muscle, and it can easily lead to the fibrosis and infected necrosis of the transplanted muscle and thus is rarely used. The pedicled muscle transplantation and the muscle transplantation with vascular and neural anastomosis are more commonly used; since the blood supply and nerves of the muscles are retained, the transplanted muscles have good contraction function, so that the movement function of the defect site can be reconstructed. Except for reconstruction of local movement function, the muscle flap can also be used for filling and repair of local defects, which has significant anti-inflammatory functions due to the rich blood supply.
3. Blood vessel transplantation. If the vascular defect length is more than 1–2 cm, and the broken blood vessel can't be directly sutured after the distance between two broken ends is shortened, it is needed to carry out the blood vessel transplantation. Under normal circumstances, both arterial and venous defects are suitably repaired with autologous veins from the body surface. The more commonly selected donor blood vessels include cephalic vein, basilic vein and its tributaries, dorsal venous networks of hand and foot, great and small saphenous veins, their tributaries, etc. In addition to bypass transplantation, the methods of blood vessel transplantation include T-shaped transplantation, Y-shaped transplantation, and patch transplantation (Fig. 1.5).
4. Nerve transplantation. The tumor invasion or surgical resection leads to peripheral nerve involvement or defect, and thus the local movement disorder and abnormal sensation occur due to loss of innervation; if the nerve defect is more than 2–3 cm, it can be repaired with nerve transplantation.

In order to achieve the optimum efficiency of nerve repair, the tension-free repair of the defects after the removal of the affected nerve segment should be performed at one stage as far as possible. In the presence of tension, the anastomosis with shortening the distance between the two broken ends of

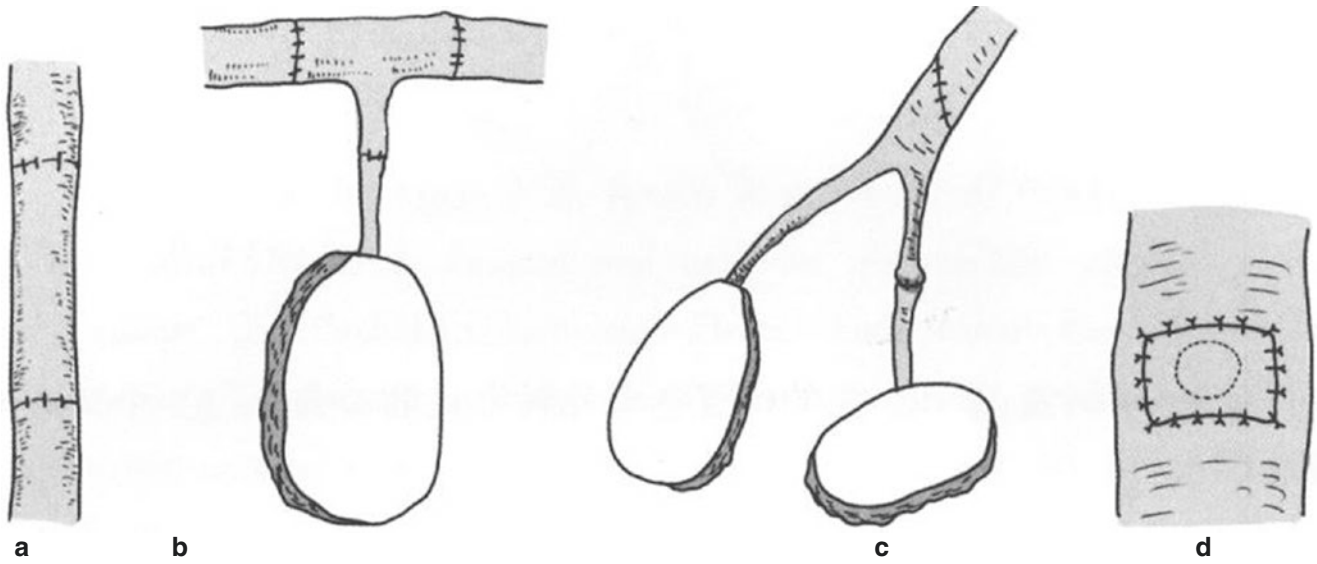

Fig. 1.5 Methods of blood vessel transplantation. (**a**) Bypass transplantation. (**b**) T-shaped transplantation. (**c**) Y-shaped transplantation. (**d**) Patch transplantation

the nerve should be avoided. At this time, it is suitable to use the free nerve transplantation in end-to-end anastomosis for repair of the nerve defects, so as to ensure a tension-free anastomosis. In addition, when repairing the nerve defects, we shall also be careful about the difference between sensory nerves and motor nerves to ensure that the corresponding nerve ends can be correctly anastomosed as far as possible. When the anatomical structure of the nerve bundle is not clear, it can also be repaired through anastomosing the membranes of nerve bundle, and finally the postoperative movement and sensory exercises are used to improve the efficacy of repair.

In the nerve transplantation, the sural nerve is most commonly selected as the donor site. The sural nerve in adults can provide a nerve segment of up to 30–40 cm, and the communicating branch of the sural nerve can also provide a nerve segment of 10 to 20 cm when a greater amount of nerve transplantation is needed. A new nerve transplantation occurs in recent years, which is called nerve implantation, including motor nerve implantation and sensory nerve implantation. The motor nerve implantation is to implant the adjacent motor nerve branch into the muscles without innervation to restore their motor function, and it has been proved that the new motor endplate can be regenerated. The sensory nerve implantation is to implant the sensory nerve into the skin without innervation and the skin flaps with poor sensory function to restore the sensation of local skin or skin flap.

5. Application of various types of biological materials. The application of biological materials in the oncoplastic surgery is detailedly shown in the twelfth section of this chapter.

In summary, the aesthetic reconstruction after radical resection of superficial tumors should include two very important parts such as functional reconstruction and appearance reconstruction; the oncoplastic surgeons need to flexibly use the various repair methods under the guidance of principles for aesthetic plastic surgery, comprehensively considering the special requirements of tumor treatment, and do their utmost to restore the function and appearance of the surgical area, thus improving the qualities of life of tumor patients.

14.4.4 Regenerative Medicine and Aesthetic Reconstruction

It has long been noted that some of the lower animals such as salamanders and geckos can completely regenerate the defect within a short period after the body tissue or organ is injured, and the appearance and function of the tissue can be fully restored to pre-injury status. The extraordinary regenerative abilities of the lower animals deeply attract the attention of researchers. Some tissues in higher mammals also show the amazing regenerative abilities; for example, the human liver after partial hepatectomy can still recover to normal volume relying on the repair and regeneration of the remaining liver cells. Therefore, can the tissue and organ defects of the body surface caused by the trauma or tumor surgery be repaired through tissue regeneration? The proposed concepts of regenerative medicine and related researches attempt to answer this question [47–49].

The regenerative medicine refers to the science of studying the development of the body under normal conditions, the structural features and functions of the tissues, and the mechanism of tissue repair and regeneration after trauma,

finding effective treatment methods on this basis, promoting the body's self-repair and regeneration or reconstructing new tissues and organs, and ultimately improving or restoring the structure and function of the damaged tissues and organs. The regeneration and repair of the tissues are the goals pursued relentlessly by the life sciences. In theory, the regeneration and repair of the tissues are highly matched with the original defect sites not only in cellular components and tissue structures but also in function and appearance, so as to achieve the best efficacy of repair, which is also the ultimate goal of the reconstruction of function and aesthetic appearance. In recent years, the research progresses in the fields of tissue engineering (see Chap. 22), and stem cells make people see the application prospects of tissue and organ reconstruction, and the repair and reconstruction research based on stem cells and tissue engineering has become a new direction in the field of plastic surgery [50–53].

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Microsurgical Techniques

2

Wei Wang, Jianhong Long, and Xiao Zhou

1 The Basic Principles of Plastic Surgical Operation [1]

1.1 Aseptic Techniques

Since any infection will directly affect the surgical outcome, the principle of aseptic technique is a principle which must be strictly enforced. The microsurgery operation is relatively complex, has longer operative time and a wider surgical field, and often involves more than two surgical fields, so that the opportunities of wound exposure and infection are increased. Especially in tissue transplantation, the transplanted tissue is a piece of ischemic tissue, and its resistance to infection certainly will be reduced before reestablishment of the blood supply. Therefore, the aseptic techniques must be strictly adhered to during microscopic plastic surgery. Once the transplanted tissue is infected, all previous efforts will be wasted. Not only will the transplanted tissue be infected and necrotized but also will the receptor site be damaged, so that the patients lose the only opportunity for repair and reconstruction. When repairing or closing a fresh wound, the operators have to strictly adhere to aseptic techniques, and the contaminated wound should be treated to become the clean wound, so that the skin graft or skip flap can survive completely to ensure the recovery of local functions. When performing the surgery in the face involving sites such as the nose, eyes, and mouth, it is difficult for the operators to make the local area absolutely sterile, but the preoperative preparation for the skin and mouth should be carried out, and at least it should be ensured that the exogenous source of infection would not be introduced into the surgical field during surgery.

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1.2 Noninvasive Techniques

Any surgical operations have some damage and destructive effects on tissues, and every operation during surgery can cause damage and destruction to numerous cells. For example, the excessive gripping, squeezing, pulling, and drying or overheating wet compressing can necrotize some tissues; they will become the bacterial culture media, even if they don't lead to the formation of significant infection, at least they will lead to formation of scar tissues during the healing. From the histological point of view, any soft tissues, blood vessels, nerves, or lymphatic vessels are viable tissues; any squeezing or rough handling can cause some degree of destruction and damage and thus resulting in secondary necrosis, while the noninvasive techniques are to reduce this kind of damage to a minimum. Each operator should form the concept of protecting tissues and ensure that the operations are steady, accurate, light, and fast, and the knives, scissors, and needles are sharp and delicate. The exposure to the air of the wound should not be too long, and the wound should be covered with the wet saline gauze instead of the hot saline gauze at any time. Especially when stopping the bleeding, sometimes due to the eagerness to stop the bleeding, the operator can't wait for the cooling of the overheating wet gauze and would like to press it on the wound right away, thus resulting in damage to the wound tissue. This damage will affect the healing of the wound.

1.3 No Dead Space Residue and No Hematoma Formation

Due to local tissue defects, the interspace appearing in subcutaneous or deep layer after wound closure is the dead space, which causes the hematoma and infection. The large

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dead space can be filled through the transfer of tissue flap, and the negative pressure drainage tube is placed to eliminate dead space; the small dead space can be removed by means of sutures and compression bandaging.

The hematoma may be caused due to imperfect hemostasis during the surgery, also due to the vasoconstrictor effects of local anesthetics or abnormal secondary bleeding. The hematoma will adversely affect the final result of wound healing; particularly it will affect the survival of the transplanted skin. The complete hemostasis should be carried out during surgery to avoid hematoma formation; if a hematoma occurs, it should be removed as soon as possible.

1.4 No Wound Exposure

No wound exposure refers to covering the wounds completely. The wound exposure easily leads to infection, so that the tissue edema occurs, and finally the scar tissues are formed. If the wound still cannot be sutured due to larger tension after widespread free dissociation, or the wound cannot be directly sutured, it is needed to eliminate the wound using skin transplantation.

1.5 Suture Under Moderate Tension

It is not appropriate to suture any wound too loosely or too tightly. The excessively loose suture often causes poor tissue alignment. The excessively tight suture and the too large tension can cause the following adverse consequences: (1) The extensive scar tissues are formed; (2) the normal blood circulation in the tissues is impeded or blocked, thus resulting in necrosis of the tissue margin; (3) the organs in facial area can be pulled and displaced, thus resulting in secondary deformity; and (4) the wound dehiscence can be caused.

2 The Basic Operation Techniques of Plastic Surgical Operation

2.1 Incision

The skin incision in plastic surgery has a great impact on the local function and appearance, requiring that the incision scar is small and hidden and does not affect the function. Therefore, when designing the incision, the operators should pay attention to the following points:

1. The incision direction is consistent with those of the cleavage lines (Langer's lines) or wrinkles (expression lines) (Fig. 2.1).
2. If the incision must pass across the expression lines during the surgery, it is necessary to change direction to make the incision go along the zigzag direction or S direction, when the incisions in the limbs need to pass across the joints, and the incisions should be made as horizontal shaped or S shaped to prevent linear contracture.
3. The facial incisions can be made along the dividing lines between the contour lines and regions, such as the hidden areas beside the nose, beside the nosewing, in front of the auricle, and in hairline margin and mandibular margin.
4. The incisions should be made using a sharp knife, and all layers of the skin should be vertically cut through at a time, avoiding being repeatedly cut to result in an irregular incision line. The beveled incision should be prevented; otherwise an uplifted scar will appear on one side of the incision after suturing.

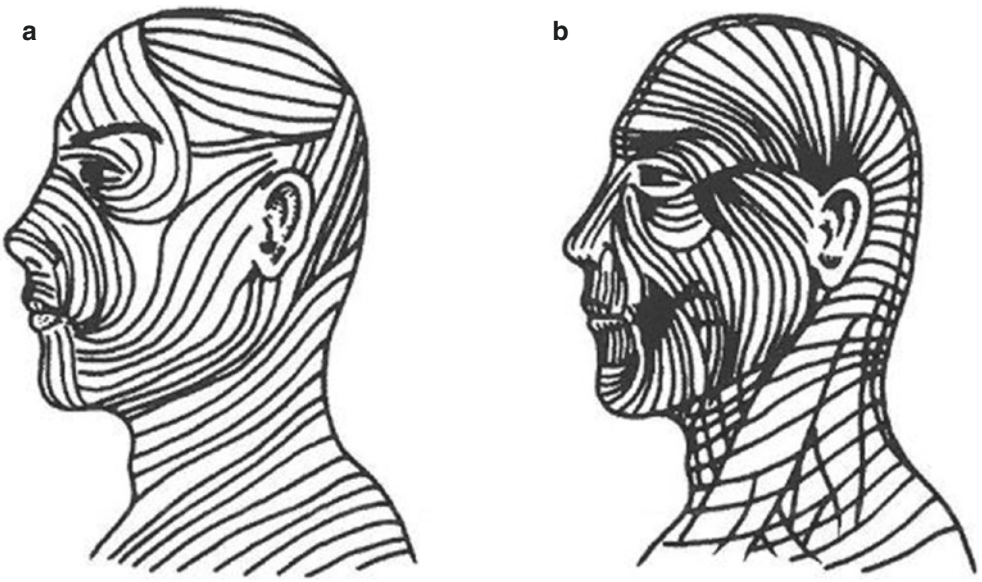

Fig. 2.1 The incision direction and the cleavage lines. (**a**) Langer's lines in the facial skin. (**b**) The directions of the facial wrinkles

2.2 Dissection

The sharp dissection should be mainly performed during surgery, which is combined with blunt dissection. Close attention should be paid to the dissection plane to reduce tissue damage and bleeding.

2.3 Hemostasis

The thorough hemostasis is a basic requirement of the surgery, and the plastic surgery requires both thorough hemostasis and slight injury:

1. The electric coagulation hemostasis can still be used during deep surgery and large flap transfer, but, in order to reduce tissue damage, we recommend using bipolar coagulation or mini electric coagulation to reduce the range of tissue charring.
2. The compression hemostasis with warmly wet saline gauzes can be used for wounds with more extensive bleeding.
3. The local application of epinephrine solution has a temporary hemostatic effect but leads to a higher incidence of secondary bleeding and the hematoma under the skin graft and the skin flap; therefore, the operators had better not use this method.
4. The ligation hemostasis is a commonly used method with most definite efficacy. In order to ensure a smooth suture without tearing the line off, it is recommended to learn and master the method of two-hand tying to tie three knots.
5. The hemostasis method such as suture ligation can be used in places where it is difficult to carry out hemostasis.
6. The appropriate application of the inflatable and rubber sheet esmarch tourniquets can reduce blood loss during the lower extremity surgery.

2.4 Washing

The plastic surgeries often have a large wound and long operative time, and it is appropriate to wash the wound during surgery and before suturing to remove tissue debris and prevent infection, which is conducive to tissue repair. The clean wound is washed with normal saline, and the contaminated wound is washed repeatedly with 1:2000 benzalkonium bromide (bromogeramine), 1.5% hydrogen peroxide solution, and normal saline.

2.5 Drainage

The extensive dissected wounds often cause postoperative hematoma, effusion, or infection due to the oozing of the blood and the imperfect hemostasis; therefore, the drainage after such surgery is often a necessary measure. The drainage methods include rubber sheet drainage, half-flat catheter drainage, cigarette drainage, and negative pressure drainage, which are selectively used according to the different conditions. The drainage is removed usually at 48–72 h after surgery, and the negative pressure drainage can be prolonged up to 3–4 days after surgery and then will be removed.

2.6 Suture

The ideal suture in plastic surgery should be the layered suture, which requires the exact alignment, moderate degree of tightness, no dead space in deep layer, and no tension in skin layer. The wound should be carefully sutured on the basis of thorough hemostasis. It should be avoided to use the large needle and thick line; the layer dislocation should be prevented; and the wound should be sutured layer by layer from deep layer to shallow layer. The commonly used suture methods include skin and subcutaneous interrupted suture, intradermic suture, continuous blanket edge suture, vertical mattress suture, horizontal mattress suture, and the suture of the flap apex of triangular skin flap, and all kinds of suture methods have their own adaptive conditions and requirements (Figs. 2.2, 2.3, 2.4, 2.5, 2.6, and 2.7).

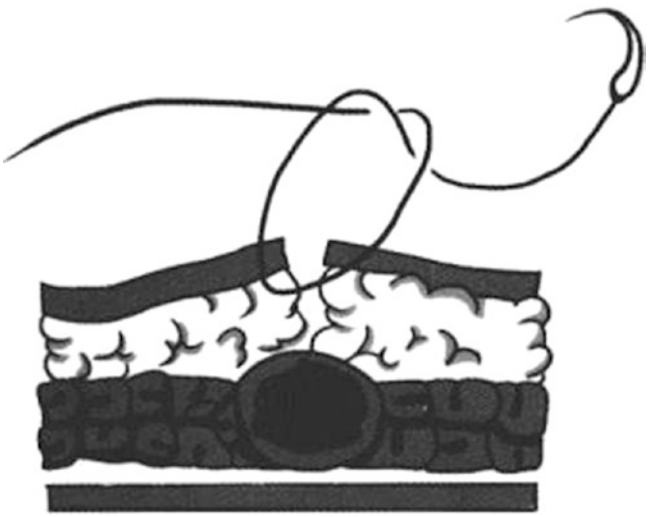

Fig. 2.2 Skin and subcutaneous interrupted suture

Fig. 2.3 Intradermic suture

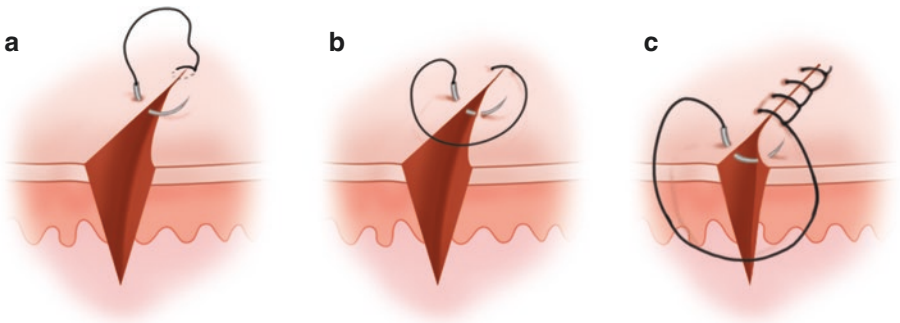

Fig. 2.4 Continuous lock stitch (**a**) Location. (**b**) Locking with the thread. (**c**) Locked up

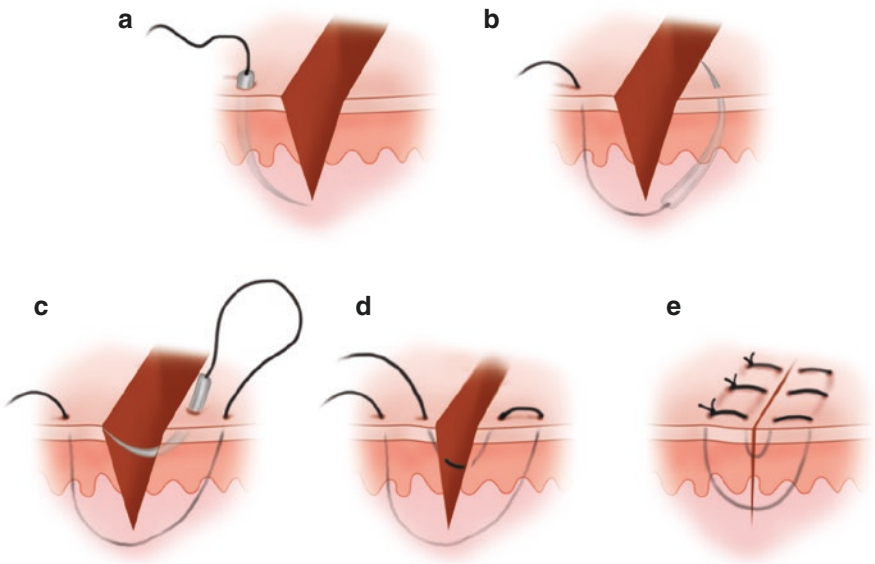

Fig. 2.5 Vertical mattress suture. (**a**) Needle pierces in on the same side and goes through the deep wound. (**b**) Needle pierces out on the other side. (**c**) Needle pierces in on the other side and goes through the shallow wound. (**d**) Needle pierces out on the same side. (**e**) completion

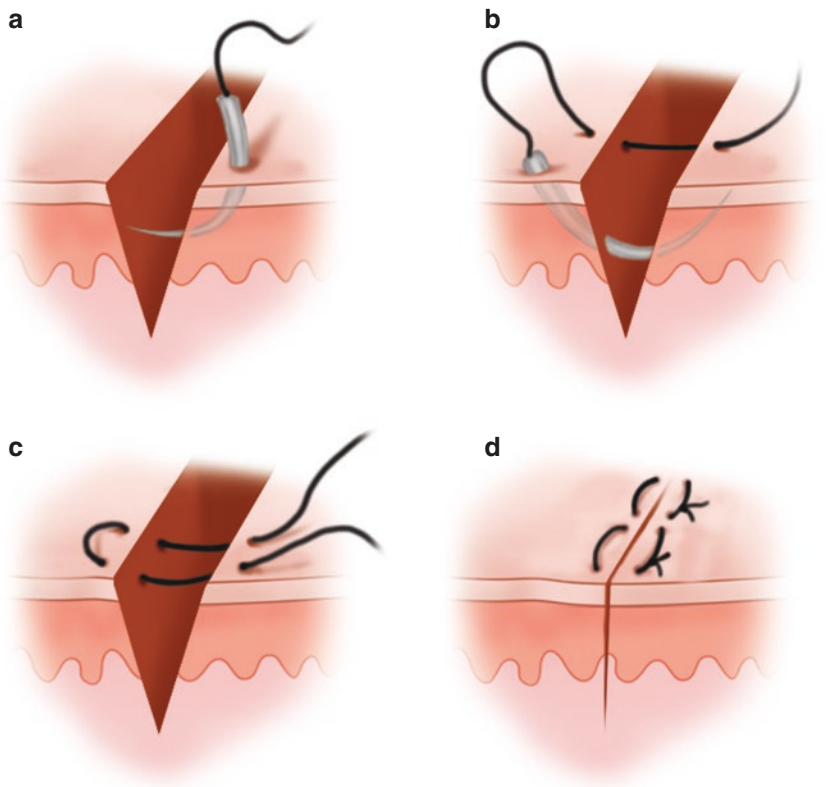

Fig. 2.6 Horizontal mattress suture. (**a**) Needle pierces in the back of the wound and pierce out. (**b**) Needle pierces in the front of the wound and pierce out. (**c**) Tie a knot. (**d**) Completion

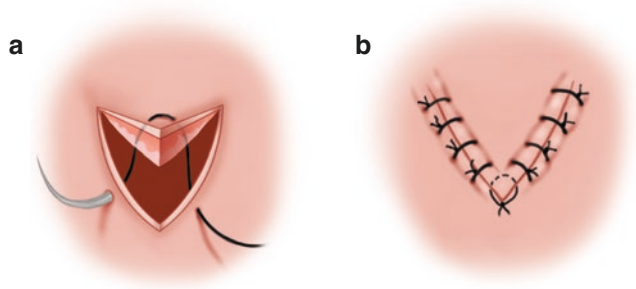

Fig. 2.7 The suture of the flap apex of triangular skin flap. (**a**) Thread goes through the subcutaneous tissue of the triangle's top. (**b**) Complete the suture

2.7 Bandaging and Fixation

The bandaging and fixation of postoperative wound should be considered as one of the important steps of the surgery, which may affect the success of surgery to some extent. For example, if the bandaging and fixation are inappropriate after transplantation of free skin graft, the skin graft failure may occur due to movement; after reconstruction of organs such as the ear and nose, the bandaging, shaping, and fixation are also very important.

3 The Basic Techniques of Microsurgery

The microsurgery refers to that under the surgical magnifying glass or the surgical microscope; the delicate surgery of small tissue is performed with microscopic equipment. The microsurgery is both a novel technology and a new interdisciplinary subject; it not only includes various technical problems in clinical surgical applications but also includes basic theory researches such as anatomy, physiology, biochemistry, pathology, and diagnostics which are associated with this technology. Therefore, the microsurgery has become an independent discipline and is called microscopic surgery or microscopic repair surgery. The microsurgery has been widely used in various surgical professional disciplines, along with the development of reparative and reconstructive surgery; microsurgical techniques will be more widely used in clinical practice [1–3].

3.1 Microsurgical Devices and Equipments

3.1.1 Surgical Microscope and Surgical Magnifying Glass

1. Surgical microscope: The surgical microscopes include types such as double binocular microscope, single binocular microscope, floorstanding microscope, suspended microscope, desktop microscope, or wall mount microscope. The floorstanding double binocular microscope is most commonly used. The magnification times of the surgical microscope automatically vary between 6 and 30 times, and the working distances are 200–300 mm, which can be adjusted as needed.
2. Surgical magnifying glass: The surgical magnifying glasses include types such as head-mounted magnifying glass, desktop magnifying glass, and eyeglass magnifying glass. The eyeglass magnifying glass is most commonly used, and its magnification times are 2.5–6 times, which is suitable for suturing the blood vessels and nerves of more than 2 mm in diameter.

3.1.2 Microsurgical Instruments

1. The micro-tissue forceps are used for clamping the vascular adventitia and epineurium and assisting in suture, withdrawal of needles, and knotting and dissecting tissue.
2. The microneedle holders have two types such as straight microneedle holder and curved microneedle holder, which are used for holding the needle, suture and knotting, etc.
3. The micro-scissors have two types such as straight micro-scissors and curved micro-scissors, which are used for trim and separation of blood vessels, nerves, lymphatic vessels, etc., and can also be used as the trimming tools of 5-0–11-0 lines.
4. The microvascular clamp is used for clamping small blood vessels and blocking blood flow. It has a lot of varieties; the clamping forces are not of uniform strength and are selectively used according to the blood vessels of different calibers.
5. The washing needle and washing equipment are used before and during vascular anastomosis to wash clean the remnant blood in the vascular lumen and keep the surgical field moist and clean.
6. The microsurgical suture needle and line are connected together, with different specifications of 7-0–12-0, which are used for sutures of blood vessels and lymphatic vessels of different calibers.

3.2 Basic Techniques of Microsurgical Operation

There is a greater difference between microsurgery and traditional surgery. The basic techniques of microsurgical operation include the basic microsurgical techniques and the repair and anastomosis techniques of small diameter vessels.

3.2.1 Basic Microsurgical Techniques

1. Application of instruments: The surgeons should master the application methods of the surgical instruments and microscope.

2. Operation practice: The surgeons should practice the microscopic dissection and separation techniques, the lifting and holding techniques of microscopic tissues, the traction and exposure techniques of microscopic tissues, and the ligation, hemostasis, and debridement techniques of the microsurgery under the microscope and should pay attention to the cooperation with the assistants during surgery.

3.2.2 The Repair and Anastomosis Techniques of Small Diameter Vessels

1. Microvascular anastomosis: The anastomosis of blood vessels of less than 2 mm in diameter should be performed under the surgical microscope or surgical magnifying glass to achieve the desired effect. The methods of microvascular anastomosis include suture, cuff technique, adhesion, mechanical anastomosis, and thermocoagulation anastomosis, and the suture method is mostly used in clinics. The modes of vascular anastomosis include end-to-end anastomosis, end-to-side anastomosis, and side-to-side anastomosis, and the end-to-end anastomosis is commonly used. Two- or three-fixed-point interrupted suture is often performed, whose key points include the following: (1) Block the blood flow: The vascular clamp is used to block blood flow. (2) Trim flat the broken end surface, cut off the damaged blood vessels until the vascular intima is smooth and the blood vessel wall is intact, and cut flat the broken ends of blood vessels. (3) Remove the adventitias of the broken ends of blood vessels: When the suture is performed, it is prevented to bring the adventitia into the vascular lumen and thus leads to thrombosis. (4) The closing of anastomotic stomas: Both ends of blood vessels are closed with the vascular closer device to be sutured in the absence of tension. (5) Wash and keep moist: Wash the remnant blood in vascular lumen and keep the surgical field moist to facilitate the suturing and reduce the blood coagulation and vascular intimal injury in the local area. (6) Suture: Accurately insert the needle; the distance between needle points and the distance between margins are well proportioned. (7) Treatment of blood leakage: When the anastomotic stomas have blood leakage or blood spurting, the additional sutures should be performed in places where blood leakage occurs. (8) Unobstructed test: Examine whether the anastomotic stomas are unobstructed. (9) The blood vessels will be buried in a good tissue bed.

Microscopic neural anastomosis: The methods for microscopic neural anastomosis include epineurium suture, perineurium suture, combined epineurium, and perineurium suture (Figs. 2.8, 2.9, and 2.10). The basic key points include the following: (1) Dissect and separate the nerves. (2) Carry out anastomosis in normal nerve site. (3) Carry out suture under no tension. (4) Avoid the nerve torsion.

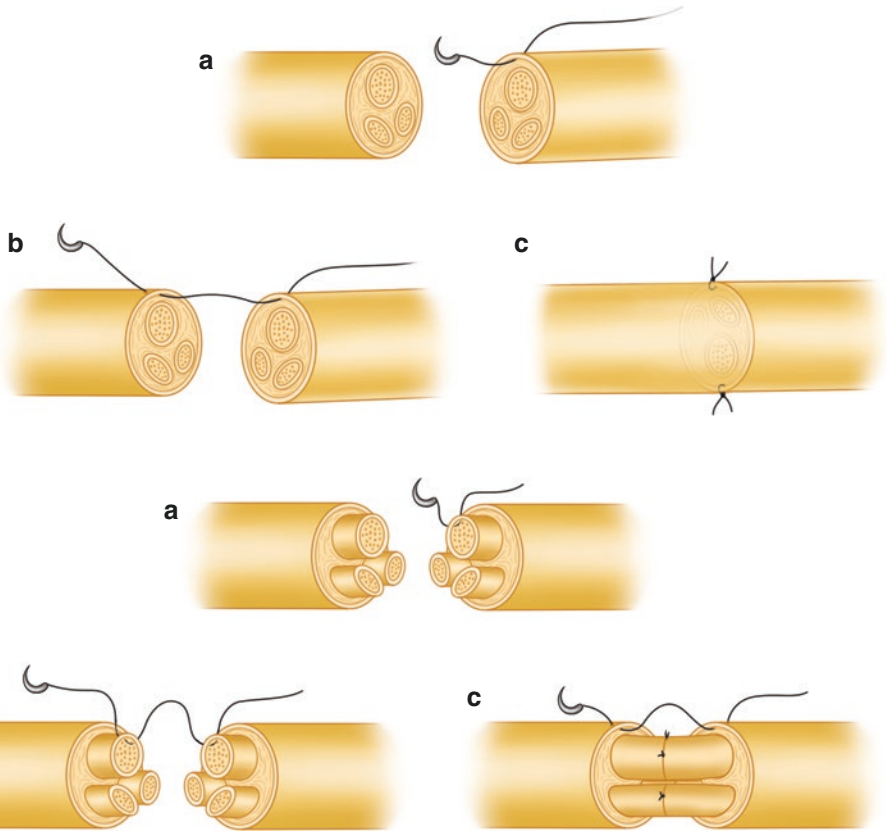

Fig. 2.8 Epineurium suture. (**a**) Location. (**b**) Insertion of the needle. (**c**) Completion

Fig. 2.9 Perineurium suture. (**a**) Location. (**b**) Perineurium suture. (**c**) Epineurium suture

Fig. 2.10 Combined epineurium and perineurium suture

3.3 Postoperative Observation and Treatment

3.3.1 Postoperative Routine Treatment

1. Infection prevention: The broad-spectrum antibiotics are used.
2. Anticoagulation treatment: The low molecular dextran, aspirin, dipyridamole, fibrinolysin drug, and heparin are used.
3. Anticonvulsant treatment: The composite Salvia miltiorrhiza injection, anisodamine, and tolazoline are used.
4. Strengthening the monitoring: The temperature, color, edema, and capillary reaction of the graft are monitored intensively.

3.3.2 Observation and Treatment of the General Condition

1. Observation of vital signs: Observe the changes in blood pressure, pulse, respiration, body temperature, and consciousness; if the vital signs of the patient are unstable or show a deteriorating trend, it is supposed to fully analyze the traumatic condition, surgery, and medication statuses to find out the problems and carry out corresponding treatments.
2. Judgment and treatment of blood volume: If the patient has symptoms of hypovolemia such as skin temperature drop in extremity ends, pale skin color, delayed nail bed capillary filling, oliguria, and increased urine-specific gravity, it is necessary to timely supplement the blood volume; the fresh blood is mainly used, and it is contraindicated to use the vasopressors.
3. Observation of bleeding tendency: When the patient has much more wound errhysis and the systemic bleeding in the skin, mucous membranes, and internal organs, the blood coagulation time and prothrombin activity should be timely detected; the dynamic observation is carried out; the fresh blood can be intravenously injected when necessary; and the clotting drugs should be used with caution.

3.3.3 Observation and Treatment of the Blood Circulation of the Graft and Retransplanted Graft

1. Causes of blood disorder: The factors such as vasospasm, thrombosis, blood vessel distortion or too large tension, hematoma, tissue edema, the tunnels where the vascular pedicles pass through are too narrow, the suture tension of the skin being too large, the braking not being strong, and the body position change have led to increased anastomotic tension and even tore the anastomotic stoma, all of which can cause the blood disorder of the graft or retransplanted graft.
2. Observation contents:
   (1) Color: If the color of the graft or retransplanted graft is slate violet, it often indicates that the venous return is obstructed; if the color is pale, it indicates that the artery blood supply is insufficient.
   (2) Skin temperature: Under normal circumstances, the skin temperature of the graft or retransplanted graft should be maintained at above 31 °C. If the skin temperature is lower than 27%, suggesting the existence of the arterial blood disorder, and if the skin temperature is between 27–31 °C, suggesting the existence of the venous blood disorder, the skin temperature is over 3 °C lower than that in healthy skin and accompanied by color change, suggesting the existence of the blood disorder.
   (3) Vascular filling and beats: The filling (veins) and beats (arteries) of the larger blood vessels in superficial layer of the graft can be observed, and they are more accurately measured by the ultrasonic Doppler blood flow meter.
   (4) Microcirculation status of the graft skin: It can be detected with laser Doppler.
3. Treatment of vascular crisis: The vascular crisis refers to a phenomenon that the blood disorders occurring in the anastomosed vessels endanger the survival of the graft or retransplanted graft, and thus it is needed to be timely treated. Its treatment steps are as follows:
   (1) Analyze the cause of vascular crisis and carry out the symptomatic treatment.
   (2) We should take active measures after observing the symptoms of vascular crisis, including position adjustment, keeping warm, antispasmodic treatment, and anticoagulation treatment, and observe closely the reaction after the treatment.
   (3) After the above treatments, if the disease condition continues to deteriorate, or has no significant improvement, the surgical exploration should be performed.

3.4 The Application Range of Microsurgery

In addition to application in ophthalmology, otolaryngology, and neurosurgery, the applications of microsurgery in replantation, transplantation, and reparative and reconstructive surgery mainly include:

1. Replantation of a severed limb (finger): The replantations of all ten severed fingers and severed distal segments of fingers have been successfully implemented at one time in China.

2. Tissue transplantation with vascular anastomosis:
   (1) Skin flap and myocutaneous flap transplantation with vascular anastomosis: It is used for repair of wounds with skin and soft tissue defects with deep tissue exposure.
   (2) Muscle transplantation with vascular and neural anastomosis: It is used for repair of muscle defects, necrosis, and denervation.
   (3) Bone and periosteum transplantation with vascular anastomosis: It is used for repair of large bone defects.
   (4) Omental transplantation with vascular anastomosis: It is used for the repair of the wound with skin and soft tissue defects and deep tissue exposure which is not suitably repaired by other skin flap with vascular anastomosis and the treatment of thrombosis obliterans and chronic osteomyelitis.
3. Thumb or finger reconstruction using toe transplantation with vascular anastomosis: At present, the reconstruction of five fingers of the whole hand has been reported.
4. Esophageal reconstruction using jejunum transplantation with vascular anastomosis: It is used for esophageal reconstruction after cicatricial esophageal stenosis, congenital esophageal defect, or atresia and resection of esophageal carcinoma.
5. Microsurgical repair of peripheral nerves: It is applied to repair the long nerve defect.
6. Micro-lymphatic surgery: It is applied in the treatment of lymph circulation disorder.
7. Small duct microsurgery: It is performed for vas deferens anastomosis, tubal anastomosis, and repair of nasolacrimal duct injury.
8. Small organ transplantation with vascular anastomosis: For example, the patients with high cryptorchidism are treated with testis transplantation vascular anastomosis.

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All Kinds of Commonly Used Tissue Flaps

3

Jianhong Long, Xinghua Yang, Xiao Zhou, and Wei Wang

1 Overview

The skin flap transplantation began in 1595; Tagiliaeozzi designed the nasal reconstruction with the upper arm skin flap. In the early nineteenth century, the transplantation of tubular skin flap was successfully designed and performed. From 1915 to 1965, the skin flap design was limited to the length-to-width ratio of the skin flap, for example, face, 3:1, and lower limbs, 1:1, and the patients with a length-to-width ratio exceeding the designed ratio should undergo the delayed surgery. In 1965, Bakinjian used and transferred the deltopectoral skin flap to repair the pharyngeal defect; thus, it was not needed to perform the delayed surgery. In 1973, Danial and Williams et al. divided the skin flaps into two types such as the axial pattern skin flap which is supplied with blood directly by the cutaneous artery and the random pattern skin flap which is supplied with blood by the myocutaneous artery according to the study on the anatomy and blood supply of the skin. In 1974, Harri and Hmori et al. performed the free skin flap graft with vascular anastomosis and achieved success. For over 30 years, due to the rise of microscopic anatomy, and the development of tissue implantation technique is enhanced, the vascular pedicled skin flap and myocutaneous flap transfer and the free skin flap transplantation with vascular anastomosis are widely used in the wounds of traumas; electric burns; and hot crush injuries with the exposure of deep tissues such as nerves, blood vessels, and tendons; and the severe soft tissue defects, which have advantages of avoiding or reducing the amputation, restoring the appearance and function, as well as preventing the secondary bleeding [1–3].

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1.1 The Concepts of Skip Flap and Skin Flap Transplantation and Indications

The skin flap refers to the composite tissue block with its own blood supply, which may include the skin, subcutaneous tissue, or deeper tissues. The process of transferring the tissue block from one place to another place is called skin flap transplantation or skin flap transfer. The place where the skin flap is formed is called the donor site, and the place where accepts the skip flap is called the receptor site. If the designed skin flap is harvested and transferred immediately into the donor site, which is called the immediate transplantation of skin flap, this kind of skin flap is called acute skin flap. If the designed skin flap undergoes delayed surgery at first to make its blood supply richer and then it is transferred, which is called the delayed skin flap transplantation, this kind of skin flap is called delayed skin flap. The skin flaps carry their own blood supply with two ways: One is that the skin flap is connected with the donor site through the pedicle, which can be a full-thickness tissue of the skin flap and can also be certain layers of the tissue such as the subcutaneous tissue, muscle, and vascular bundle. This kind of skin flap is called as pedicled skin flap, and the process of transferring the pedicled skin flap into the receptor site is called pedicled skin flap transfer; another is that the blood vessels in the skin flap are anastomosed with the blood vessels in the receptor site. This kind of skin flap is called free skin flap, and the process of transferring the free skin flap into the receptor site is called free skin flap transplantation.

The skin flaps after transplantation can survive completely on their own blood supply at early phase; with the progress of the healing process, the skin flaps can gradually get blood supply from the receptor sites, while the dependences on their own blood supply decrease or even this

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dependence disappears. At the moment, the pedicle of the pedicled skin flap can be cut off if necessary.

The skin flap transplantation is one of the most basic and most commonly used operation techniques, and its main indications include the following aspects [4–6]:

1. Repair of wounds with skin and soft tissue defects and the exposure of the bones and joints, cartilage, tendons, vital organs, nerves, and blood vessels.
2. Repair of perforating defects.
3. Repair of wounds with poor blood supply, such as the radiation-induced ulceration and the ulcer in chronic osteomyelitis.
4. Repair of wounds in places that are grinded and compressed, such as the heel ulcers and bedsores.
5. Organ reconstruction, such as reconstructions of fingers, ears, nose, penis, and vagina.
6. Functional reconstruction, for example, the latissimus dorsi myocutaneous flap is transplanted to reconstruct the elbow flexion function.

1.2 The Blood Supply Types and the Vascular Architecture of the Skin

The most basic condition for the skin flap survival is the existence of good blood circulation; therefore, to understand the blood supply type and vascular architecture of the skin is of great significance for the correct selection and design of the skin flap. The blood supply to the whole human body can be divided into three levels, namely, the inner vascular system, the muscle vascular system, and the skin vascular system.

1.2.1 The Inner Vascular System

The inner vascular system is composed of the main trunk blood vessels of the human body. These blood vessels are continuations of the aorta, whose walls have strong elastic fibers; can pulsate along with the contraction and expansion of the heart, which will help to promote blood flow and maintain perfusion pressure; and have an effect in distributing the blood throughout the body.

1.2.2 The Muscle Vascular System

The feeding blood vessels of the muscle vascular system are derived from the inner vascular system, and they can be divided into five types such as types I–V. Type I is the single branch type, and the muscle has only a feeding artery, such as gastrocnemius muscle and tensor fasciae latae muscle. Type II is the type of main branch plus subbranch, namely, the muscle has a larger main feeding artery and some smaller secondary feeding arteries, such as gracilis muscle. Type III is the double-branch type, namely, the muscle has two feeding arteries of almost the same size, such as rectus abdominis muscle and gluteus maximus muscle. Type IV is the type of segmental vascular branches, namely, the muscle has a series of smaller segmental feeding arteries, but has no main feeding artery, such as sartorius muscle and tibialis anterior muscle. Type V is the type of main branch plus segmental vascular branches, namely, the muscle has a main feeding artery and some segmental feeding arteries from different directions and sources, such as latissimus dorsi muscle and pectoralis major muscle. The main function of the muscle vascular system is to feed the muscles, and the blood vessels of some muscles still have a role in feeding the superficial skin tissues.

1.2.3 The Skin Vascular System

The skin is supplied with blood by two types of cutaneous arteries, namely, the direct cutaneous artery and the myocutaneous artery. Both have corresponding concomitant venous reflux systems. The skin vascular system exists in the three layers such as deep fascia, subcutaneous fat, and skin. It is composed of five vascular plexuses in the deep fascia, subcutaneous, subdermal, intradermal, and subepidermal areas which have their own independent systems and are connected with each other (Fig. 3.1), and the arteries of each arterial vascular plexus also have concomitant venous reflux systems.

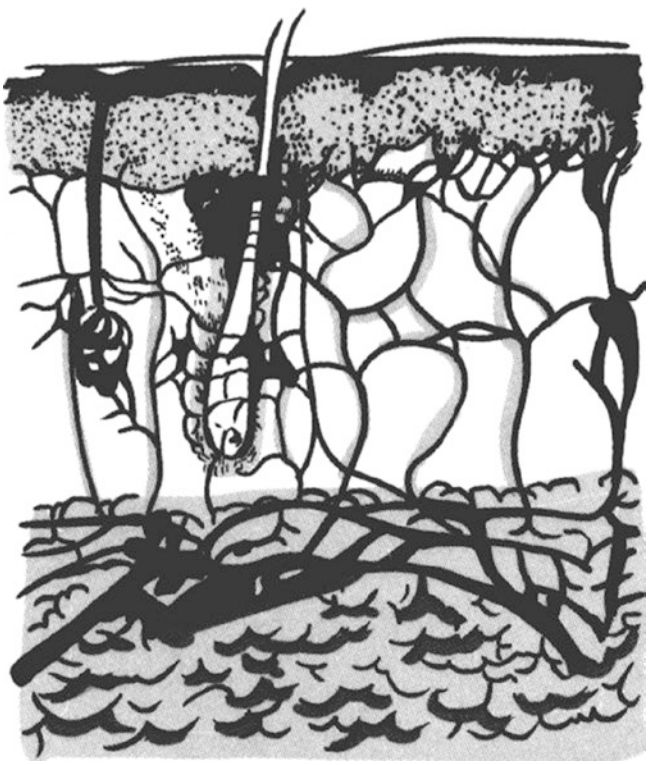

Fig. 3.1 The diagram of skin vascular system

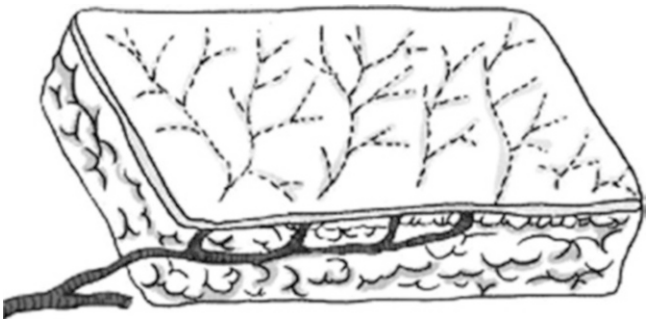

Fig. 3.2 The diagram of skin flap with direct cutaneous artery

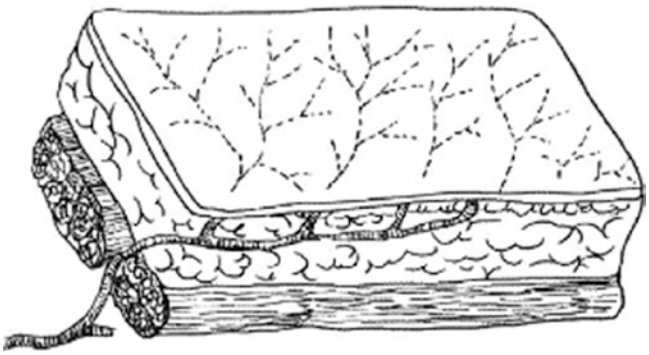

Fig. 3.3 The diagram of skin flap with the cutaneous artery from the intermuscular space

1. The direct cutaneous artery originates from the inner arterial trunk, passes out from the deep fascia through the intermuscular space or intermuscular septum, goes along the direction parallel to the skin surface in the subcutaneous tissue in the shallow surface of the muscle, and gives off branches along the way to feed the subcutaneous fat and skin (Figs. 3.2 and 3.3). The blood vessels taking the direct cutaneous artery as the axis can be formed into axial pattern skin flap, such as the circumflex scapular artery, superficial epigastric artery, dorsal pedal artery, and radial artery [7, 8].
2. Myocutaneous artery: The myocutaneous artery originates from the artery feeding the muscles, which gives off the myocutaneous branch to vertically pass out the deep fascia from the muscle and enter into the above skin tissue to turn into the myocutaneous artery to feed the subcutaneous tissue and skin. The vast majority of human skins cover the muscles, and every muscle has blood vessels; therefore, the myocutaneous arteries are the feeding arteries of the vast majority of human skins. The random pattern skin flaps can be formed through taking the myocutaneous arteries as blood vessels. If the arteries entering into the muscle are taken as the feeding blood vessels, the muscle and the above skin tissue can be harvested concurrently to form the myocutaneous flap (Fig. 3.4).

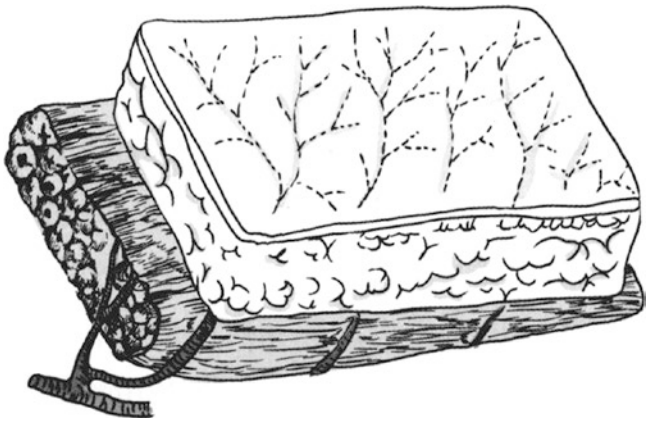

Fig. 3.4 The diagram of skin flap with the intramuscular blood vessels

3. Deep fascial vascular plexus: The obvious deep fascial vascular plexus exists in the deep fascia and the loose connective tissues above and under the deep fascia. The deep fascial vascular plexuses are more obvious in the limbs, including three layers such as subfascial layer, fascial layer, and epifascial layer, and the epifascial vascular plexus is mostly abundant. The blood supply sources of these vascular plexuses include direct cutaneous arteries, myocutaneous arteries, and the recurrent branches of subcutaneous vascular plexus. When a skin flap is formed in the clinic, if the deep fascia is included, the skin flap becomes a fasciocutaneous flap; its blood supply is more abundant than that of the usual skin flap, and its survival length increases by 15–20%.
4. Subcutaneous vascular plexus: It is located in the superficial fascia; thus, it is also called superficial fascial vascular plexus. The superficial fascia divides the subcutaneous fats into two layers such as superficial layer and deep layer. The superficial layer is denser, and the deep layer is looser. Within this superficial fascia, there exists the vascular plexus going in horizontal direction, and its degree of development varies in different parts of the body, which is more abundant in the body trunk than that in the lower limbs. The superficial fascial vascular plexus has richer anastomoses with the down deep fascia vascular plexus and the above skin vascular plexus, whose blood supply comes from the branches of two kinds of cutaneous arteries. The presence of this vascular plexus is the anatomical basis of the formation of subcutaneous fat flap (Fig. 3.5).
5. Subdermal vascular plexus: It is located at the junction of the dermis and subcutaneous fat. The vascular plexus is broad and abundant and is the main blood supply system of the skin; many final branches of the two kinds of cutaneous arteries end up in this layer. This vascular plexus gives off many small arteries, the walls of which have

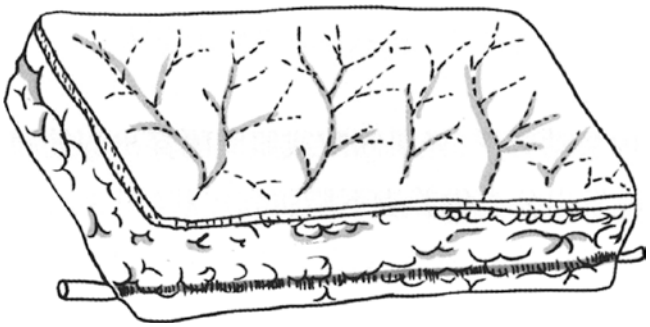

Fig. 3.5 The diagram of skin flap with the main blood vessel plus small branch blood vessels

continuous smooth muscles, and its main function is to distribute the blood. Some small arteries run obliquely or vertically upward into the reticular dermis or join into the human dermal vascular plexus or continue to run upward and are connected to each other to form into the arch anastomosis; other small arteries run downward to feed the subcutaneous fat and various glands. The subdermal vascular plexus is important for maintaining the blood supply of the skip flap, and it should be protected when the skin flap is formed; otherwise, it is very difficult for the skin flap to survive.

6. Dermal and subepidermal vascular plexuses: The dermal vascular plexus is located in the reticular dermis, while the subepidermal vascular plexus is located between the lower bound of the dermal papilla ridge and the dermal-epidermal line, and the two layers of vascular plexuses provide real blood circulation to the skin. The small artery walls of the dermal vascular plexus have discontinuous smooth muscle components, which mainly have a thermal regulation effect. The subepidermal vascular plexus belongs to the capillaries, whose walls have no smooth muscle, and it mainly has nutritional functions.

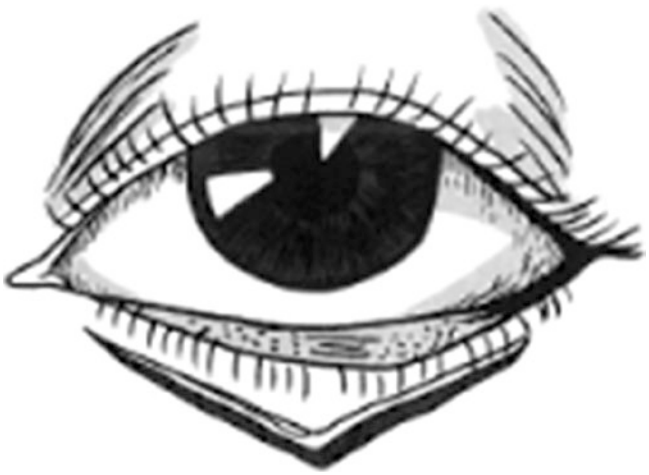

Fig. 3.6 The use of V-Y skin flap to correct the slight ectropion of lower eyelid

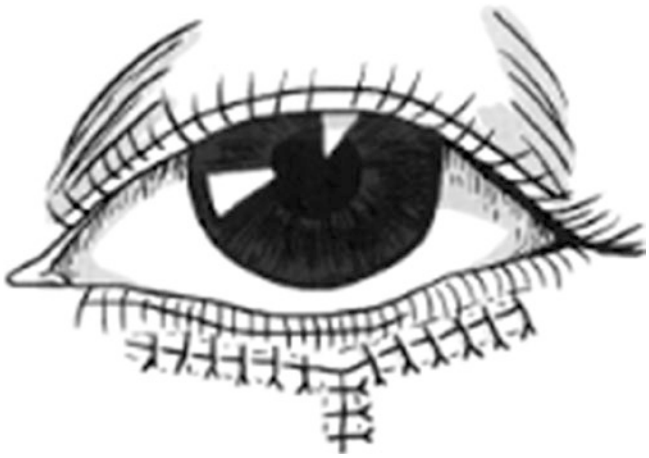

Fig. 3.7 The use of V-Y skin flap to correct the slight ectropion of lower eyelid

1.3 Classification of the Skin Flaps

1.3.1 The Skin Flaps Are Classified According to the Distance Between the Donor Site and the Receptor Site and the Transfer Modes

1. Local skin flap: The local skin flap is the skin flap formed in the adjacent area of the receptor site, which can be further divided into two types such as advancement skin flap and pivot skin flap according to the transfer modes. The advancement skin flap can be pushed forward directly into the receptor site and does not need any rotating or lateral movement. It includes single-pedicle advancement skin flap and double-pedicle advancement skin flap. V-Y skin flap (Fig. 3.6) and Y-V skin flap (Fig. 3.7) also belong to the advancement skin flaps. The pivot skin flap refers to the skin flap which rotates around the pivot point in the skin flap base, and its rotating arc radius is the line of maximum tension of the skin flap. All the rotation skin flap (Figs. 3.8 and 3.9), translocation skin flap, and insertion skin flap belong to the pivot skin flaps. The standard rotation skin flap is generally semicircular. The translocation skin flap is generally rectangular, and the rhomboid skin flap, bilobed skin flap, and the skip flap formed after Z-plasty also belong to the translocation skin flaps. The rotation skin flap is not as closely proximate to the defect area as the translocation skin flap and the insertion skin flap. There are normal tissues between the rotation skin flap and the defect area, and the rotation skin flap must cross over the top of the adjacent tissue or pass through underneath the adjacent tissue to reach into the defect area during the transfer.

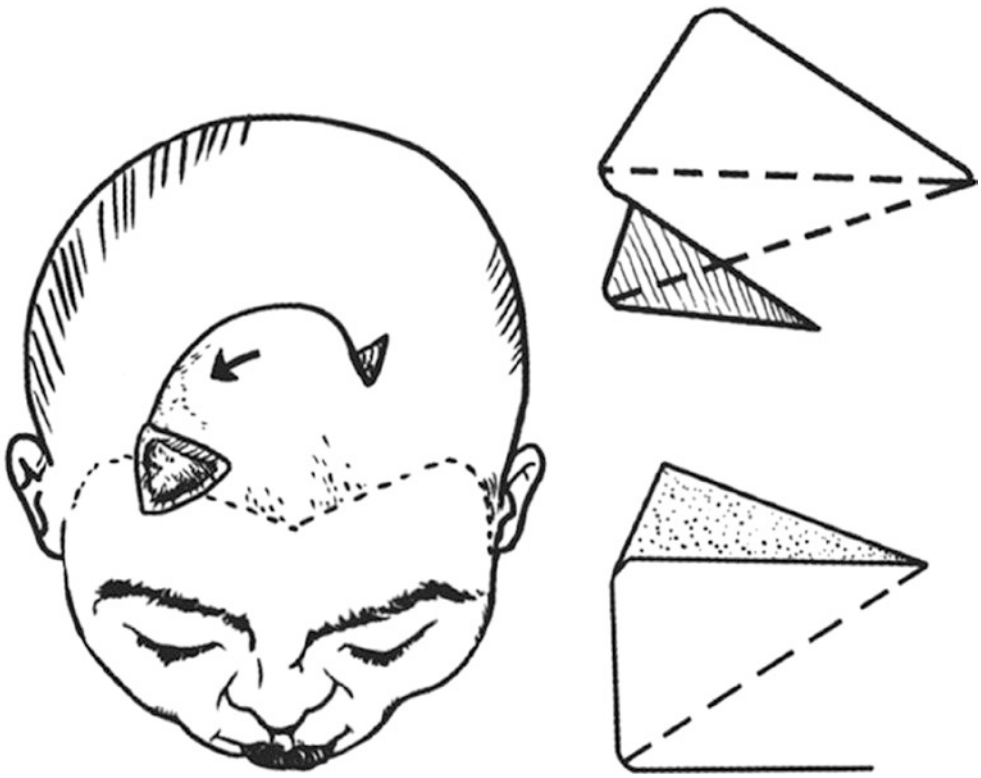

Fig. 3.8 The design of the rotation skin flap (1)

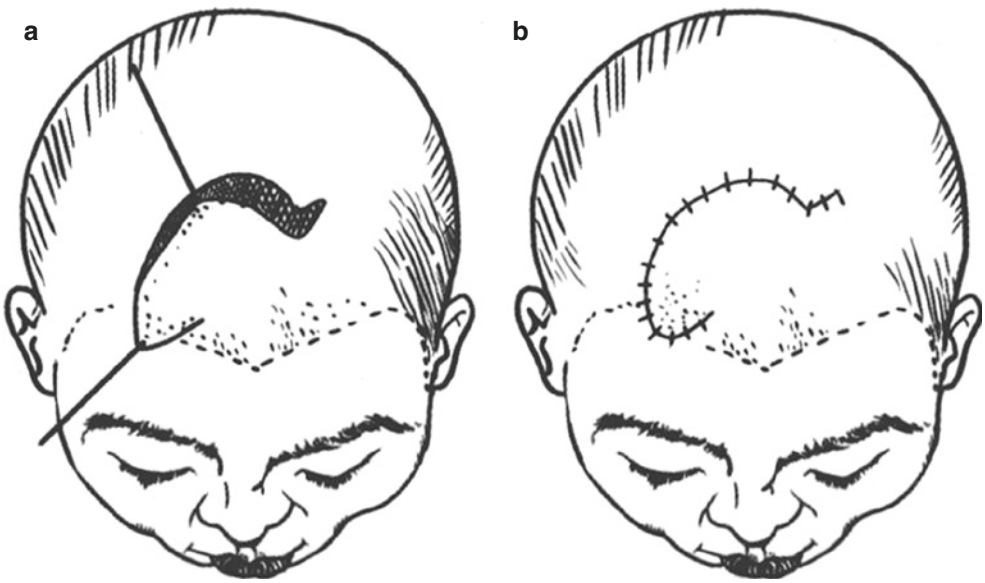

Fig. 3.9 The design of the rotation skin flap (2)

2. Distal skin flap: The skin flap formed in the distant site away from the receptor site is called the distal skin flap. Such skin flaps can be transferred into the receptor sites using direct and indirect methods or with vascular anastomosis. The skin flap which is directly transferred is called the direct distal skin flap, such as the cross-leg skin flap and the abdominal pedicled skin flap which is transplanted to the back of the hand; the skin flap which is indirectly transferred is called the indirect distal skin flap, such as abdominal pedicled tubular skin flap which is transferred into the face and neck wounds using the wrist carrying method; the skin flap which is transferred by means of vascular anastomosis is called the free skin flap, such as the dorsalis pedis skin flap which is transplanted to the back of the hand; in addition to that, the distal skin flap is transferred by means of vascular anastomosis; in general, it is needed to carry out operations for more than two times to complete the entire transplantation process of the distal skin flap.

1.3.2 The Skin Flaps Are Classified According to the Blood Supply Types

The skin flaps can be divided into two types such as the skin flaps supplied with blood by the myocutaneous artery and the skin flaps supplied with blood by the direct cutaneous artery according to the blood supply types. The skin flaps with the myocutaneous artery can be further divided into two types such as random skin pattern flap and myocutaneous flap; the skin flaps with the direct cutaneous artery refer primarily to the axial pattern skin flap. The myocutaneous flaps and the axial pattern skin flaps can only be formed in some specific areas.

1.3.3 The Skin Flaps Are Classified According to the Composition

The skin flaps can be divided into simple skip flap and compound skin flap according to the composition. The compound skin flap includes fasciocutaneous flap, myocutaneous flap, osteocutaneous flap, and neurosensory skin flap. The simple skip flap only contains skin and subcutaneous tissue, and it will be called the fasciocutaneous flap if the deep fascia is also included. The myocutaneous flap is the skin flap including muscles; if the skip flap contains bone tissues, it will be called the osteocutaneous flap. The neurosensory skin flap refers to the skin flap including cutaneous sensory nerves.

1.3.4 The Skin Flaps Are Classified According to the Anatomical Features and Clinical Application Methods of the Blood Supply of the Skin Flap

1. Axial pattern skin flap: It has been described in detail in Sect. 3.4 of this chapter, and thus it will not be repeatedly described here.
2. Prefabricated axial pattern skin flap: The donor sites of the human axial pattern skin flaps are limited after all. The skins in some areas have good textures and hidden locations, but don't have an ideal axial blood vessel. The prefabricated skin flap refers to that an axial blood vessel is artificially implanted into the area under a non-axial pattern skin flap, and then after a period of time, when the implanted axial blood vessel is linked up with the skin blood supply, it can be used as axial pattern skin flap. Shen Zuyao et al. transplanted the greater omentum into an area under the abdominal skin and used the right gastroepiploic blood vessel as the pedicle to make the omental axial pattern skin flap. The temporal vascularized skin flap designed by Chen Baoju et al. is that at the superficial surface of the superficial temporal blood vessels, the scalp is cut open and lifted up, and then it is folded and sutured, and the skin transplantation is performed within the distribution area of the superficial temporal blood vessels; after the transplanted skin graft survives, it will be harvested together with the superficial temporal blood vessels for free transplantation, and the folded scalp will be separated again and sutured back into the previous place The research and application of such prefabricated axial pattern skin flap open up a new source for free skin flap transplantation.
3. Combined skin flap: When it is required to repair some soft tissue defects in an extra-large range or repair two skin flaps with different functions (or other tissue flaps) in the defect area at the same time, this is not a problem which can be solved only by a single skin flap or myocutaneous flap. The combined skin flap is that two free skin flaps with independent vascular pedicles are connected to form an assembly with a common vascular pedicle using the method of vascular anastomosis method, in order to repair some extensive and complex wounds. For example, the latissimus dorsi myocutaneous flap is connected with a finger (toe) nail skin flap to repair the large-area skin defect in the thumb, palm, and volar forearm; or the latissimus dorsi myocutaneous flap is connected with the fibula to repair the calf skin defect combined with a large tibial defect. If the latissimus dorsi myocutaneous flap is used to be connected with other skin flaps, the vascular pedicle of the latissimus dorsi myocutaneous flap can be separated from the thoracic dorsal blood vessel to the subscapular blood vessel, whose branch circumflex scapular blood vessel is anatomized with the vascular pedicles of other skin flap. If the forearm skin flap is used to be connected with other skin flaps, the distal end of the main blood vessel is anastomosed with the vascular pedicle of another skin flap using the characteristics of the radial blood vessels running through the entire length of the skin flap. The former is called the bridge flap, while the latter is called the terminal flap, and this combination is also known as the two tandem skin flaps. Due to the composite application of the skin flap and myocutaneous flap, the repair of severe trauma has reached a new technological level [9–11].
4. Venous skin flap: The venous skin flap is a new type of skin flap with nonphysiological blood circulation. In recent years, the scholars at home and abroad consider that the blood flow can also make the skin flap survive only through the venous approach after conducting the experimental studies and clinical applications of venous skin flaps, of which, there are venous skin flaps nourished by the venous blood, and there are also venous skin flaps nourished by arterial blood. The emergence of the venous skin flaps has changed the traditional concept that the conventional free skin flap must have a complete set of arterial and venous systems. The advantages of the venous skin flaps include (1) which can avoid sacrifice of an artery in donor site and receptor site; (2) the subcutaneous superficial vein has a thick diameter and a constant location, which is visible to the naked eye and is easy

to dissect and anastomose; and (3) many subcutaneous vein networks make the donor sites of the skin flaps more extensive. Although the venous skin flaps have the above advantages, the hemodynamic change and survival mechanism of the skin flap are not yet very clear, and there is also no lack of failure examples in various reports. Therefore, the venous skin flaps are still in the stages of experimental studies and clinical trials, and many problems remain to be further explored.

1.4 The Selection of the Skin Flaps

The skin flaps are available in each part of the body. A defect site can be repaired selectively using a variety of skin flaps. Whether the selection of the skin flap is correct determines the success of the surgical repair; therefore, it should be considered based on the situations in donor site and receptor site, the degree of operation difficulty, the patient's tolerance, and the surgeon's familiarity degree for skin flap harvesting. The selection of the skin flaps and the surgical design should follow the principles from simple to complex, safe, reliable, and effective.

1.4.1 The Ortho-position Skin Flap Is Preferably Selected to Repair the Receptor Site

Since the color, texture, and thickness of the adjacent skin are close to those of the receptor site, and the transfer is convenient, the ortho-position skin flap should be preferred firstly. For example, the scapular skin flap and lateral thoracic skin flap are selected for repair of axillary skin tissue defects, and the neck platys myocutaneous flap is selected for repair of defects in maxillo-cervical area.

1.4.2 The Myocutaneous Flap Is Selected to Repair the Receptor Site with Deeper Tissue Defects or Severe Infection

The myocutaneous flap has a large volume of tissue and a rich blood supply, and it can fill the defects and has strong resistance to infection. For example, the latissimus dorsi myocutaneous flaps are selected for repairs of the wounds of serious electrical burns or chronic ulcers.

1.4.3 The Skin Flap Is Selected According to Functional Needs of the Receptor Sites

1. The medial plantar island skin flap is preferred for repair of heel defects, and the heel will have both feeling and rub resistance after the repair.
2. The burn injury in the upper arm can cause biceps or triceps necrosis. It is not only needed to repair the skin defects, but also is needed to reconstruct the functions of elbow flexion and extension of the biceps or triceps. The latissimus dorsi myocutaneous flap with nerves is used, and the latissimus dorsi muscle is used to replace the biceps or triceps to restore the functions of elbow flexion and extension.
3. When the Achilles tendon is burnt and necrotized, it will be repaired by free transplantation of the tensor fasciae latae myocutaneous flap, and part of the fascia lata femori is formed into a roll to reconstruct the Achilles tendon, which can achieve a good effect.
4. When there is a concurrent bone defect and malformation, the osteocutaneous flap is used to reconstruct the bone defects.
5. The dorsalis pedis skin flap with extensor digitorum longus is used to repair the tendon defects in the wrist area.

1.4.4 The Skin Flap Is Selected According to Blood Supply Sources

The skin flaps supplied with blood mainly by a branch artery are selected. It is avoided as far as possible to sacrifice the main blood vessels of the limbs.

1.5 Transplantation Methods of Skin Flaps

The harvesting of axial pattern skin flap is not restricted by the length-to-width ratio; as long as it is designed within the supply scope of the axial pattern blood vessel, the skin flap will not be necrotized. Its clinical use is more flexible than that of the random pattern skin flap, and two methods such as local transfer and free transplantation can be formed. During the local transfer, the pedicle can carry some skins (peninsula shaped); the blood vessel can also be completely dissociated, and an island-shaped skin flap is formed, the rotating radian is big, and it is easy to be transferred; the free transplantation requires vascular anastomosis; thus, the operation is slightly complicated.

1.5.1 Pedicled Transfer

The pedicled transfer is divided into two modes such as adjacent transfer and distal transfer according to the defect sites. For example, the defects in the wrist area are often repaired with the distal iliolumbar skin flap with pedicled superficial iliac circumflex blood vessel; the iliolumbar skin flap can be formed into various shapes according to the need of hand defects, and the operation method is simple, which is convenient to be used in the grassroots units. The disadvantage is that it requires reoperation at 3 weeks after operation to cut off the pedicle. The adjacent transfer of the island-shaped skin flap is more flexible, for example, the island-shaped latissimus dorsi myocutaneous flaps with pedicled thoracic dorsal arteriovenous vessels can repair the defects in occipitalia, the top of the head, face, neck, chest, and upper limbs to the wrist area. In order to increase the length of the trip of

the skin flap, when the defects in the head and neck are repaired, the skin flap penetrates out from underneath the pectoralis major muscle, which can increase the length of 5–6 cm.

There are more than 70 skin flaps and myocutaneous flaps in various parts of the body; in general, the skip flap is harvested at the nearest site, which is simple and operable. In terms of repair and reconstruction, as long as the surgeons are familiar with the commonly used skin flaps (Table 3.1) and can flexibly use them, the needs can be basically met. For multiple regional injuries in upper limb, when it is difficulty to repair them with a skin flap, the multiple skin flaps and combined skin flap can be used to repair them, for example, the latissimus dorsi myocutaneous flap combined with the lateral thoracic skin flap is used to repair the defects in wrist and palm of the forearm, and the latissimus dorsi myocutaneous flap combined with the iliolumbar skin flap is used to repair the circumferential soft tissue defects in elbows and forearms. The extensive and circular wound from elbow to wrist can be repaired with the huge thoracoabdominal skin flaps. The paraumbilical blood vessels and the lateral cutaneous branches of intercostal blood vessels are taken as the axes; when the thoracoabdominal skin flap is harvested, the lower boundary of the skin flap is located underneath the iliac crest in the groin to the lateral border of sacral rectus in the waist and along the axillary line to the tenth intercostal space; the medial side of the skin is located at the midline of the rectus abdominis muscle up to the umbilical region. Attention is paid to protect the cutaneous branch of the paraumbilical blood vessel, the skin flap is separated and lifted, the forearm is placed at the thoracoabdominal area, and then the wounds in the forearm and wrist are wrapped with the skin flap. A part of the wound in the inner side of the forearm is not wrapped with the skin flap, which clings to the surface of muscle membrane of the obliquus externus abdominis muscle, and it will be covered with an appropriate length of skin which is harvested at the pedicle site when the pedicle is cut off.

It is supposed to keep limb length to the greatest extent for the patients with amputation, and the defect wound in the stump should be covered with the skip flap. Especially for the upper limbs, retaining the elbow joint, shoulder joint, and a certain length of the radius, ulna, and humerus has an important significance for retaining the limb function and assembling the prosthesis. For the limb necrosis with deep burn wound in the armpit, sometimes it is necessary to

Table 3.1 Pedicled transfer and repair of commonly used skin flaps and myocutaneous flaps

Names of skin flaps	Main axial pattern blood vessels	Repair sites
Forehead skin flap	Superficial temporal artery	Face, cheekbone, mouth floor
Head skin flap	The parietal branch of the superficial temporal artery or the occipital artery	The top of the head
Neck platysma myocutaneous flap	Facial artery, superior thyroid artery, transverse cervical artery	Jaw, neck, chin
Trapezius myocutaneous flap	Transverse cervical artery	Neck, jaw
Deltopectoral skin flap	The perforating branch of internal thoracic artery	Face, jaw, neck
Pectoralis major myocutaneous flap	Thoracoacromial artery	Neck, jaw
Latissimus dorsi myocutaneous flap	Thoracodorsal artery	Occipitalia, the top of the head, face, neck, shoulder, prethoracic area, upper arm, forearm
Scapular flap	Circumflex scapular artery	Shoulder, armpit, upper arm
Lateral thoracic skin flap	Lateral thoracic artery	Armpit, chest wall
The iliolumbar skin flap	Superficial epigastric artery, superficial iliac circumflex artery	Perineum, penile reconstruction, hand (pedicled transfer)
Forearm skin flap	Radial artery	Hand (retrograde transfer)
The dorsal skin flap of index finger	The first dorsal metacarpal artery	Thumb, thumb web
The tensor fasciae latae myocutaneous flap	Lateral femoral circumflex artery	Lower abdominal wall, groin
Transverse rectus abdominis myocutaneous	Superior epigastric artery, inferior epigastric artery	Chest wall, groin, inner thigh
The medial crural skin flap	Posterior tibial artery	Knee, upper calves
Gastrocnemius myocutaneous flap	Sural artery	Knee, pretibial area
Dorsalis pedis skin flap	Dorsal pedal artery	Ankle area, heel, pretibial area
Medial plantar skin flap	The medial plantar artery	Heel, ankle area
Anterolateral femoral skin flap	Femoral anterolateral artery	Groin, perineum, knee (retrograde transfer), upper pretibial area
Saphenous artery flap	Saphenous artery	Groin, perineum, oberschenkel, pretibial area, knee

perform the shoulder joint disarticulation to repair the defect wound in the stump. In order to preserve shoulder joint and the length of the part of the humerus, the stump of the humerus is implanted subcutaneously in the lateral chest, and the axillary wound is directly sutured and closed after adduction of the shoulder joint. A month later, the lateral thoracic skin flap is separated and lifted to partially repair the stump, and the axillary scar release is carried to produce shoulder abduction, and the skin graft transplantation is performed for the wound fault.

1.5.2 Free Skin Flap Transplantation with Vascular Anastomosis

Some wounds which cannot be repaired with pedicled skin flap transfer can only be repaired with free skin flap. Since the free skin flap needs vascular anastomosis, the surgeons are required to have a certain operation techniques under microscope. The key to success is the quality of vascular anastomosis surgery and performing vascular anastomosis at the site of the originally damaged blood vessels. The high-voltage electrical burns are often accompanied by varying degrees of vascular injuries, and the location of the vascular anastomosis should be 3–5 cm away from the damaged site. The surgical microscope observation shows that the blood vessel endangium is smooth and slippery without exfoliation and obvious edema, and thus it is more reliable to perform vascular anastomosis here. For larger wounds or the receptor sites without blood vessels available for anastomosis, the following methods may be taken:

1. Tandem skin flap: The tandem skin flaps can only include the vascular network skin flaps with blood vessel branches of the arterial stems, such as the radial artery forearm skin flap, dorsalis pedis skin flap, and medial crural skin flap. The distal blood vessels are anastomosed with the blood vessels in another piece of skin flap, and two skin flaps are connected together to repair a larger wound.
2. Combined skin flap: The combined skin flaps have the same vascular pedicle, for example, the latissimus dorsi myocutaneous flap is combined with the scapular skin flap; thus, the dissection is performed from the subscapularis artery. Because the subscapularis artery from the axillary artery is divided into the circumflex scapular artery and the thoracodorsal artery to feed the scapular skin and the latissimus dorsi muscle, respectively, the skin in the entire shoulder and back area and the latissimus dorsi muscle can be resected.
3. The bridge-like cross-skin flap with vascular anastomosis: For transplantation of the bridge-like cross-skin flap with vascular anastomosis, if there are no blood vessels in the receptor site available for anastomosis, the blood vessels in the contralateral normal limb can be used for anastomosis. If there is a large soft tissue defect in the lower leg of one side, the axial pattern blood vessel of the skin flap can be anastomosed with the posterior tibial vessel or the pretibial blood vessel in the lower leg of the other side to form a bridge-like repair of contralateral limb defect.
4. Transplantation of carried free skin flap: In the past, the wrist-carried skin tube is often used to repair the distal wound, since the formation time of the tubular skin flap is longer. It is not suitable for immediate repair of the wound defect. Now it has been rarely used. However, in some special patient cases, if the local damage is more severe, which cannot be repaired by other methods, the wrist radial artery and cephalic vein can also be taken as the blood vessel for anastomosis in receptor site to carry free skin flap or myocutaneous flap to repair the wound defect in sites such as the groin, abdominal wall, or contralateral upper limbs.

After transplantation of the bridge-like cross-free skin flap and the wrist-carried tubular skin flap, it is needed to fix the limb for 3–4 weeks and then cut off the pedicle; meanwhile, the original blood vessels (posterior tibial artery and radial artery) are anastomosed again to ensure an adequate blood supply to the limb.

1.5.3 Transplantation of Superthin Skin Flap

The superthin skin flap is the subdermal vascular network skin flap. The excessive subcutaneous adipose tissue in the skip flap after dissociation is cut off; while the subdermal vascular network and the fat with the thickness of 2–3 mm are retained, and the pedicle area is lightly thicker, then the skip flap is extended and the subdermal vascular network can be observed. The advantages of this skin flap are that the appearance is not significantly bloated; the time for cutting off the pedicle can be advanced, as early as 10 days or so; and the pedicle can be cut off. But for the tendon-exposed wound with aponeurosis damage, after the transplantation of the superthin skin flap, the muscle tendon is adapted to be adhered to the subcutaneous tissue and, thus, affecting the functional activity; therefore, it is best to cover a layer of deep fascia on the muscle tendon without aponeurosis; thus, the muscle tendon has a certain sliding function in the movement. Only the skin flap with the deep fascia flap can achieve these results.

1.6 Monitor of Blood Circulation After Skin Flap

Good blood circulation is a basic condition for skin flap survival; therefore, monitoring the status of blood circulation flap will be of great importance in determining the time of

cutting off the pedicle for the pedicle skin flap, confirming whether the delayed skin flap is safe, judging the prognosis of skin flap, and early detecting the vascular crisis. There are a variety of testing methods for skin flap blood circulation, and they can be divided into two broad types such as objective and subjective tests.

1.6.1 Subjective Test

1. Color change: Compared with before transplantation, if the skin flap becomes obviously pale, it indicates the insufficient arterial blood supply; if the skin flap becomes purple, it indicates the venous reflux obstacle. Because there is a big difference in skin colors in different parts of the body, it is not very reliable to judge the blood circulation according to the changes in the color of the skin flaps.
2. Capillary refill test: The capillary refill test is one of the microcirculation detection methods commonly used in clinic. Gently press the skip flap with the fingers or the mouth of the test tube, so that the local skip flap is pale; if the blood capillaries are immediately filled after decompression, it indicates good blood circulation; if the blood capillaries are filled slowly, it indicates poor blood circulation. But if the test is applied in the patients with pale skin flap, it is often difficult to judge the situation of the capillary filling. Moreover, even if the skin flap is completely dissociated, sometimes the phenomenon that the skin flap becomes pale after compression and the blood capillaries are filled after decompression can also occur. Therefore, this test has its limitations.
3. Puncture bleeding test: Puncture the skin flap with 18-gauge hypodermic needle or the 11-gauge hypodermic needle to observe the bleeding status; if there is no bleeding, it indicates the poor arterial perfusion; if the bleeding is bright red, but it is more slowly, it indicates that there is some degree of arterial spasm; if the bleeding is active and bright red, it indicates normal arterial perfusion or some degree of congestion; if the bleeding is dark purple, it indicates venous reflux obstacle.

1.6.2 Objective Test

1. Measurement of percutaneous partial pressure of oxygen: The partial pressure value of oxygen in the skin is closely related to its blood supply; if there is a good blood supply, the oxygen partial pressure is high; otherwise the oxygen partial pressure is low. Therefore, the use of transcutaneous partial pressure meter of oxygen to monitor the oxygen partial pressure change in the skin flap is conducive to determining the condition of the blood circulation. The method has the advantages of noninvasiveness and allowing continuous observation, but its application is limited by the high price.
2. Tissue pH measurement: When the tissue hypoxia exists, the anaerobic metabolism is strengthened, and the local lactic acid is accumulated, leading to decreased pH value. Therefore, monitoring the pH changes within the skin flap can judge indirectly its blood supply and prognosis. When the pH within the pedicled skin flap is decreased down to 0.35, the skin flap necrosis will occur.
3. The ultrasound and laser Doppler flowmeter examination: The former can be used to determine the blood flow condition of the axis blood vessel within the axial pattern skin flap, and the latter can be used to detect the microcirculation status of 1 mm^3 tissue within the depth of 1.5 mm under the skin surface. Both are noninvasive detection technologies for continuous observation, but the instruments are expensive, and it is required that the examinators have certain experiences.
4. Temperature measurement: At the same external conditions, the temperature of the skin depends primarily on its blood supply; therefore, measuring the temperature of the skin flap can indirectly judge its blood circulation state. The commonly used instruments include infrared temperature instrument and thermocouple thermometer. The temperature measurement types mainly include surface temperature measurement and temperature difference measurement. It is reported that if the surface temperature in the central part of the free skin flap is 3 °C lower than that in the nonsurgical skin, it indicates the formation of the arterial thrombosis; if it is decreased by 1 ~ 2 °C, it indicates the formation of venous thrombosis. It is also reported that if the absolute temperature is below 30 °C after skin flap transplantation, it indicates the occurrence of vascular crisis. Some experimental studies have shown that if the surface temperature of the pig skin flaps is 2.4 °C lower than that of normal skin, it indicates the vein occlusion; if it is decreased by 2.6 °C, it suggests the artery occlusion. The temperature difference measurement is mainly used to determine the patency of anastomosed blood vessels within the transplanted free tissues. The specific detection method is to sew the thermocouple electrodes into both sides of the arterial anastomosis site and record the temperature difference. If the temperature difference is more than 32 °C, it suggests the occurrence of vascular crisis.
5. Other monitoring methods: The optical plethysmograph can be used to measure the tissue blood flow of the skin within the depth of 1–1.5 mm and help determine that the blood supply disorder of the skin flap is arterial disorder or venous disorder. The basic principle of the clearance test is to inject a substance into the skin, and then observe its clearance rates occurring over time, thereby to determine the blood circulation status in the skin flap. There are also methods such as sodium fluorescein staining

in vivo, electromagnetic blood flow measurement, microvascular imaging, radioactive microsphere measurement, and in vivo microscopic examination.

2 Random Pattern Skin Flap

2.1 The Blood Supply of the Random Pattern Skin Flap

The arterial blood supplies of the random pattern skin flaps include three sources:

1. Direct cutaneous artery: The artery originates directly from the arterial trunk, passes through intermuscular space and fascia and reaches the subcutaneous adipose layer, and then is incorporated into the subdermal vascular network. This kind of artery only supplies blood to the skin tissue, which is called direct cutaneous artery.
2. Myocutaneous artery: The myocutaneous artery originates from the arterial trunk; enters into the muscle; gives off branches within the muscle, of which, some branches give off branches progressively; passes through the perimysium and enter into the endomysium to form microcirculation; and provides blood supply to muscles. Other branches are the branches of the intramuscular perforator. They go out of the muscles, pass though the deep fascia, and reach to the subcutaneous adipose tissue layer. The calibers of the myocutaneous perforators are relatively small. They repeatedly give off branches in the subcutaneous adipose tissue layers and anastomose with other arterial branches to constitute subdermal vascular network and dermal vascular network.
3. Mixed artery: The mixed artery refers to that after being given off from the deep arterial trunk, the artery is divided into the muscular branch and the cutaneous branch immediately to feed the muscle and skin tissues, respectively, and the two are not interlaced with each other. The skin flap is provided with blood by the pedicle to maintain its metabolism in the transfer process. If its blood supply comes from the direct cutaneous branch or the cutaneous branch of the mixed artery, this kind of skin flap is called axial pattern skin flap. If its blood supply comes from the musculocutaneous perforator of myocutaneous artery, this kind of skin flap is called the random pattern skin flap. Because the caliber of the myocutaneous perforator which feeds the random pattern skin flap is smaller, it cannot be used for bonding anastomosis, and thus the pedicle of the skin flap is required to keep connected with the donor site, so that the blood circulation of the skin flap is uninterruptedly operated. This transfer is called pedicled transplantation, and such skin flap is called the pedicled skin flap.

2.2 The Indications for Random Pattern Skin Flap Transplantation

The random pattern skin flap contains the adipose tissues, and the pedicle supplies blood to the skin flap tissue to maintain its blood circulation and metabolism, and the random pattern skin flap has functions such as repairing the skin tissue defects, resisting the infection, improving the blood supply of the receptor site, and preventing the adhesions and filling sunken defect. After healing, the skin color and texture will not be changed, and no shrinkage will occur at late stage, which is the most widely used means for tissue repair. It is mainly applied to:

1. Repair of perforating defects
2. Organ reconstruction, such as reconstructions of the ear, nose, fingers, and external genitals
3. Repair of deep wounds with exposed important tissues, such as repairs of wounds with exposed bones, joints, cartilages, muscles, and important blood vessels
4. Repair of wound in the place where there exists friction and extrusion, such as repairs of the heel ulcers and bedsores
5. Repairs of wounds with poor blood supply, such as repairs of radiation ulcers and osteomyelitis-induced chronic ulcers

2.3 Classification of Random Pattern Skin Flaps

2.3.1 Classification According to the Sites Where the Skin Flaps Are Formed

The random pattern skin flaps can be divided into head skin flap, skin flap, chest skin flap, back skin flap, abdominal skin flap, upper arm skin flap, and lower limb skin flap according to the sites where the skin flaps are formed.

2.3.2 Classification According to the Relationship Between the Skin Flap Donor Site and Receptor Site

According to the relationship between the donor site and receptor site of the skin flap, the random pattern skin flaps can be divided into:

1. Local skin flap
   (a) Neighboring skin flap: The donor site is adjacent to the receptor site, but both are separated by normal skin tissue.
   (b) Ortho-position skin flap: The donor site is connected to the receptor site.
2. Distal skin flap
   (a) Direct skin flap: The donor site and the receptor site are not at the same anatomic site, but the skin flap is

transferred directly from the donor site to the receptor site without passing through the intermediate station. For example, the abdominal skin flap is directly transferred to repair the skin tissue defect in the forearm. If one side limb is the donor site, and the skin flap after formation is directly transferred to repair the wound in the other side limb, this kind of skin flap is called cross-skin flap.

(b) Indirect skin flap: The skin flap is transferred to the intermediate station; after the blood circulation between the skin flap and the intermediate stations is established, the skin flap carried by the intermediate station is transferred to the receptor site. For example, in order to repair the skin tissue defect in the head with the abdominal skin flap, it is needed to suture one end of the skin flap with the forearm (intermediate station); after the blood supply which is sufficient to feed the skin flap is established, the abdominal skin flap carried by the forearm is transferred to receptor site in the head.

2.4 Classification According to the Shape of the Skin Flap

The random pattern skin flaps can be divided into rhomboid skin flap, triangular skin flap, tongue-shaped skin flap, bilobed skin flap, flat skin flap, and tubular skin flap (skin tube) according to their shapes.

2.5 Classification According to the Pedicle Situation

The random pattern skin flaps can be divided into single-pedicle skin flap, double-pedicle skin flap, and subcutaneous pedicle skin flap (the skin tissues around the skin flap are cut open, but the subcutaneous tissues are not exfoliated and are taken as the pedicle of skin flap).

2.6 Classification According to the Subcutaneous Tissue Layers Contained in the Skin Flaps

According to the subcutaneous tissue layers contained in the skin flaps, the random pattern skin flaps can be divided into:

1. Fasciocutaneous flap: The fasciocutaneous flap is the skin flap containing various layers of tissues from the skin to the deep fascia.
2. Subdermal vascular network skin flap (thin skin flap): The subdermal vascular network skin flap only contains the skin and subdermal vascular network, as well as the thin adipose tissue which is reserved for the protection of vascular network.
3. Traditional skin flap: The traditional skin flap refers to the skin flap containing various layers of tissues from the skin to the superficial surface of the deep fascia.

2.7 The Principles for the Design of Random Pattern Skin Flap

The nutritional metabolism of the random pattern skin flap is completed by the blood which passes through the pedicle to enter into the subdermal vascular network and dermal vascular network, and the blood supply of the pedicle comes from the myocutaneous perforator of the myocutaneous artery. These myocutaneous perforators have small calibers, low perfusion pressure, and limited supply scope, in order to ensure that the skin flap has no blood supply disorder in the transfer process and can survive successfully and get good curative effect. When the donor site is being selected and the skin flap is being designed, certain principles should be abided by.

2.7.1 Principles for Selection of Donor Sites

1. The donor site of the skin flap should be selected in the adjacent area of the receptor site. The skin color and texture are similar. The number of operations is less, and the operation is relatively simple.
2. It is not allowed to cause the dysfunctions and morphological abnormalities in the donor sites after harvesting of the skin flap. The functional sites of the joints and the exposed sites are generally not selected as the donor sites.
3. The local skin tissues are normal, and there are no acute and chronic inflammations or other skin lesions.

2.7.2 Principles for Skin Flap Design

1. Appropriate length-to-width ratio: During the transfer, the blood supply maintaining the nutritional metabolism of the random pattern skin flap is completely dependent on the subdermal vascular network from the pedicle, but the scope of perfusion is limited. If the formed skin flap exceeds the scope of perfusion, the skin flap will have ischemic necrosis. According to the clinical practice experience, the ratio of the length of the skin flap to the width of the pedicle should generally not be more than 1.5:1. The length-to-width ratio of the skin flap should better be 1:1 in the sites such as the lower extremities; but the length-to-width ratio of the skin flap can exceed the limit of 1.5:1 in the sites such as head and neck with rich blood supply; sometimes, when the length-to-width ratio of the skin flap is up to 3:1, no blood supply disorder has occurred. If the length-to-width ratio of the designed skin flap exceeds the limit of 1.5:1, it is appropriate to perform skin flap delay at first.

2. Comply with the directions of the blood vessels: The skin flap is designed along with the direction of the blood vessels as much as possible. The pedicle is located in proximal end of the blood vessel. The torso midline is generally located in the blood vessel-lacking area. When designing the skin flap, we should try to avoid exceeding the torso midline.
3. Adopt the reverse design method: A piece of paper is sheared into a figure of the skin flap according to the shape of the tissue defect wound, whose area is slightly larger than the actual defect area. The paper figure of the skin flap is placed in the donor site, and the pedicle of the paper figure of the skin flap is fixed. It is experimented that the skin flap is lifted and transferred to observe whether the pedicle position of the skin flap is appropriate and the direction of the formed skin flap is suitable. In the transfer process, it is required that the skin flap has no tension and the pedicle has no excessive distortion. After the transfer of the skin flap, if the tension is too large and the pedicle is excessively distorted, these are common causes of blood supply disorders occurred after transfer of random pattern skin flap. The adjustment is repeatedly carried out until the satisfaction is achieved, and then the methylrosanilinium chloride is used to mark the location.

   There are several things that we should pay attention to:

   (a) When a local rotation skin flap is designed, particular attention should be paid to that the distance between the rotation pivot point of the skin flap and the farthest point of the skin flap must be greater than or equal to the distance between the rotation pivot point of the skin flap and the farthest point of the defect wound; otherwise, the skin flap will not be able to successfully repair the wound after transfer.

   (b) When a distal direct skin flap is designed, it is needed to attach the paper figure of skin flap onto the receptor site, and then the receptor site-carried paper figure is matched with the donor site. It is experimentally detected where the best position of the pedicle in the donor site is, so that the skin flap can be transferred to repair the wound most successfully, and the patient will also feel more comfortable. After the pedicle is determined, and then the pedicle of the paper figure of the skin flap is fixed, the paper figure is spread out onto the donor site, and the specific location of the skin flap is marked.

   (c) When a distal indirect skin is designed, the pedicle of the paper figure of the skin flap should be fixed with intermediate station and is carried to the donor site and the receptor site. The steps for transfer of skin flap are repeatedly rehearsed, and the pedicle position of the skin flap and the direction to form a skin flap are selected.
4. The designed skin flap should be greater than the skin flap in the wound; the skin flaps after harvesting usually have a certain degree of contraction; therefore, it is designed that the area of skin flap in the donor site should be greater than the area of the wound in the receptor site by 10–15%, in order to prevent occurrence of the tension after transfer and suture which will affect the blood supply.

2.8 Local Skin Flap Transplantation

The skin flap formed by the skin tissue around the receptor site is called the local skin flap, which has advantages that the skin color and texture are in consistency with those of the receptor site; the transfer operation of the skin flap is simple and convenient, and the transfer and repair can be completed in one operation, and it is the most commonly used skin flap transplantation.

2.8.1 Advancement Skin Flap

The advancement skin flap is the skin flap formed in the adjacent site of the defect wound; after the skin flap is stripped off, it is advanced into the defect area through sliding to repair the wound, and it is also known as the sliding skin flap (Figs. 3.10 and 3.11).

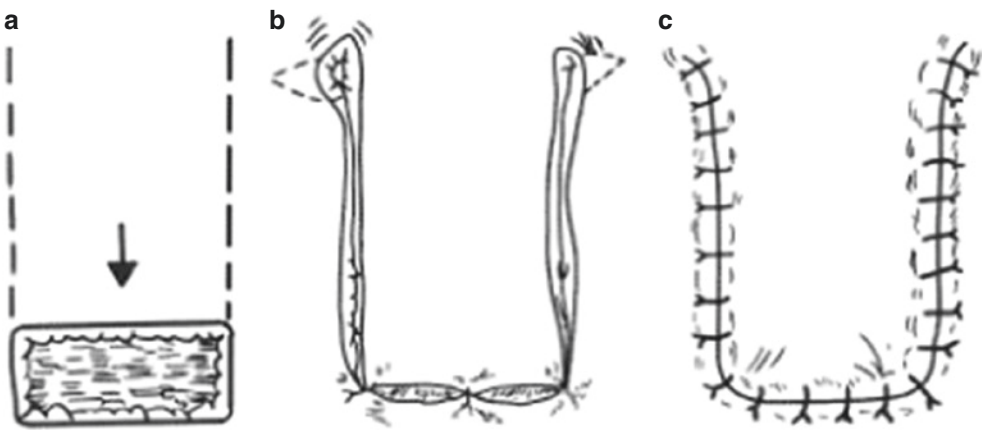

Fig. 3.10 Sliding skin flap. (**a**) Design of sliding advancement skin flap. (**b**) The sliding skin flap is advanced to repair the wound. (**c**) Suture

1. Design: At one side or both sides of the defect wound, according to the need of repair, the skin flaps can be designed as tonguelike, rectangular, and triangular and can be designed as single or double skin flaps. When a double-pedicle skin flap is designed, the length-to-width ratio of the skin flap can be doubly increased (3:1). The methylrosanilinium chloride is used to mark out the incision line.
2. Transfer: The skin and subcutaneous tissue are incised open along the designed incision line. The skin flap is dissociated from the distal end of the skin flap (at the superficial surface of the deep fascia) to the pedicle, and it is advanced through gliding after adequate dissociation and is transplanted to cover the wound in the receptor site. In general, no secondary wound will appear in the donor site of single-pedicle skin flap, but the skin wrinkles will often be formed at both sides of the pedicle. The smaller wrinkles will disappear themselves in the future; otherwise, a piece of triangular skin tissue is removed in the place where skin wrinkles exist, so as to flatten the skin wrinkles and heal the wound; if it is estimated that the removal of this triangular skin tissue may affect the blood supply of the skin blood supply, this triangular skin tissue should be retained to be removed in the two-stage operation. The donor site where the double-pedicle skin flap is formed often cannot be sutured without tension; otherwise, the secondary skin defect wound will appear, which needs to be repaired through harvesting the split-thickness skin.

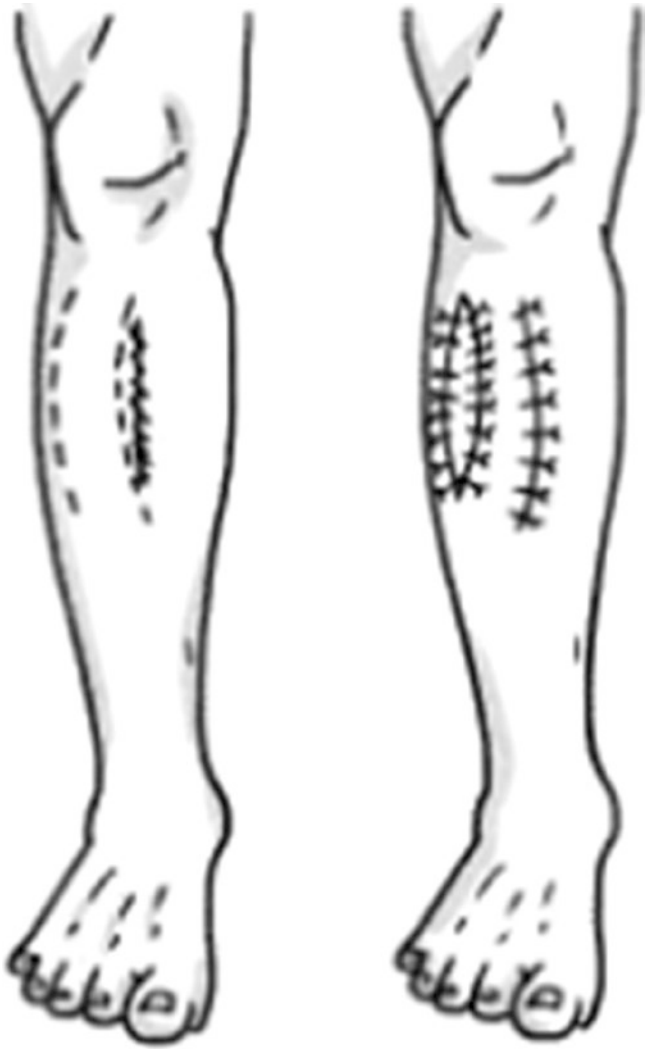

Fig. 3.11 Double-pedicle gliding skin flap

2.8.2 Rotation Skin Flap

The rotation skin flap is the skin flap formed in the adjacent site of the defect wound, and it is used to repair the defect through rotational transplantation. This kind of skin flap is flexible and changeable compared with the advancement skin flap and is widely used.

1. Design
   (a) Tongue-shaped skin flap: The skin flaps are generally designed to be tongue-shaped. According to the shapes and sizes of the skin defect wounds, following the principles of skin flap design, the skin flaps are designed at one or both sides of the defect wounds, and the methylrosanilinium chloride is used to mark them (Fig. 3.12). When the skin flap is designed, attention should be paid to that the distance between the rotation pivot point of the skin flap and the farthest point of the skin flap must be greater than or equal to the distance between the rotation pivot point of the skin flap and the farthest point of the defect wound margin; otherwise, the skin flap will not be able to cover the entire defect wound, even if the entire defect wound is covered with an effort. The blood supply will be affected due to excessive tension, when the donor site of the rotation skin flap is

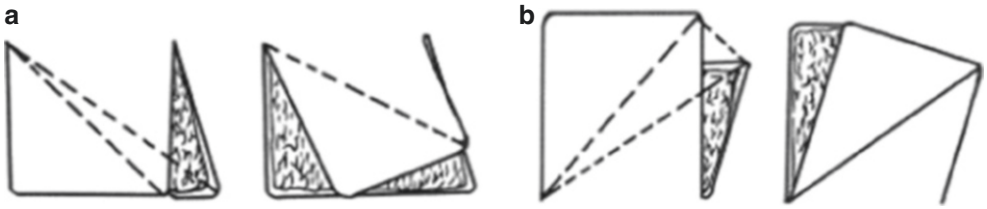

Fig. 3.12 Design of rotation skin flap. (**a**) The design of rotation skin flap is incorrect, resulting in tension. (**b**) The design of rotation skin flap is correct

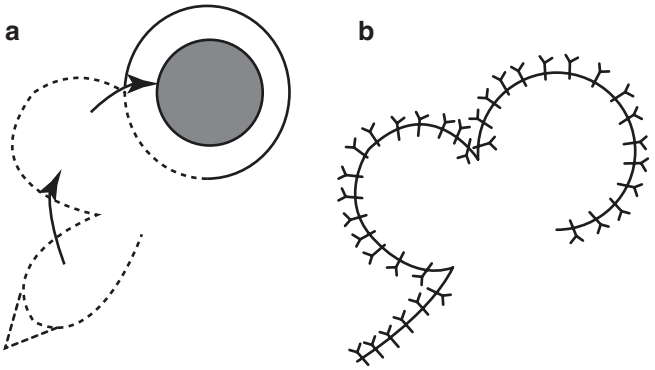

Fig. 3.13 Bilobed skin flap

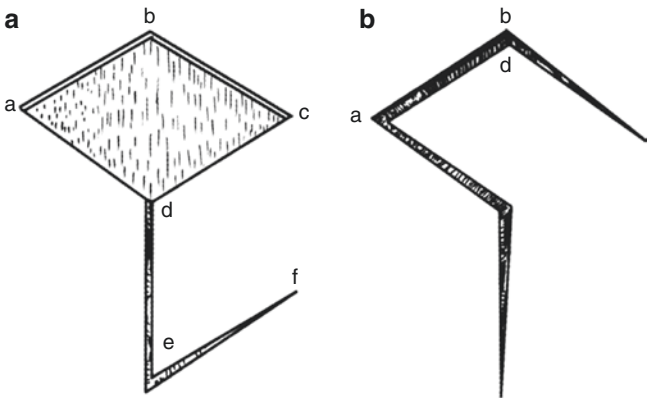

Fig. 3.14 Design of rhomboid skin flap

located in the functional site or exposed site and because the wound is larger and cannot be directly sutured. If the wound is repaired with skin graft, it may be possible to affect the function or morphology. Therefore, a smaller skin flap is redesigned in the adjacent area of the wound, which is rotated to repair the wound in the donor site of the first skin flap. In general, the wound in the donor site of the smaller skin flap can be directly sutured. When the pedicles of the two skin flaps are located in the adjacent areas, they can be connected into a pedicle. This kind of skin flap is called the bilobed skin flap (Fig. 3.13).

(b) Rhomboid skin flap: If the defect wound in receptor site is rhomboid-shaped, the skin flap can be designed as the rhomboid-shaped skin flap for transfer repair or designed as the polygonal (similar to rhomboid-shaped) skin flap for repair. This skin flap is most appropriately designed in the cervical area, and it has certain advantages for transfer repair of the rectangular defects in the lower face. The design of rhomboid skin flap is shown in Fig. 3.14, wherein abcd are rhomboid-shaped defects. The extension line of bd is made as de, ensuring that de = ab; then the parallel line ef starting from the e is made parallel to dc, and de and ab are sutured with each other after transfer.

2. Harvesting and transfer

(a) Tongue-shaped skin flap: The skin and subcutaneous tissue are incised open along the designed incision line. The dissociation is performed at the superficial surface of the deep fascia from the distal end of the skin flap to the pedicle, and the skin flap is completely lifted, and then the skin flap is rotated and transferred to repair the wound. In order to avoid excessive distortion after the transfer, a small piece of triangular skin tissue on the outside of the pedicle can be removed.

(b) Bilobed skin flap: After the first skin flap is harvested and transferred, the skin flap is incised, harvested, and transferred, and then the donor site of the second skin flap is repaired, and the donor site of the second skin flap is directly sutured.

(c) Rhomboid skin flap: Incise the skin along the design line, deep up to the superficial surface of the deep fascia; dissociate along the superficial surface of the deep fascia. It is noted that the dissociation scope should be larger, and thus the skin flap after transfer can be sutured without tension.

2.8.3 Subcutaneous Pedicle Skin Flap

Subcutaneous pedicle skin flap is an advancement skin flap, namely, the edge of the skin flap is completely incised open, then the subcutaneous tissue of the skin flap is taken as the pedicle, and using its looseness, the skin flap is slid and transferred to repair the defects, which is commonly used in the repair of skin tissue defects in fingertips (Fig. 3.15) and has advantages that the operation is simple and the incision heals smoothly. But the subcutaneous tissue pedicle of such skin flap has no well-known artery and is not similar to the island skin flap; thus, the advancement distance is limited.

1. Design: According to the need of repair in the donor site, the skin flaps can be designed as triangular, round, rectangular, or polygonal skin flaps. Since the advancement distance of the skin flap is limited, the skin flaps are often designed to be located in the adjacent areas of the defects. If the skin flap formed in the adjacent area on one side of the defect is not sufficient to repair the defect, multiple subcutaneous pedicle skin flaps can be formed simultaneously in the adjacent areas on two or three sides of the defect, and then they are glided and transferred to repair the defect.
2. Transfer: The skin and subcutaneous tissues are incised open along the marked incision line, directly down to the deep fascia, but they are not dissociated. The skin flap is

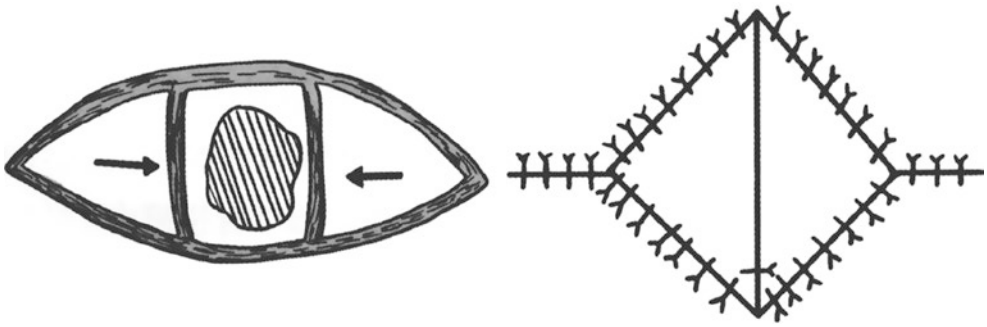

Fig. 3.15 Design and suture of bilateral advancement subcutaneous pedicle skin flap

slid and advanced into the defect area to cover the wound. The areas around the skin flap are sutured directly after a short separation; if it is difficult to perform a direct suture, the repair can be performed through transfer of the skin flap formed at its adjacent areas.

2.9 Distal Skin Flap Transplantation

When it is inappropriate or impossible to harvest the skin flap in adjacent areas of the defect, the skin flap far away from defect area is transferred into the donor site to repair the defect, which is called the distal skin flap transplantation. The skin flap is transferred directly from the donor site into the receptor site, which is known as distal skin flap transplantation; if the skin flap needs to be transited in the intermediate station and then is transferred into the receptor site, it is known as indirect distal skin flap transplantation. If the donor site is located in the limb of one side, and the formed skin flap is transferred to repair the tissue defects in the limb of the other side, it is called as the cross-skin flap transplantation. More than two operations are often required to complete the whole process of the distal skin flap transplantation.

2.9.1 Direct Distal Skin Flap

1. Design: The repair of the tissue defect in the forearm with the abdominal skin flap is taken as an example. A piece of paper is sheared into a figure of the skin flap with an area slightly larger than the defect wound according to the shape of the defect. The paper figure of the skin flap is fixed onto the defect area in the forearm, and then the paper figure carried by the forearm is transferred and placed into the abdomen (Fig. 3.16); the specific location is appropriate if the patient feels more comfortable, and it is estimated that the pedicle will not be unduly distorted in the process of skin flap transfer. Then the pedicle of the paper figure is fixed onto the abdomen; after that, the forearm is moved away, and the paper figure will be flattened; the abdominal skin flap is drawn up according to the paper figure.
2. Transfer: The skin tissues are incised open along the design line of the skin flap, which is lifted from the superficial surface of the deep fascia. The flap area is transplanted into the receptor site, and the wound margin of the skin flap is interruptedly sutured with the wound margin of the receptor site (Figs. 3.17, 3.18, and 3.19). The pedicle is still connected to the donor site to ensure that the skin flap can get the blood supply from the donor site, namely, before the flap area of the skin flap establishes sufficient blood circulation; the skin flap can maintain its nutritional metabolism based on the blood supply of the pedicle. The secondary wound in the donor site after harvesting of the skin flap is treated depending on the size of the skin flap; if the wound is smaller, it can be directly sutured; if the wound is larger and cannot be sutured, it will be repaired with the harvested split-thickness skin graft. A sufficient blood circulation can be established between the flap area and the donor site at 2–3 weeks after surgery; after the vascular occlusion test confirmed that the blood circulation can maintain the metabolism of the skin flap, the pedicle separation can be carried out. The pedicle is cut off; the skin flap and the incision in the donor site of the forearm are sutured,

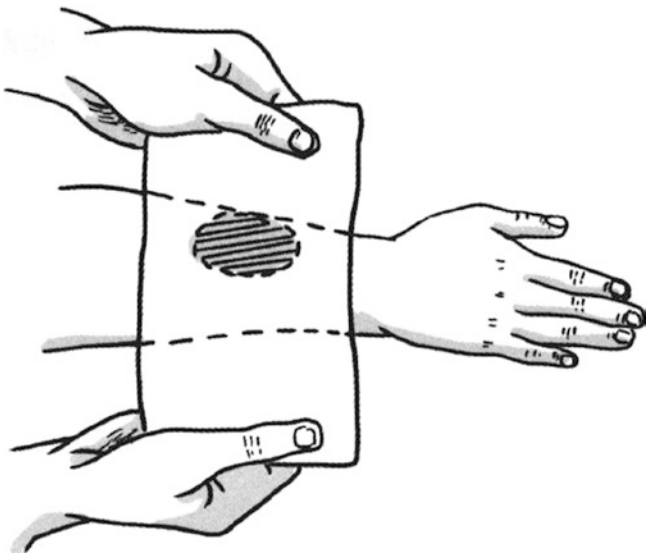

Fig. 3.16 Design of distal skin flap

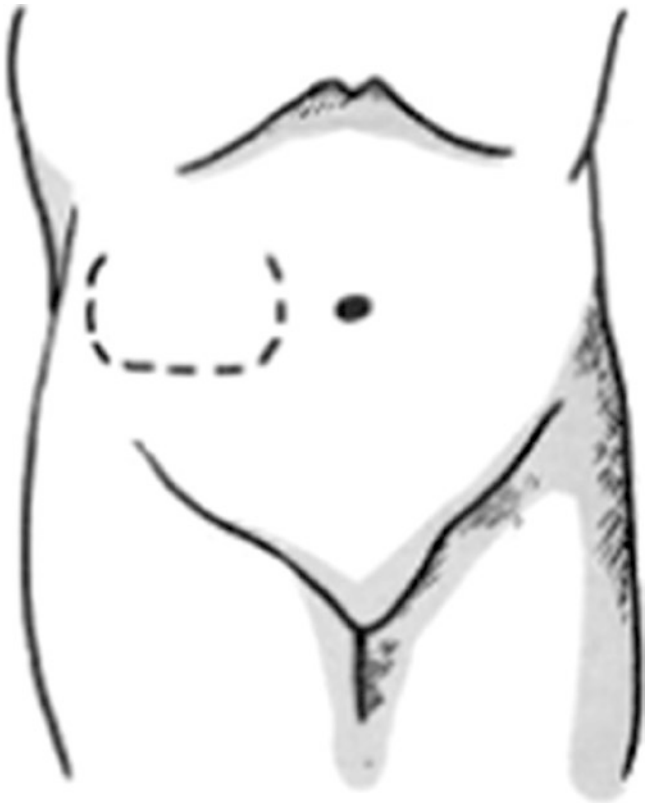

Fig. 3.17 Design of distal skin flap (1)

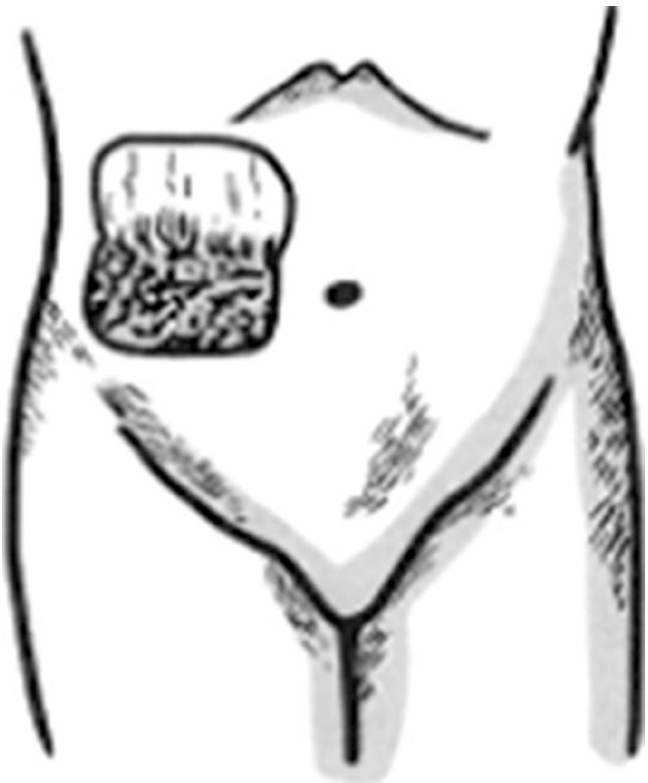

Fig. 3.18 Design of distal skin flap (2)

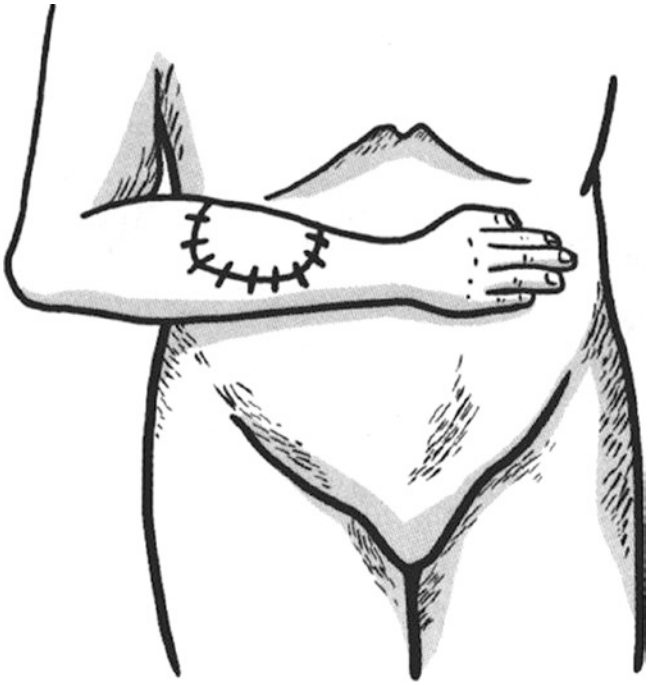

Fig. 3.19 Design of distal skin flap (3)

respectively; and the skin flap transfer operation is completed. At the moment, in general, the wound in the donor site is directly sutured.

2.9.2 Indirect Distal Skin Flap

The indirect distal skin flap refers to the distal skin flap needing transition in the intermediate station. After the skin flap is formed from the donor site, the pedicle of the skin flap is transplanted into the intermediate station, after the blood supply which can maintain the metabolism of the skin flap is established between the skin flap and the intermediate station, and then the skin flap carried by the intermediate station is transplanted to the receptor site. At about 3 weeks after surgery, the sufficient blood supply has been established between the skin flap and receptor site, and then the pedicle of the skin flap is cut off from the intermediate station. More than three operations at least are required to complete the whole process of the distal skin flap transplantation.

1. Design: The intermediate stations are usually designed and placed in the wrist or forearm. The skin flaps are designed according to the reverse design method, and the repair of tissue defects in the right temporal area with the abdominal skin flap is taken as an example. According to the size and shape of the temporal defect, a paper figure with an area slightly larger than the defect wound is sheared, and then the paper figure is used to cover the right temporal defect area. The left forearm (intermediate station) is transferred into the right temporal area, and the pedicle of the paper

figure of the flap is fixed in the forearm and is marked; the paper figure carried by the forearm is transferred to the abdomen; then the paper figure is fixed in the abdomen; after the paper figure is flattened, the methylrosanilinium chloride is used to mark it. The specific locations of the abdominal skin flap and its pedicle are appropriate if the patient feels more comfortable, and the pedicle will not be unduly distorted in the transfer process.

2. Implementing the harvesting and transfer surgery by stage.
   (a) The first-stage operation: According to the design, the pedicle of the skin flap is incised open and harvested. The broken end wound of the pedicle is used to print a blood marker in the marked area on the left forearm, and a skin flap which turns to the medial side is formed along the size of the blood marker. The forearm is transferred to the abdomen, and then the pedicle of the abdominal skin flap is sutured with the forearm wound and the reversed skin flap. When the suture is performed, it is noted that 1–2 needles of mattress sutures are performed at the centers of the pedicle and the forearm wound to prevent the formation of dead space. The forearm and abdomen are properly fixed after surgery.
   (b) The second-stage operation: At 2–3 weeks after the previous operation, the pedicle of the skin flap has been integrated with the intermediate station (left forearm) and healed; after the vascular occlusion test confirms that the blood supply from the pedicle can maintain the metabolism of the skin flap, the second-stage operation can be carried out. The abdominal skin flap is incised open and harvested, which is carried by the forearm (intermediate station) and transferred to the temporal defect area. The wound margins on the both sides of a segment of skin flap which is close to the pedicle are usually sutured with each other, so that there is no exposed wound in the pedicle, and the chance of postoperative secondary infection is reduced in the skin flap after operation. The forearm is fixed with the head after operation.
   (c) The third-stage operation: At 2–3 weeks after the second-stage operation, good blood circulation has been established between the skin flap and temporal area (donor site), which is confirmed by the vascular occlusion test, and then the third-stage operation can be carried out. The pedicle attached to the intermediate station is cut off, and then the temporal defect area is repaired. The forearm skin flap lifted in the first-stage operation is sutured back into the previous place after the removal of the scar tissue.

After the first- and the second-stage operations, it is very important that the limb taken as the intermediate station must be properly fixed with the abdomen and the donor site to prevent the skin flap avulsion (Figs. 3.20, 3.21, 3.22, 3.23, and 3.24).

Fig. 3.20 The formation of the forearm wound (intermediate station) and the fixed suture of the pedicle of skin flap (1)

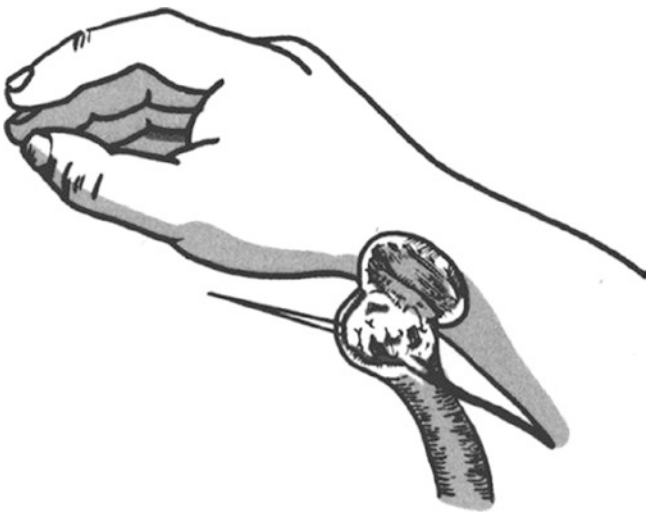

Fig. 3.21 The formation of the forearm wound (intermediate station) and the fixed suture of the pedicle of skin flap (2)

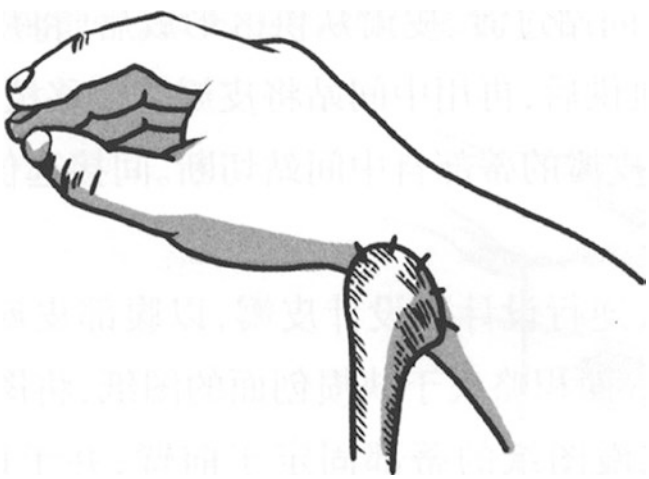

Fig. 3.22 The formation of the forearm wound (intermediate station) and the fixed suture of the pedicle of skin flap (3)

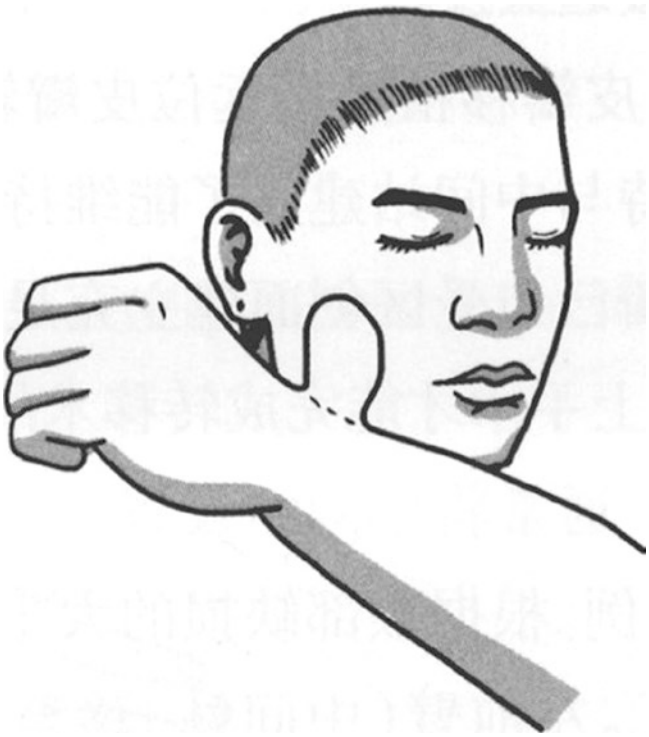

Fig. 3.23 The formation of the forearm wound (intermediate station) and the fixed suture of the pedicle of skin flap (4)

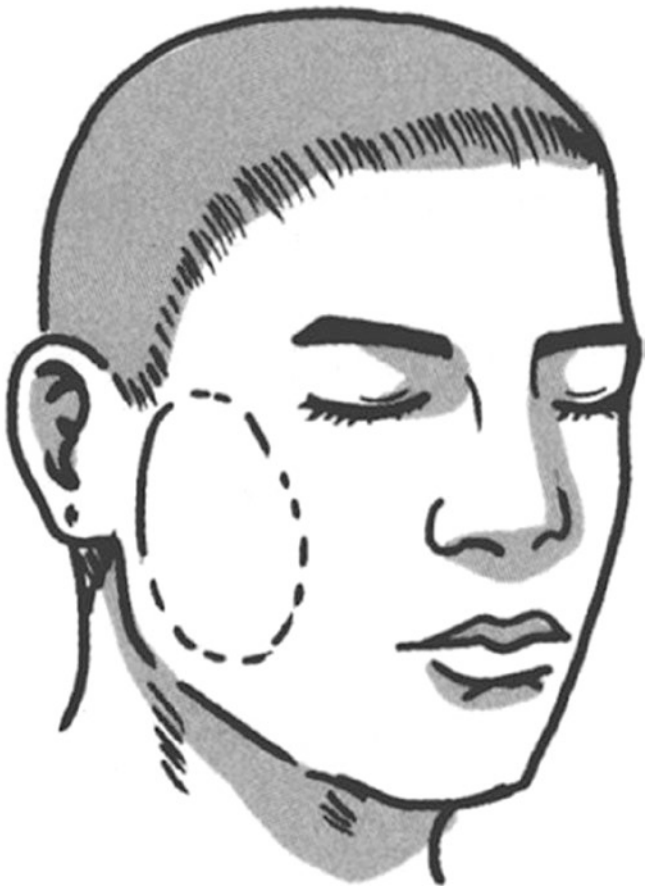

Fig. 3.24 The situation after repair of facial defect with forearm skin tube

3 Tubular Skin Flap

The wound margins on both sides of the skin flap are sutured with each other to form into a tubular skin flap in the process of the formation and transfer; hence, this kind of skin flap is named as the tubular skin flap (skin tube for short) (Fig. 3.25). Correspondingly, the skin flaps whose lateral sides are not sutured with each other, with a flat shape, are collectively called the flat skin flap. Compared with the flat skin flap, the skin tube has the main advantages that no wound is exposed in the transfer process, and the chances of infection are greatly reduced; and its disadvantages are that multiple operations are required to complete the whole transfer process. The scar formation is increased once along with that every operation is performed, and more skin tissues are lost in the process of completing the transfer.

3.1 Skin Tube Design

An elongated skin flap is designed in the donor site; because the skin flap has two pedicles, the length-to-width ratio is generally 2.5–3:1; if the donor site is located in the

Fig. 3.25 The sites where the skin tubes are prepared

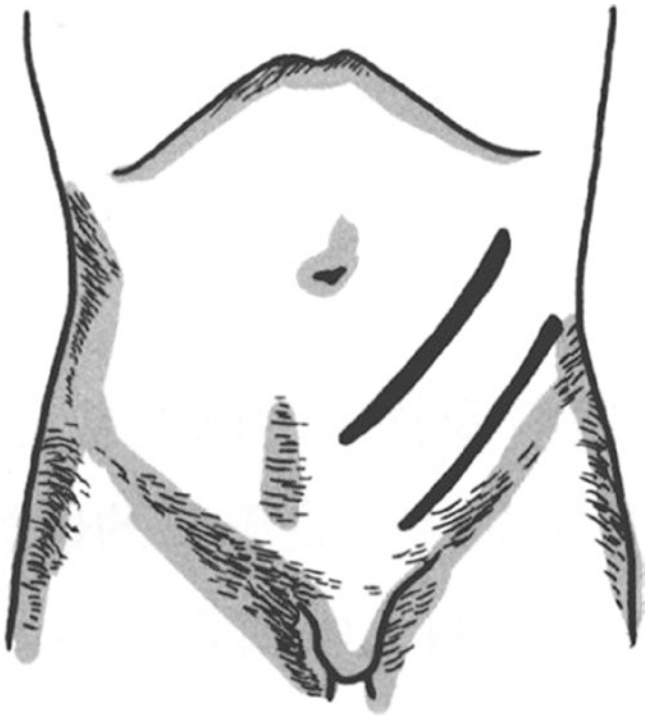

Fig. 3.26 Skin tube formation (1)

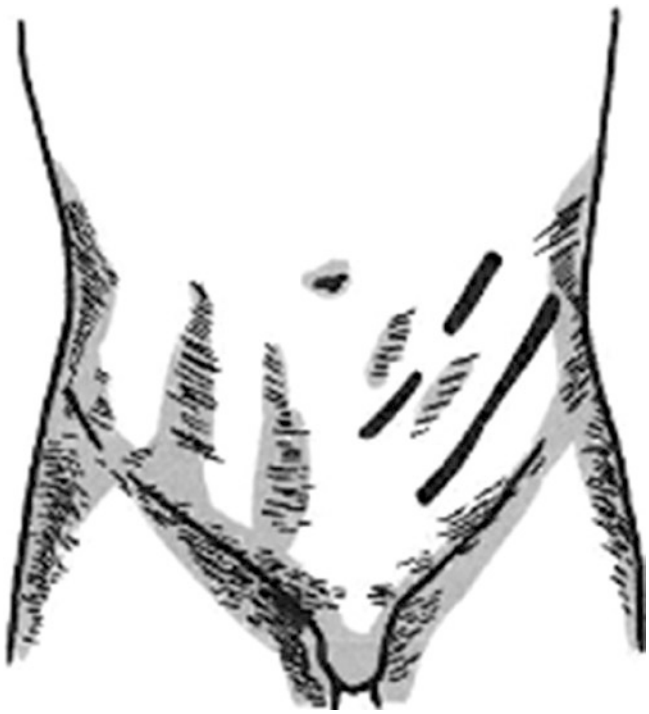

Fig. 3.27 The "bridge" in the middle part of the skin tube (1)

site with a good blood supply, the length-to-width ratio can be enlarged to 5:1. If the desired length-to-width ratio exceeds the ratio limit due to the need of repair, 1–2 pedicles (called "bridge") can be added to the middle part of the skin tube (Figs. 3.26, 3.27, 3.28, 3.29, and 3.30). There are more operations in the process of skin tube transfer; the higher the number of operation is, the more the loss of skin tissue is. Therefore, in general, the design area of the skin tube should be greater than the wound area in the donor site by 30%.

The elongated skin flaps are not necessarily designed as rectangular skin flaps. They can be designed into the S-shaped and C-shaped skin flaps (Fig. 3.31), in order to increase the actual length of the skin tube.

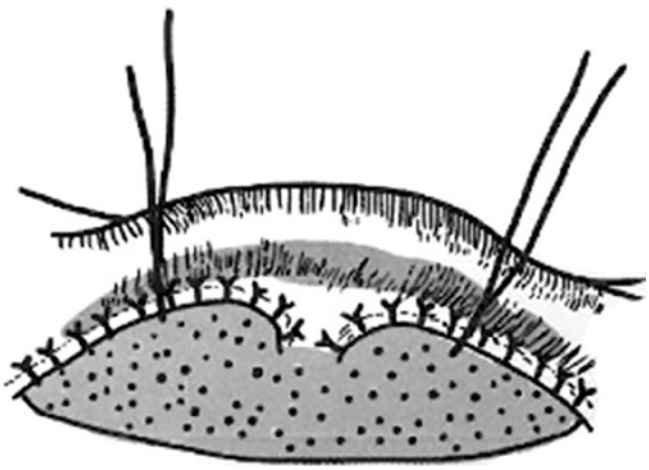

Fig. 3.28 The "bridge" in the middle part of the skin tube (2)

3.2 Skin Tube Formation

The skin and subcutaneous fat on one side of the elongated skin flap are incised open according to the designed incision line. The dissociation is performed along the superficial surface of the deep fascia, directly reaching to the incision line on the other side of the skin flap. It is noted that a triangular-shaped area of subcutaneous tissue is reserved, respectively, in the pedicles at the both ends of skin flap (Fig. 3.32) when the dissociation is performed, so as to prevent emergence of the dead spaces in the pedicles after skin tube is sutured. It is experimented that the skin flap edge which has been dissociated is rolled to the incision line in the other side which has not been dissociated. It is estimated that the skin flap after being sutured into the skin tube has neither tension nor dead space, and then the incision line on this side is incised. Otherwise, the location of the incision line on one side which is not incised open is adjusted to change the width of the elongated skin flap, and then the skin and subcutaneous fat is incised open along the adjusted drawing line. After careful hemostasis, the skin flap is sutured into the skin tube with the full-thickness interrupted suture (Fig. 3.33). If the secondary wound in

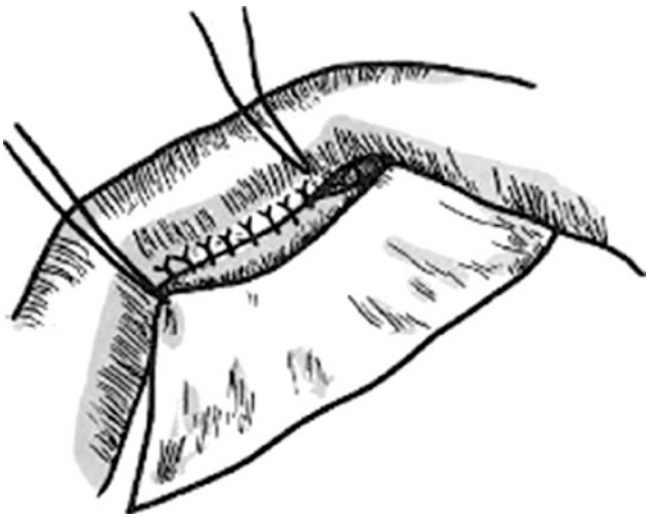

Fig. 3.29 Skin tube formation (2)

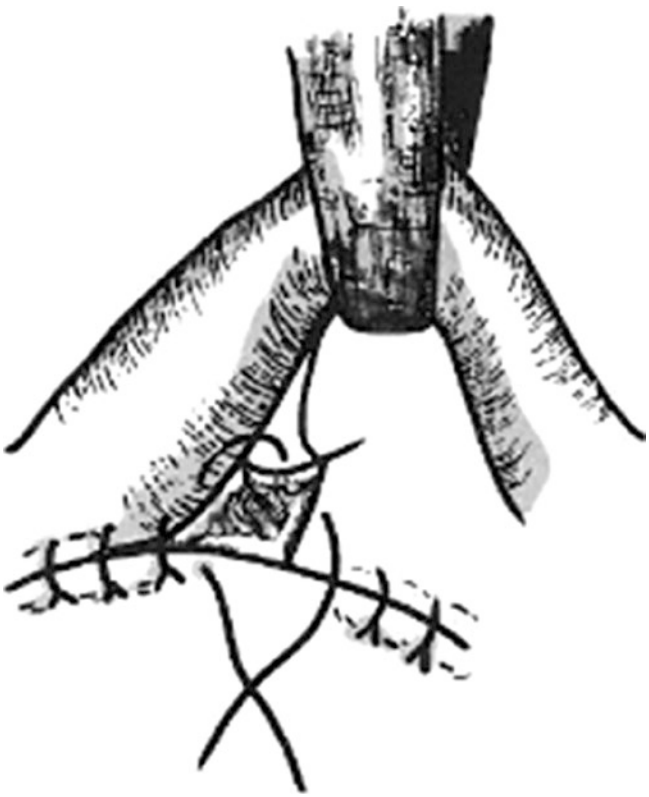

Fig. 3.30 Skin tube formation (3)

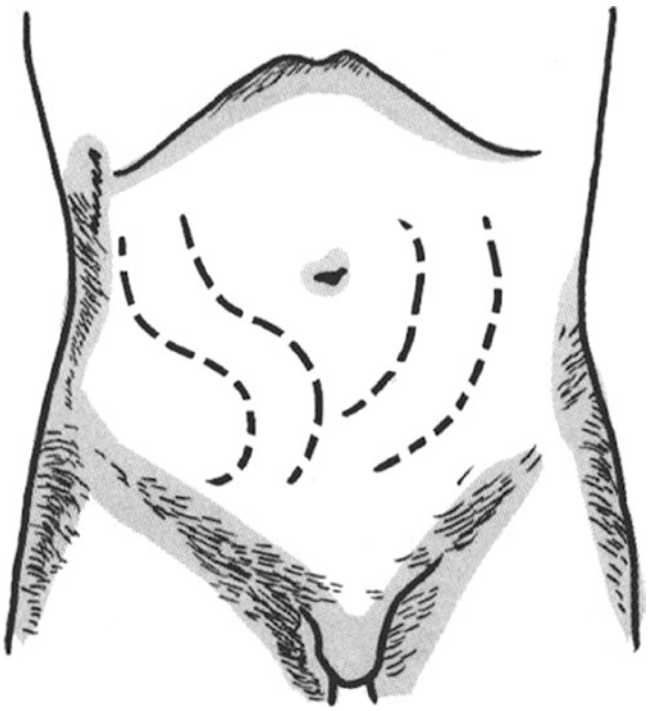

Fig. 3.31 Formation of S-shaped and C-shaped skin tubes

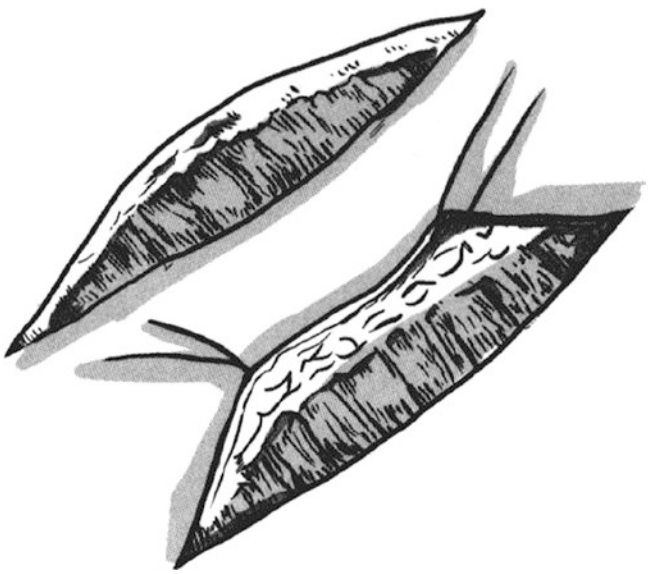

Fig. 3.32 Skin tube formation

the donor site where the skin tube is formed can be directly sutured, the wound in the connecting area between the two pedicles of the skin tube and the donor site should be sutured by means of a mattress suture (Fig. 3.34), so that the wound is completely closed; if the secondary wound cannot be directly sutured, the split-thickness skin graft will be additionally harvested and transferred to repair the wound (Fig. 3.35). After the formation of the skin tube and before carrying out bandaging, a gauze roll which has the same size of the skin tube and is slightly longer than the skin tube is placed, respectively, on both sides of the skin tube to prevent the skin tube compression (Fig. 3.36), and both ends of the gauze roll are fixed onto the skin in the donor site, respectively, with a stitch.

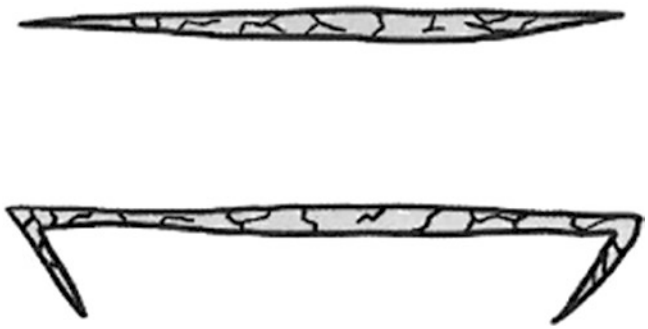

Fig. 3.33 Unilateral additional incision suture (1)

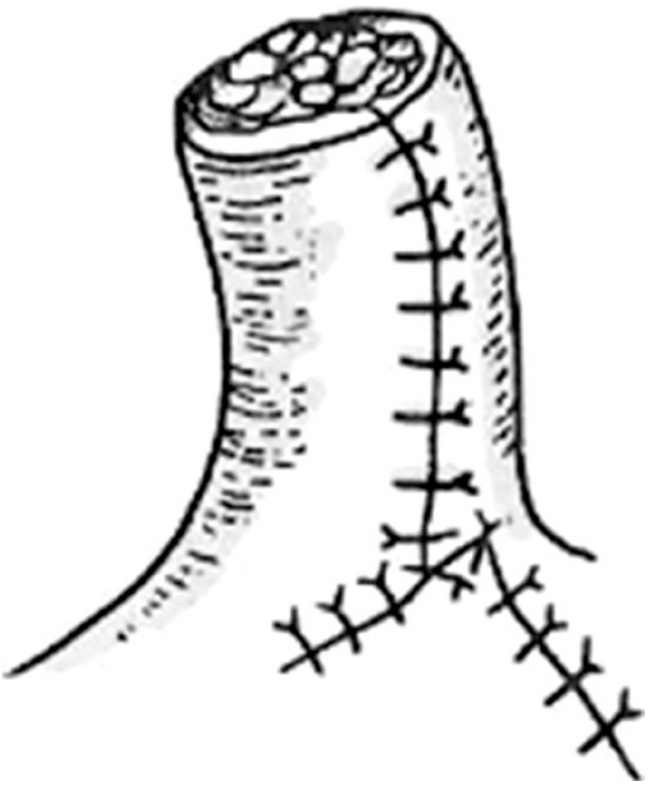

Fig. 3.34 Unilateral additional incision suture (2)

3.3 Skin Tube Transfer

The skin tube can be transferred at 3 weeks after formation. The skin tube transfer includes two methods such as direct transfer and indirect transfer.

3.3.1 Direct Skin Tube Transfer

The skin tube transfer can be performed at 3 weeks after the formation of the skin tube, after the vascular occlusion test suggests that the blood supply of the pedicle of the skin tube is good enough to maintain the nutritional metabolism of the whole skin tube. The end where the vascular occlusion test is performed is cut off from the donor site; if the broken end has no active bleeding or the skin tube is pale, it indicates poor blood supply; thus, the broken end of the skin tube should be sutured back into its original place. After 3 weeks, the vascular occlusion test and skin tube transfer are carried out again; if the broken end has active bleeding, it indicates good blood supply, and then the transfer can be carried out. According to the need of repair, at first, the skin tube is cut open along the suture scar, and the scar tissue is removed; finally the skin tube is flattened and transplanted to repair the defect in the receptor site, and finally, the wound margin is sutured interruptedly. The pedicle is cut off at 2–3 weeks later. The pedicle of skin tube is cut and trimmed, and the wounds in the donor site and the receptor site are sutured, respectively.

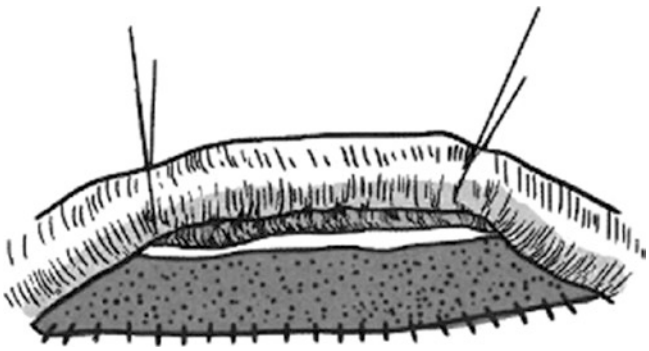

Fig. 3.35 The skin graft is used for the donor site under the skin tube

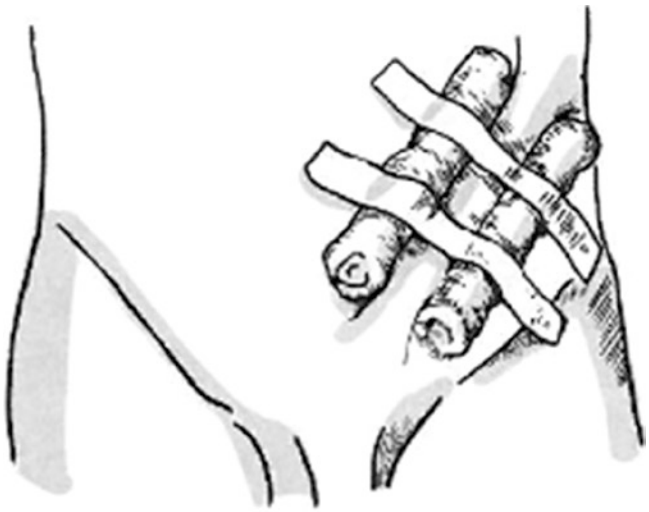

Fig. 3.36 The bandaging method for the formed skin flap

3.3.2 Indirect Skin Tube Transfer

The indirect skin tube transfer is similar to the indirect method for flat skin flap transfer. The intermediate station must be as a transition in the indirect skin tube transfer, and the wrist is usually taken as the intermediate station. At 3 weeks after the formation of the skin tube, the vascular

occlusion trials suggest good blood supply in the pedicle; thus, the first-stage transfer is performed. The pedicle of the skin tube is cut off and is transferred to the intermediate station (see Figs. 3.20, 3.21, 3.22, 3.23, and 3.24). After its establishment of good blood supply with the intermediate station, the second-stage transfer is performed. The pedicle at the other end of the skin tube is cut off, so that the skin tube is completely separated from the donor site, and then is incised open to form into a skin flap. At last, the skin tube carried by the intermediate station is transferred to repair the defect in the receptor site. After a good blood supply has been established between the skin flap and the donor site at 2–3 weeks later, the pedicle is cut off to complete the whole process of transplantation. Before each transfer operation is performed, it is required to carry out vascular occlusion test.

There are two commonly used methods for the vascular occlusion test:

1. The color agent which is not easy to fade or 10% silver nitrate is used to mark the area where it is to be cut off during the time of transfer. The rubber strip is used to bypass the skin tube along the marked line, and then is fastened and tightened until that the blood flow is completely blocked. If there is no change in the color of the skin tube at 1 h after the rubber strip is fastened, it suggests that the pedicle at the other end of the skin tube has been able to provide good blood circulation.
2. The sphygmomanometer pneumatic cuff is used to fasten the limb which carries the skin tube at the proximal side of the intermediate station, the sphygmomanometer is inflated until the pressure is higher than the arterial pressure (systolic pressure). If the distal end of the fastened limb has already felt numb and cold, and there is no change in skin color of the skin tube, and the skin temperature is normal, it suggests that the skin tube has a good blood supply, and its connection to the intermediate station can be cut off.

The vascular occlusion test can also be used for training of the skin tube blood supply; at 2–3 weeks after the formation of the skin tube, the blood flow is blocked for 2–3 min on the first day, once a day; the time of blocking the blood flow is extended day by day until the skin tube has a good blood supply.

One or more "bridges" can be designed in the middle segment of the ultralong skin tube, namely, every "bridge" is a pedicle, thus increasing the blood supply to the skin tube. During the skin tube transfer, the "bridge" should be cut off at first; the treatments before and after surgery are the same as those of cutting off the pedicle, namely, it is needed to perform the vascular occlusion test before surgery, and the next stage of the operation can only be carried out at 2–3 weeks after surgery.

4 Axial Pattern Skin Flap

The axial pattern skin flap is also known as the arterial skin flap. It is the skin flap which is designed through taking the well-known artery as the axial artery. The entire skin flap is provided with blood by the axial artery; thus, the skin flap is not limited by the traditional length-to-width ratio, and the scope of the infusion of the axial artery is taken as the maximum area of the skin flap. In order to expand the area of the skin flap, a random pattern skin flap can be carried at the distal end of the axial pattern skin flap.

The existence of the axial artery is a prerequisite for the formation of axial pattern skin flap, which is also the dominant factor to determine the characteristic of the axial pattern skin flap; therefore, the axial pattern skin flap should be named according to the axial artery which constitutes the skin flap. The random pattern skin flap can be named after the place where it is located, such as chest skin flap and abdominal skin flap. It can also be named according to its shape, such as leaf skin flap, triangular skin flap, and tubular skin flap. These names can sufficiently show the properties of the skin flaps. For the naming of the axial pattern skin flap, the axial artery should be included in the name of each skin flap to show its characteristics, and it also can avoid the occurrence of the confusing phenomenon of different skin flaps having the same name or the same skin flap having multiple names. For example, in term of the forearm axial pattern skin flap, if the radial artery is taken as the axial artery, it should be named as the radial artery forearm skin flap; if the ulnar artery is taken as the axial artery, it should be named as the ulnar artery forearm skin flap. For another example, the posterior tibial artery can be taken as the axial artery of the axial pattern skin flap in the anteromedial calf, and the cutaneous branch of the tibial nutrient artery can also be selectively used as the axial artery; the selectively used axial blood vessels are different; the characteristics of the skin flaps are different. The skin flap taking the posterior tibial artery as the vascular pedicle should be referred to as the posterior tibial arterial skin flap in the anteromedial calf. Because this skin flap has large-caliber blood vessels, the vascular anastomosis operation is easy with a high success rate, but it requires the sacrifice of a main artery in the calf, and it should be considered as the contraindication in the patients with anterior tibial artery dysfunction. The skin flap in the anteromedial calf takes the cutaneous branch of the tibial nutrient artery as the vascular pedicle, it is thin and its texture is fine, it does not require the sacrifice of a main artery in the calf, and the wound in the donor site is small, but the vascular caliber is not as thick as that of the tibial artery, with higher technical requirements for anastomosis. It should be referred to as the skin flap in the anteromedial calf with the cutaneous branch of the tibial nutrient artery, in order to be differentiated from the skin flap in the anterome-

dial calf with the posterior tibial artery. It is not rare that a skin flap has two or more than two names, for example, in terms of the perineum axial pattern skin flaps which take the posterior artery of the labia (scrotum) as the axial arteries, some are called as the perineum axial pattern skin flaps, and some are also called as the pudendal thigh skin flaps. If the axial artery is marked in its name, not only will the characteristics of the skin flap be clear at a glance but also will the name confusion be avoided.

4.1 Classification of Axial Pattern Skin Flaps

1. Peninsula axial pattern skin flap: The peninsula axial pattern skin flap is usually called the pedicled axial pattern skin flap. In the process of transplantation, in addition to the axial blood vessel, the skin and subcutaneous tissue in the pedicle are also connected with the donor site. This kind of skin flap is transferred into the donor site by means of pedicled transfer, and the specific operation is similar to the local transplantation of the random pattern skin flap.
2. Island skin flap: In the process of island skin flap transplantation, only the axial blood vessel bundle of skin flap in the pedicle is connected to the donor site. After the formation of the skin flap, the skin in the proximal end of the pedicle is incised open to isolate the axial blood vessel bundle, and the island skin flap is transferred into the receptor site usually through subcutaneous tunnel or incising open the normal skin tissue between the donor site and the receptor site. When the vascular pedicle is being isolated, it is needed to retain a little loose connective tissue to prevent damage to blood vessels. In the process of the transfer, the width of the subcutaneous tunnel should be sufficient to prevent the vascular bundle compression.
3. Free skin flap: In the process of transplantation, the axial artery and vein are cut off; the skin flap is completely separated from its donor site. The artery and vein in the vascular pedicle of the skin flap are anastomosed, respectively, with those in the receptor site with the small vascular anastomosis technique, so that the skin flap can get the blood supply immediately from the donor site.

4.2 The Advantages of Axial Pattern Skin Flap

1. The blood supply of the axial pattern skin flap is rich and has a strong resistance to infection; therefore, it can be used for repair of contaminated skin tissue defects or skin tissue defects with poor blood supply
2. The area of the axial pattern skin flap is not restricted by the length-to-width ratio. The skin flap can be formed within the scope of perfusion of the axial artery, and thus, it is designed flexibly and can meet the need of repair of skin defects of different shapes.
3. When the distal axial pattern skin flap is transferred, the axial blood vessel bundle of skin flap can be anastomosed, respectively, with the arteries and veins in the receptor site. The whole process of the skin flap transfer can be completed in an operation, which can reduce the pain of the patient and shorten the hospital time.
4. According to the need of defect repair in donor site, the pedicles of the axial arteries and veins of two or more skin flaps can be anastomosed with each other to form into the common vascular pedicle shared by multiple skin flaps, and then the axial arteries and veins of this vascular pedicle are anastomosed, respectively, with those in the receptor site, so that the multiple skin flaps are transplanted by means of series or parallel connection.

4.3 Commonly Used Axial Pattern Skin Flaps

The pedicled or free transplantation of commonly used axial pattern skin flaps for repairs is shown in Table 3.2.

5 Free Skin Flap

5.1 Overview

The skin flap consists of the skin and subcutaneous tissues with blood supply. The part of the skin flap connected with the body is known as the pedicle, which is the blood supply source of the skin flap after transfer. When the skin flap is being harvested, the pedicle is composed of the skin, subcutaneous tissues, fascias, muscles, or blood vessels which are not completely cut off. After the skin flap is completely cut off, the vascular anastomosis is performed with the microsurgical techniques to re-establish the blood supply, and this kind of skin flap is called the free skin flap. The area providing the tissue structure of the skin flap is called the donor site of the skin flap; the area repaired and covered by the skin flap is called the receptor site of the skin flap. In the early stage of skin flap transfer, its blood supply and nutrition depend entirely on the pedicle. In the late stage, the blood supply of the skin flap can also be obtained from the tissues in the bottom of the receptor site and the surrounding areas.

The free skin flap transfer or transplantation began in 1972 and is currently the most important treatment means in plastic surgery. The free skin flap transplantation technique

Table 3.2 Pedicled or free transplantation of commonly used axial pattern skin flaps for repairs

Names of skin flaps	Main axial pattern blood vessels	Repair sites
Parietal skin flap	The parietal branch of superficial temporal artery	Scalp, beard, and eyebrow defect
Forehead skin flap	The frontal branch of superficial temporal artery	Face, organ defects, oral perforating tissue defect
Temporal skin flap	Superficial temporal artery	Face, ear, nasal, and orbital reconstructions, free transplantation for repair of hand soft tissue defect, and joint exposure
Postauricular skin flap	Posterior auricular artery and superficial temporal artery – posterior auricular artery	Forehead, the area around the eye, nose, face, or free transplantation
Deltopectoral skin flap	The perforating branch of internal thoracic artery	Jaw and neck
Lateral thoracic skin flap	Lateral thoracic artery	Armpit, chest wall
Lateral thoracoabdominal skin flap	Lateral cutaneous branch of the intercostal artery	Breast reconstruction, thoracic dorsal areas, contralateral forearm
Paraumbilical skin flap	Paraumbilical branch of the inferior epigastric artery	Contralateral thoracoabdominal wall, contralateral forearm and hand or free transplantation
The iliolumbar skin flap	Superficial epigastric artery, superficial iliac circumflex artery	Forearm, hand, perineum, great trochanter, or free transplantation
Scapular skin flap	Circumflex scapular artery	Shoulder, armpit, upper arm or free transplantation
Medial arm skin flap	Superior ulnar collateral artery	Maxillofacial and cervical regions, shoulder, elbow, or free transplantation
Lateral arm skin flap	Radial collateral artery	Shoulder, axilla, elbow, or free transplantation
Forearm (radial artery) skin flap	Radial artery	Hand (retrograde transfer) or free transplantation
Dorsal skin flap of index finger	The first dorsal metacarpal artery	Thumb, thumb web
Anterolateral thigh skin flap	The descending branch of femoral anterolateral artery	Groin, perineum, greater trochanter, descend retrograde to the knee, upper pretibial region or free transplantation
Medial femoral skin flap	The cutaneous branches of the femoral artery	Free transplantation for repair of soft tissue defects in sites such as planta pedis and hand
Saphenous arterial skin flap	Saphenous artery	Pretibial area, knee, forearm, hand, and palm
The medial crural skin flap	Posterior tibial artery	Knee, upper crus, ankle, palm, or free transplantation
The lateral crural skin flap	Peroneal artery	Knee, pretibial area, lower crus, ankle, or free transplantation
Dorsalis pedis skin flap	Dorsal pedal artery	Ankle, heel, pretibial area
Medial plantar skin flap	Medial plantar artery	Heel, ankle, palm of the hand, thumb web

greatly facilitates the developments of plastic surgery, orthopedics, trauma surgery, hand surgery, and other related professions, and it is a major innovation for surgical techniques in the second half of the twentieth century. The free skin flap transplantation with vascular anastomosis has characteristics such as flexible skin flap design, diverse tissue constituents, random size and rich blood supply, and less number of operations. The free skin flap transplantation can be used in the early and late surgical repairs of severe traumas to preserve limbs, reduce amputations, and maximize the functional recovery; it can make the one-stage repair of body surface tumor resection possible; it can meet the needs of repairs of different tissue and organ defects in trauma surgery and oncological surgery; it can maximally guarantee complete removal of the lesions to protect and reconstruct the tissues and vital organs and to obtain a satisfactory appearance. The pedicled skin flap has irreplaceable advantages for some patient cases. But the free skin flap transplantation requires skilled microsurgical techniques, which has disadvantages such as longer operative time, needing more staff and certain equipments and complex technical operations. Indeed the free skin flap transplantation has certain risks and failure rates.

The general and local conditions; vascular conditions, especially the blood circulation statuses such as the blood vessel diameter, location, and distance; and the healthy conditions of the blood vessels themselves and their surrounding tissues in the patients should be carefully examined and objectively evaluated before free skin flap transplantation. The patency and directions of the pedicle blood vessels and

the vascular conditions in the receptor sites should be routinely detected with Doppler blood flowmeter before surgery, and the directions of the blood vessels in the body surfaces of patients are marked with methylene blue. If necessary, the computer tomography angiography is performed to reduce the blindness of operation.

5.2 The Indications for Free Skin Flap Transplantation

The free skin flaps are mainly used for repair of distal defects, functional reconstruction, and organ reengineering. But the microsurgical operation is complicated and time-consuming with large trauma. For example, once the operation fails, it will cause new trauma or new dysfunction in the patient. Therefore, its scope of application must be strictly controlled. It is generally considered that the indications for free skin flap transplantation include:

1. Protection of important tissues, structures, and organs such as bones, joints, large blood vessels, nerves, and eyes.
2. Reconstruction of organs such as the nose, lips, ears, eyelids, eyebrows, tongue, and esophagus.
3. Functional reconstruction for facial paralysis, blepharoptosis, and tendon.
4. Repair of perforating defects in sites such as the cheek, nose, palate, and mouth floor.
5. Repair of chronic intractable ulcers and chronic osteomyelitis.
6. Repair of deep tissue defect wounds.
7. There are normal blood vessels available for anastomosis in the receptor site and its neighborhood.
8. The patients can tolerate long-time operations and have no serious vascular diseases.

5.3 Selection of the Donor Site

1. The skin in the donor site of the skin flaps has normal appearance, soft texture, and no scar.
2. The blood vessel positions are constant and stable and are easy to dissect. The vascular pedicle lengths are more than 2–3 cm, and the outer diameters of blood vessels are more than 1 mm.
3. The donor site is relatively located in a hidden area and can provide a skin flap of sufficient size. The thickness and color of the skin flap can meet the needs of receptor site.
4. It is better for the skin flap to have a sensory nerve for anastomosis.
5. The function and appearance of the donor site is not affected after skin flap harvesting.
6. The nerves, tendons, and bones which are connected with the skin flap can be simultaneously harvested in the donor site of the compound skin flap.

5.4 Preparation of the Donor Site

5.4.1 Treatment of the Wound in the Receptor Site

The fresh trauma wound should be treated with complete debridement as far as possible, and no foreign bodies and devitalized tissue are left, while the broken deep tissues are properly repaired. For the wound with chronic infection, the infected wound, sinus tract, scar, dead bone, and inflammatory granulation tissues should be completely removed during operation. If the bone is exposed in the chronic ulcer lesion, the superficial layer of bone substance in the bone surface should be chiseled away. The wound is adequately washed with benzalkonium bromide solution after focus debridement, so that the receptor site is changed into a basically healthy and relatively sterile wound. Thereafter, the surgical instruments and the surgeon gloves should be replaced, and the isolation gowns should be disinfected. The treatment of sterile wound involves removing the diseased tissues, dissecting the blood vessels that need to be sutured, and repairing the deep tissues which have been damaged.

5.4.2 Selection of the Blood Vessels in the Donor Site

1. In the chronic infectious lesion, the blood vessels in the neighboring area are affected by the long-standing inflammation, often resulting in blood vessel wall thickening and narrow vascular lumen, and the anastomosis must be performed only after the diseased arteries are removed.
2. In the patients with limbs treated by radiotherapy or with arterial intubation for drug liquid infusion, its local blood vessels suffer varying degrees of damages, and it is supposed to look for intraoperatively the blood vessels which can be suitable for anastomosis at first.
3. If it is estimated that the distal blood circulation of the diseased limb will be affected after the main blood vessels have been cut off, the end-to-side anastomosis should be performed, or their branches are selectively anastomosed, and the trunk blood vessels can also be connected by bridges with the distal and proximal ends of the blood vessels in the receptor site using the characteristic that some trunk blood vessels pass throughout the whole length of the skin flap.
4. The positions of the major blood vessels in the proximal lower leg are deeper, in order to facilitate the operation and prevent the clamping pressure on vascular anastomotic stoma which is caused by soft tissues such as muscles; the transplanted tissue flap can be reversely placed,

so that the vascular pedicle can be anastomosed with the relatively superficial blood vessel in the distal limb.
5. If one of the major blood vessels of the limb has been damaged or broken, the proximal end of this blood vessel should be used for anastomosis as much as possible.

5.5 Selection and Design of the Free Skin Flaps

With the deepening of the research on the anatomy of skin blood vessels, there are a growing number of the donor sites of free skin flaps available for selection. Clinically, the suitable skin flaps (or fascia flap, muscle flap, bone flap, osteocutaneous flap, and composite tissue flap) should be selected flexibly according to the defect scope, the structural characteristics of the defected tissues, and the repair requirements for morphology and function in the donor site and the vascular calibers in the donor and receptor sites. But it is realized in clinical practice that the latissimus dorsi myocutaneous flap pedicled with the thoracic dorsal artery and the scapular skin flap pedicled with the circumflex scapular artery are the most commonly selected and used free skin flaps, because they have large vascular calibers, long pedicles, constant anatomies, and large area available for harvesting; the skin flap can be directly drawn and sutured if its width is generally no more than 10 cm. In addition, the donor sites are hidden, and there are fewer impacts on the function and appearance of the patient. But the disadvantage is that when the skin flap is applied in the important functional sites such as planta pedis, the sensory recovery is slow. The anterolateral femoral skin flap pedicled with the descending branch of circumflex femoral artery is also one of skin flaps available for selection. The forearm skin flap and the dorsalis pedis skin flap produce a greater cost, and the symptoms such as swelling and pain will occur in some cases; therefore, the selection of free skin flaps should be careful. The dorsalis pedis skin flap with extensor digitorum brevis tendon is the ideal donor site for repair of hand injuries with tendon defect. In addition, when the free transplantation of the thumb nail skin flap and the second toe is carried out, the dorsalis pedis skin flap is often carried and used simultaneously. The skin flap design should follow the principles of the point, line, and surface. The position, size, anatomical level, and vascular pedicle of the skin flap are determined according to different characteristics of the blood supply.

For large composite defect in the head and neck area, especially for large composite mandibular defect in oral cavity, a single free skin flap transplantation often cannot meet the needs of restoring the shape and function at the same time. The best repair method for such defects is the double free skin flap transplantation technique.

Now, more commonly used combined skin flaps include iliac bone flap + forearm skin flap, fibular flap + forearm skin flap, fibular flap + rectus abdominis myocutaneous flap, and fibular flap + anterolateral femoral skin flap. The blood vessels of two tissue flaps can be anastomosed, respectively, with two sets of blood vessels in the receptor site; the blood vessels of a tissue flap can also be anastomosed with the blood vessels in the receptor site, and the blood vessels of other tissue flaps are anastomosed with the distal blood vessels of the previous tissue flap to form into tandem skin flaps. The subscapular artery system composite flap (scapula flap/scapular skin flap/latissimus dorsi flap) can also achieve the effect of double free flaps, but its biggest drawback is the need to change the body position during the preparation of tissue flap. It is impossible to perform two groups of operations at the same time. In addition, compared with the fibula, the bone mass of the scapula is insufficient to meet the conditions for dental implant implantation; and the scapula reconstruction is difficult. It is more difficult to achieve ideal restoration of appearance and function of the mandible; therefore, we usually do not advocate the use of the subscapular artery system composite flap for repair of oral mandibular defect and prefer to use the method of double free flap transplantation. The double free flap technique is currently the best way to repair the large oral mandibular defect, and has good effects in improving appearance and function in the patients after surgery, but it has characteristics such as large technical difficulty, long operation time, and large operative trauma; therefore, the indications should be strictly selected to ensure the success of the repair.

For the patient with large wound in the receptor site which is difficult to be repaired with single free skin flap, it can be designed to be repaired by free transplantation of combined skin flaps, such as free transplantation of combined latissimus dorsi muscle and iliopsoas muscle skin flap.

5.6 Precautions for Free Skin Flap Transplantation

1. Selection of skin flaps: The flap, muscle flap, and myocutaneous flap with appropriate vascular calibers should be selected according to repair needs in the receptor sites and the vascular conditions.
2. Preparation of micro-blood vessels in donor site: Before the microscopic anastomosis is performed, 1–2 cm blood vessel for anastomosis is disected, and a light blue or light yellow silica gel sheet is put under the blood vessel as the backing sheet, so that the blood vessel is showed clearer and is easy to suture. The heparin-saline infusion is often carried out when the anastomosis is performed, so as to ensure that the end of the blood vessel is clean and wet.

3. Conditions for vascular anastomosis: It is required that the blood vessels to be anastomosed must be normal blood vessels, which demonstrate a state of full filling and lie in the soft tissues, surrounded by loose connective tissues with soft walls; after the blood vessel is cut off, the vascular walls are milky white and clear, and the intimal and medial membranes are closely attached. If it is found that the blood vessel for anastomosis is damaged during surgery, it can only be anastomosed after the damaged part is removed, and otherwise, it will be highly vulnerable to thrombosis. If the length of the blood vessel is not enough, another healthy blood vessel can be taken for bridge connection.
4. The diameters of the blood vessels which are to be anastomosed with each other should be similar: The diameters of the blood vessels for end-to-end anastomosis are best to be approximate to each other. If the diameter difference is too large, not only is it difficult to anastomose the blood vessels, but also is there a great disparity in diameter at the anastomotic site after anastomosis, and the blood vessel wall is not flat and smooth, so that there will be turbulence when the blood flow passes through, making the blood more likely to form a thrombosis. If the diameter difference is no more than one fourth of their diameters, the end-to-end suture can be performed. When the diameter difference is more than one third of their diameters, the end of the blood vessel with smaller diameter should be cut into beveled or fish head shape to increase the diameter. If the diameter difference is more than one half of their outer diameters, the end-to-side anastomosis should be performed.
5. The tension of the blood vessel should be appropriate: If the tension during vascular anastomosis is too large, it can narrow the blood vessel lumen and enlarge the suture hole and easily lead to damage of the blood vessel wall. There is only vascular intimal injury in less serious case; the anastomotic tear will occur in serious case, and a thrombosis is easily formed; if there is no vascular tension, it may produce severe bending or folding of blood vessels, with poor blood flow; therefore, the tension at the vascular anastomosis site should be appropriate. If the distance between the two ends is 3 cm or more, and the actual defect is more than 2 cm, it needs to be connected and repaired using blood vessel transplantation.
6. The operation should be stable, precise, light, and handy: When the blood vessel in the pedicle of the skin flap is anastomosed with the blood vessel in the receptor site, it is required that each suture must be accurate, the stitch lengths and edge distances are uniform, and it is completed with a needle to reduce unnecessary damage as much as possible and avoid increased vascular wall damages due to repeatedly inserting a needle. Don't excessively pull, clip, and squeeze the blood vessels; avoid clumsy and unnecessary duplication and inconvenient operations. It should be avoided that any instrument enters into the vascular lumen It is best not to use the mechanical expansion, and it is not advocated to perfuse and wash the transplanted tissues to avoid damaging the vascular intima.
7. Noninvasive operation: Since the blood vessels are small and cannot afford injuries caused by clipping, ligation, and pulling, every action of the surgeon must be careful and gentle. When pulling the blood vessels, the surgeon can only gently grip the adventitia with a tweezer; it is forbidden to clip and hold the vascular wall and port. It should be careful to separate and dissect the vascular pedicle. If the artery is to be separated apart from the vein, it is best to complete the operation under the microscope, so as to prevent accidental injury or damage due to rude separation. When the suture is performed, the line knot should not be too tight; otherwise, it would produce tension in the peripheral tissues of the blood vessels and thus cause ischemic necrosis.
8. Proper trimming of the adventitia in the broken end and stump washing: Removing the adventitia of the anastomotic stoma of the blood vessel can prevent the adventitia to be suspended in the blood vessel lumen or enter from the needle eye into the blood vessel lumen along with the suture line, and it is an important measure to prevent anastomotic thrombosis. Therefore, before the vascular anastomosis was performed, the adventitia within the range of 2–3 mm around the anastomotic stoma of the blood vessel should be routinely removed. The method for removing the adventitia is that under a surgical microscope, the adventitia around the anastomotic stoma of the blood vessel is lifted with a tweezer, and it is pulled out of the anastomotic stoma just like that the sleeve is taken off and then is trimmed. After being trimmed, the remaining adventitia retracts back naturally to a place 2–3 mm away from the anastomotic stoma. It is not advocated that the adventitia is stripped too completely. Otherwise, it is not conducive to the consolidation and healing of the anastomotic stoma.
9. The vascular bed is kept healthy and smooth: The anastomosed blood vessels must be located within the relatively flat and healthy surrounding tissue to promote the patency and healing. The vascular bed is uneven or the blood vessel is covered by peripheral soft tissues with poor blood supply, which can induce the blood vessel spasm and even lead to blood clots. Therefore, prior to suturing blood vessels, the surrounding muscles and fascias with good blood supply should be used to pave and cover the bones or fixtures under the blood vessels; after the vascular suture is completed, the surrounding soft tissues such as healthy muscles and fascias are used to cover the blood vessels, so as to leave no dead space.

10. The compression or distortion of the vascular pedicle is prevented: After the skin flap is transplanted into the receptor sites, the preliminary suture fixation of skin flap is made at first. When the vascular pedicle is passed through the subcutaneous tunnel, it is needed to prevent vascular distortion. The subcutaneous tunnel should be large enough to prevent the compression of vascular pedicle due to tissue swelling or hematoma. The positions of the blood vessels are adjusted to avoid that the blood vessels are crossed; when it is impossible to avoid the crossing of blood vessels, the vein should be made to pass over the artery. Before vascular anastomosis, the axes and positions of the blood vessels should be accurately aligned to prevent distortion and rotation; otherwise, if the blood vessel distortion is found after the vascular anastomosis is completed and the blood flow is restored, the suture lines will have to be cut off to perform the anastomosis again.
11. Correct suture: The suture is accurately performed in strict accordance with the requirements for inserting needle and tying a knot in microvascular anastomosis, and the sequence for inserting needle should be appropriate.
12. Three "anti-"treatments: It includes anti-infective, antithrombotic, and anticonvulsive treatments.

5.7 Postoperative Management

How to monitor and maintain the patency of the anastomosed blood vessels after operation is of vital importance. To put prevention first, the following measures should be taken:

5.7.1 General Treatment

1. The place where the skin flap transplantation is performed is wrapped with large pieces of wound dressing, in which a window is opened in the middle part to observe the blood supply. The diseased limb is properly immobilized and placed in a position slightly higher than that of the heart.
2. Because the wound is instilled continuously with heparin solution during the operation, and the wound continues to dissipate heat, the temperature of the tissue flap is significantly reduced, the micro-blood vessels are in a contraction state, and the microcirculation is affected. Therefore, the rewarming of the transplanted tissue flap after operation is very important in the cold season. After the patient returns back to the ward, the diseased limb should be covered with the electric blanket or warmed with a hot-water bag with right temperature, and the room temperature is kept at 25–30 °C, so that the transplanted tissue can recover to normal temperature about 2–3 h later. After that, the warming apparatus cannot be used in the local area, and the room temperature is maintained at 25 °C.
3. The blood circulation of the skin flap is closely observed, and the blood circulation should be observed and recorded once every half hour within 24 h after operation, once every 1–2 h within 24–48 h, and once every 3 ~ 6 h within 3–10 days. The observation contents are as follows:
   (a) Skin color: When the venous reflux is obstructed, the skin color presents as dark red at first; with the aggravation of the obstruction, the skin color changes from the initial dark red color into the purple or blue color. When the arterial blood flow is obstructed, the skin color changes from ruddy color into light color or pale color.
   (b) Swelling: The degree of swelling can be determined according to the dermatoglyphs. If the dermatoglyphs disappear, it indicates the severe swelling. If the dermatoglyphs are increased, it indicates that the arterial blood supply is blocked.
   (c) Skin temperature: The normal skin temperature is 34–35 °C at a room temperature of 25 °C. The skin temperature in the transplanted tissues usually recover back to the level which is equal to or 1–2 °C slightly higher than that in the adjacent parts or the contralateral corresponding parts at 2–3 h after operation; if the skin temperature in the transplanted tissues is 1–2 °C lower than the normal skin temperature in the adjacent parts, or it decreases 2–3 °C again after rewarming, it suggests that the blood supply disorder will occur, which must be observed strictly.
   (d) Capillary filling phenomenon: The capillary filling is accelerated when the venous reflux is obstructed, while it is slower down when the arterial blood supply is obstructed. If the skin color has been changed, this phenomenon is not easy to be observed.

   Observations on the above four indicators should be integrated and analyzed comprehensively. In addition, the transcutaneous oxygen analyzer and the laser Doppler tester can be used to determine the blood circulation of the skin flap.
4. The patient should stay in bed for 1–2 weeks after operation, and the general basic nursing works should be performed during this period. Smoking is strictly prohibited.

5.7.2 Three "Anti-"treatments

It is noted that the antithrombotic, antispasmodic, and anti-infection treatments should be carried out.

5.8 Postoperative Complications

The occlusive thrombosis and the blood circulation disorders due to other causes are the most serious complications; if they are not treated properly or timely, this will lead to skin flap necrosis.

5.8.1 Related Factors for Thrombosis

1. Damage to blood vessel walls: The surgery causes varying degrees of damages to blood vessels. The endothelial cells are damaged, and the subendothelial collagen fibers are exposed, which are the main reasons for thrombosis. The medial muscles and internal elastic membranes will have different degrees of breakages and necroses due to the suture ligation or the tension suture, which can also promote thrombosis. If the adventitia is stripped excessively, this will directly affect the blood supply of the blood vessel wall and its repair process.
2. Hemodynamic disorder
   (a) Low flow velocity: The factors such as hypovolemia and increased blood viscosity can easily lead to thrombosis.
   (b) Turbulent flow: It is also known as the eddy current. When the fluid flows in a pipeline; once the pipeline changes from thin to thick, bifurcates, and turns a corner; and the wall is not smooth or the flow rate is changed, all will cause a whirlpool which stays in the same place and reversely rotates, and that is the turbulent flow. The blood flow in the whirlpool rotates in situ continuously to produce a centrifugal effect and thus leads to the aggregation of various substances which can induce thrombogenesis.
3. The blood coagulation changes include: (1) The trauma, including surgery itself, makes the procoagulant substances enter into the blood circulation; and in (2) blood concentration, the blood viscosity is increased, the red blood cells and platelets are excessively increased, or the fibrinolytic system and other anticoagulant functions are inhibited.
4. The vascular compression and distortion include:
   (a) Cross-clamping of artery and vein, especially the artery, compresses the vein and thus causes venous reflux obstruction.
   (b) The skin-closing tension is too large, and the subcutaneous tunnel is too narrow, so that the vascular pedicle or the blood vessels in the receptor site are compressed, or the blood vessels are compressed because of secondary hematoma and tissue edema in the wound. The harvesting of the tissue flap under tourniquet control often easily causes the small bleeding points.
   (c) The position of the transplanted tissue flap is improper and thus leads to vascular distortion or excessive tension.
5. The vasospasm and postoperative infections include: the trauma in blood vessel walls and various other stimuli can cause vasospasm, occlude the blood vessel, and thus lead to thrombosis, while the thrombosis will aggravate the vasospasm, so as to constitute a vicious cycle. The postoperative infection can not only make the wound impossible to achieve the primary healing, but what is more serious is that the inflammation involves the blood vessel wall layer, and increases damages to blood vessel walls, resulting in thrombosis and even the blood vessel wall necrosis and anastomotic bleeding.

5.8.2 The Specific Measures for Thrombosis Prevention

1. Precise vascular anastomosis technique: This is a guarantee for the success of the microvascular surgery. It is required that each operation should be gentle, meticulous, and accurate, and it needs to strive for success at a time. It is forbidden to use the sharp instrument to enter into the blood vessel lumen, and the operator can't directly clamp the blood vessel wall with a tweezer, but can gently clamp some adventitial tissues. In order to prevent that the blood vessels are put aside long and dried, they should be infused with heparin saline from time to time to keep moist.
2. Proper treatment of the tissue around blood vessels includes:
   (a) Avoid the cross-clamping of artery and vein; if it cannot be avoided in fact, the vein should be placed above the artery.
   (b) In order to avoid that the skin tension after suture is too large, when the skin flap and muscle flap are designed, full consideration should be given to the elastic retraction of receptor site and the skin flap, and the subcutaneous tunnel to be passed through by the vascular pedicle should have sufficient width.
   (c) It should be avoided that the anastomosed blood vessels have excessive distortion or tension.
   (d) The wound hemostasis is performed carefully, and the wound suction drainage is carried out.
   (e) It is avoided that the skin in place where the suture is performed is too tight and the bandaging is too tight.
3. Prevention of vasospasm: The common causes for vasospasm are pain, pulling blood vessels in the surgery, trauma, hypovolemia, too low room temperature, inadequate bone internal fixation or inappropriate limb position, etc., and the appropriate measures should be taken against the causes. After excluding these factors, the topical antispasmodic solution can be externally applied in the areas surrounding the blood vessel. Sometimes, the intractable vasospasm is difficult to be identified from the thrombogenesis, and the surgical exploration should be timely performed.
4. The infection prevention includes: (1) Maintain a sterile environment, and implement aseptic techniques strictly; (2) the preoperative design is carried out carefully to shorten the operative time; (3) the thorough debridement is performed in the receptor site; (4) the wound hemostasis is performed carefully; and (5) the antibiotics are rationally used.

5. Application of anticoagulation and antispasmodic drugs: The drugs include anticoagulants such as low molecular dextran and dipyridamole and the intramuscular antivasospasm drugs.

5.8.3 Diagnosis and Treatment of Thrombosis

1. Essentials of diagnosis
   (a) Arterial thrombosis: The skin color gradually changes from rosy to pale; the wound margins have no bleeding; the dermatoglyphs are increased; the capillary backflow phenomenon is slowed or disappears; the skin temperature is decreased and is 1–2 °C lower than that of the adjacent normal skin. When the skin temperature is measured, the false appearance whether it is caused by local heat preservation or affected by the substrate temperature should be excluded.
   (b) Venous thrombosis: The skin color changes from dark red to cyanose; there is swelling or blisters; the wound margins have no bleeding and present as dark red; the capillary backflow phenomenon is accelerated; the skin temperature is 1–2 °C lower than the normal level.
   (c) The difference between vasospasm and thrombosis: The vasospasm crisis occurs suddenly, and it is recoverable after antispasmodic treatment. The vasospasm occurs mostly during surgery and in the later period after surgery, namely, at 48 h later, and occlusive thrombosis is more commonly seen within 48 h after surgery. In addition, the stubborn and persistent spasm often occurs on the basis of thrombosis. Therefore, it is sometimes very difficult to distinguish between the two.
2. Processing step
   (a) First, open the dressings; observe whether there is inadequate drainage in the subcutaneous area, and the hematocele compresses the blood vessels. Some suture lines can be removed in the place with large skin tension.
   (b) The patients are given immediately antispasmodics, and the diseased limb is warmed or raised at the same time according to the specific situation.
   (c) After the above processing, if no recovery is observed after a period of time, the surgical exploration should be actively performed.

For the artery or vein anastomotic thrombosis, it cannot be treated simply through taking out the embolus, and this section of blood vessel with embolus should be cut out and then the anastomosis is carried out; if the length of blood vessel is not enough, the vein graft can be performed. Where the venous embolus is longer (indicating that the blocking time is longer), in addition to vein treatment, the artery anastomotic stoma should be carefully explored, because the rate of concurrence of arterial anastomotic thrombosis is very high. If there exists venous thrombosis, and the transplanted tissue flap has extravasated blood with purple color, the normal saline diluted heparin solution can be used to infuse the artery at appropriate pressure until the heparin solution outflowed from blood vessels is clear.

6 Complications of Skin Flap Transplantation and Their Prevention and Control

The skin flap is a piece of skin and subcutaneous tissue with blood supply; its blood supply and nutrition in the early stage rely solely on the pedicle. The pedicle of the skin flap and subcutaneous tissue can not only be the skin and subcutaneous tissue with blood supply, but it can also be a single vascular pedicle (including the anastomosed vascular pedicle). The skin flap is transferred into the receptor site; after a new blood supply is established between the skin flap and the tissue wound in receptor site, the whole process of skin flap transplantation is just completed. At the moment, some skin flaps still need to cut off the pedicles and undertake repairs.

In the process of formation and transfer of the skin flap, the most important of all is to ensure the survival of the skin flap. However, the blood supply disorder of the skin flap, skin flap necrosis, hematoma under the skin flap, skin flap avulsion, and skin flap infection can occur in practice. In addition, it should not be ignored that the skin flap is bloated, the pedicle is erosed, the skin is wrinkled, the joint is rigid, and the muscle is atrophic. It is very important to understand these complications and their causes and master the methods of prevention and cure.

6.1 Blood Supply Disorder of the Skin Flap

Whether the blood supply disorder of the skin flap occurs depends on whether the arterial blood supply is sufficient and the venous blood reflux is unobstructed; if the arterial blood supply is rich, the venous blood reflux is sufficient, and the effective circulating volume flowing through the skin flap per unit time is relatively constant and can ensure the nutrition and metabolism of the skin flap, the skin flap will survive. Conversely, the insufficient blood supply or reflux disorder decreases the effective circulating volume flowing through the skin flap per unit time; the blood supply of the skin flap disorder will occur, thus resulting in nutrition and metabolic disorders of the skin flap. If the blood supply disorder of the skin flap is not promptly improved, this will result in partial or total skin flap necrosis.

The blood supply disorder of the skin flap includes arterial blood supply insufficiency and venous reflux disorder.

The arterial blood supply insufficiency is demonstrated as pale skin flap and decreased local skin temperature which are often caused by the temporary reactive vasospasm. If this kind of situation occurs during the surgery, it will be recovered after being wetly compressed with warm saline gauze for a period of time; if this kind of situation occurs after the surgery, it will be recovered soon after treatments such as effectively complementing the blood volume, preserving the heat, relieving the pain, and administrating antispasmodic drugs. If the main artery supplying blood to the skin flap is accidentally injured, while it cannot be compensated by the adjacent blood vessels, this can cause mummification necrosis; if the arterial blood supply insufficiency occurs due to the blood vessel variation or that the main blood vessel is not contained within the skin flap, the result will also be not good. The venous reflux disorder is demonstrated as flap cyanosis and congestion swelling, the pink or purple spots will appear in the skin flap in less severe cases, the blisters or blood blisters will appear in severe cases, and the purple black blisters will appear in more severe cases. The venous reflux disorder mostly occurs in the distal skin flap, and is gradually aggravated with an expanded scope, and it will no longer develop gradually 5 days later. It manifests as excoriation in less severe cases which has no great effect on the survival of the skin flap, partial skin flap necrosis in severe cases which needs to be repaired with skin transplantation, and skin flap necrosis and falling off in more severe cases which will lead to surgical failure.

6.1.1 Causes

1. Internal cause
   (a) Improper selection of donor site of the skin flap, for example, the tissues in donor site of the skin flap are imperfect, has a wide range of scars or vascular disease.
   (b) The length-to-width ratio is improper when the random pattern skin flap is designed (in general, the length-to-width ratio should not exceed 2:1, and it should not exceed 3:1 in face and neck area), and there is no delay in advance, resulting in insufficient blood supply to the distal skin flap. The insufficient blood supply is due to the fact that the axial pattern skin flap exceeds the feeding range of the well-known blood vessel or due to the blood vessel variation.
   (c) When the skin flap is designed, whether the venous reflux is sufficient and whether the transplanted skin flap is in a position which is beneficial to venous reflux are not well thought out.
2. External factors
   (a) The feeding blood vessels are damaged during surgical operation, or the blood vessel feeding the skin flap is not included within the pedicle, or the stripping layers are at different depths.
   (b) The local tension is increased due to the internal pressure caused by the hecatombs which occurs within the skin flap or skin tube, so that the blood vessels are compressed and the blood supply is affected; in addition, the hecatomb has toxic effects: it can cause skin vasospasm, endanger the blood supply, and thus lead to the distal skin flap necrosis.
   (c) The angle is too large when the skin flap is transferred, so that the pedicle is twisted.
   (d) The suture is improper, the distance between needles is too short, and the edge distance is too long, so that the skin flap tension is too great.
   (e) When the bandaging and fixation are carried out, the pedicle tension is too large, or the pedicle is folded and compressed to affect the blood supply or lead to the obstruction of venous reflux.
3. The postoperative treatment is improper; the postoperative body position or partial braking is improper; the pedicle of the skin flap has too large tension or is twisted and folded. All the above factors can lead to poor venous reflux in the skin flap. The compression caused by wound dressings and the excessively tight winding around the pedicle obstruct the venous reflux. The wound effusion or exudates cannot be drained out timely due to the poor drainage or complete obstruction, and thus the hemorrhage or effusion appears under the skin flap, and its internal pressure or toxic effects can affect the blood supply of the skin flap.

The skin flaps will often have edema after operation. The patients are not treated timely when the swelling is formed and the blood supply is affected by the tension, for example, a few sutures are removed or the drainage strip is additionally placed. The receptor site is treated improperly before operation or the aseptic techniques are not strictly adhered to, so that the local infection will occur and can cause or aggravate the blood supply of the skin flap.

6.1.2 Prevention

The surgical timing, the type of skin flap and the donor site should be correctly selected before surgery. It is best to detect the running direction and distribution of axial pattern blood vessel with Doppler ultrasonic flow detector, and measure the size and range of the skin flap in advance, and it is required to be familiar with the anatomy of the axial pattern skin flap and the safe blood supply scope. When the skin flap is designed, the length-to-width ratio and safety degree should be fully considered for the random pattern skin flap, and the axial pattern skin flap should not exceed the safe blood supply scope of the axial pattern blood vessel. It is designed that the size of the skin flap should be 20–25% greater than that of the defect area to avoid excessive tension after the transfer. If it is considered that there are some unsafe factors, the delayed surgery should be performed at first, and

then the skin flap transfer operation is performed. In the operation process, the principles of aseptic techniques and noninvasive operation should be strictly complied with, and the anatomic hierarchy of the surgery is clear to avoid injuring the main feeding blood vessels or nerves. The thorough hemostasis is carried out for the wounds and the area under the skin flap. When the skin flap is transferred and sutured, it should be avoided that the skin flap tension is too large and the pedicle is twisted and folded. A drainage tube should be indwelled and kept unobstructed, then the skin flap should be covered with a suitable dressing and properly fixed, and the nursing and monitoring are strengthened. In addition, special attention should be paid to the blood supply of the skin flap, the wound, and the drainage conditions, in order to timely detect problems and deal with them. Because there are strict time limits for skin flap blood supply disorder, we should strive to eliminate the causes of blood supply within a few hours, and we must not delay or wait to miss the opportunity; otherwise, it will lead to adverse consequences.

6.1.3 Treatment

If it is found intraoperatively that the blood supply disorder of the skin flap occurs due to feeding blood vessel injury or other causes (pale skin flap or cyanosis, etc.), the best treatment is to stop the surgery, and the skin flap is sutured back into previous place, which is equivalent to perform a delayed surgery. If the skin flap still has no blood supply after being sutured back into previous place, it should be considered that the skin flap is taken down and cut into the split-thickness or full-thickness skin graft for carrying out skin transplantation to cover the wound. If the blood supply disorder of the skin flap occurs after transfer, it is necessary to carefully analyze and promptly look for as well as eliminate the causes of the blood supply disorder. If the cause is that the pedicle is compressed, stretched, or folded, it is supposed to adjust the body position or perform a partial braking again; if the cause is the arterial spasm, the sedative and analgesic drugs, heat preservation, and blood volume expansion are applied, or the drugs which can dredge microcirculation and dilate blood vessels are applied. The hyperbaric oxygen therapy should be carried out as soon as possible when conditions permit. The internal causes such as improper donor site selection and unreasonable skin flap design lead to venous reflux disorder, blood flow stasis, and flap cyanosis; at present, there is lack of effective treatment measures. Some methods that promote venous reflux are tentatively adopted, for example, the affected area is bandaged with compression dressing; the diseased limb or distal skin flap is lifted; the massage is performed with fingers from the distal skin flap to the pedicle; and the small veins are transplanted through microsurgical anastomosis. The methods to relieve venous congestion can also be tentatively used, for example, the small leeches are used to suck the blood and the physiological saline solution with heparin, and lidocaine is used for hydropathic compress after the sutures in skin flap are removed. In addition, the local cooling methods can reduce the metabolism and sometimes have a certain effect. Although there are many methods, the effects are poor.

6.2 The Hematoma Under the Skin Flap

The hematoma under the skin flap has not only an internal pressure effect but also a toxic effect on the skin flap, resulting in the vasospasm in the skin flap, which is the cause of skin flap necrosis.

6.2.1 Causes

1. The factors related to the patients themselves: The main factor is the problems in coagulation mechanism. Some patients have normal BT, CT, PT, and KPTT, but they often have repeated bleeding during operation.
2. If the intraoperative hemostasis is not complete or the hemostasis method is improperly applied, for example, the vasopressors such as epinephrine are added into the local anesthetics; the saline gauzes or adrenaline saline gauzes are used for compression hemostasis, electric coagulation hemostasis, and clamping hemostasis. No obvious bleeding points are observed during operation, but the intravascular pressure, especially the intravenous pressure, is increased after operation due to multiple factors such as the fixation of limbs, the transportation of patients, and the blood pressure recovery of patients, so that the temporarily closed broken mouths of the blood vessels will be ruptured to lead to bleeding.

6.2.2 Prevention

1. Whether there is a presence of bleeding tendency should be determined before operation, and the patients with abnormal blood coagulation mechanism should be treated. The surgery is prohibited in female patients in the menstrual period, and the surgery is unfavorable within 1–3 days before and after the menstrual period.
2. The reliable hemostasis methods are used during operation, for example, the ligation hemostatic method is used for the larger blood vessels; the bipolar electrocoagulation forceps are used for the hemostasis of small bleeding points; the unipolar electrocoagulation hemostasis is rarely used or is not used; and it is avoided to use the saline gauze or adrenaline saline gauze for compression hemostasis.
3. The skin flap edge is not sutured too tightly.
4. The drainage membrane is placed. It is better that a negative pressure drainage tube is indwelled.
5. When necessary, the hemostatic drugs such as vitamin K1 and etamsylate are used prophylactically before and during operation.

6.2.3 Treatment

When a hematoma under the skin flap is found, the sutures should be removed immediately to remove the hematoma and wash it clean with saline gauzes. If it is found that there are still some active bleeding points, the patient should be transferred into the operating room for completely removing the blood clots and stopping bleeding, and the drainage membrane or the negative pressure drainage tube would be placed.

6.3 Skin Flap or Skin Tube Avulsion

6.3.1 Causes

After transfer, the skin flap or skin tube avulsion will occur due to the facts that the patient is not fixed and immobilized well; the patient involuntary screams in his sleep; and the body and limbs have violent activities or the patient falls down from the bed. The young people quarrel and fight noisily or fall down carelessly, which can also cause skin flap avulsion. The avulsion is likely to occur at any time between transferring the skin flap or skin tube and cutting off the pedicle and sometimes will occur when the disinfection is carried out; therefore, no negligence is allowed.

6.3.2 Prevention

In the transfer process of the skin flap or skin tube, the patient should be properly fixed and immobilized to prevent that the activities of the limbs or head and neck lead to skin flap or skin tube avulsion, particularly in the early postoperative period, for example, particular attention should be paid to the period when the patient is anesthetized and is not yet fully awake and the phase when the patient doesn't adapt to the body posture.

6.3.3 Treatment

The patients with skin flap or skin tube avulsion generally need to be transferred into the operating room for wound debridement and suture. The patient should be properly fixed, and the time from the surgery to cutting off the pedicle is required to be recalculated. Sometimes, the patients with skin flap or skin tube partial avulsion or rupture will be sutured and fixed in the ward or operating room depending on the situation.

6.4 Skin Flap or Skin Tube Infection

6.4.1 Causes

In general, the skin flap or skin tube is less likely to have serious infection in the transfer process, but in patients with severe trauma, such as electrical burns, severe pressure thermo-injury, or crush and avulsion injury, there may be some residual necrotic tissues in the wound due to the fact that the wound itself is infected or polluted more heavily, or the devitalized tissues are not identified precisely when the debridement is performed, which will lead to wound liquefaction infection; even the skin flap cannot be attached to. When the pedicle of the skin flap is cut off, because there is a wound underneath the pedicle, the blood supply is poor after cutting off the pedicle, or the suture is performed with an effort when there is a tension, so that the incision infection occurs easily or even the wound is difficult to heal.

6.4.2 Prevention

In the prevention of infection, it is necessary not only to pay attention to the general condition of the patient but also to strengthen the local treatment and take various measures to enhance the systemic resistance of the patient, such as correction of anemia and malnutrition and treatments of diabetes and diseases with immune function defect or low immune function. The aseptic techniques should be strictly applied during operation. The wound debridement in the receptor site should be performed carefully. The wound is washed repeatedly with plenty of saline solution, 3% hydrogen peroxide solution, and 1‰ benzalkonium bromide and then is disinfected; then the devitalized tissues are completely removed, and the hemostasis is performed precisely. Before the skin flap is transferred into the wound, the receptor site is washed with saline solution and benzalkonium bromide, with hydrogen peroxide solution if necessary, and it is washed with antibiotic solution under special circumstances. After the transfer of skin flap, the drainage membrane or negative pressure drainage tube should be placed to perform adequate drainage to prevent hematoma formation. In addition, the reasonable preventive application of antibiotics should be carried out.

6.4.3 Treatment

The postoperative timely observation is performed; if the signs of infection (redness, swelling, heat, pain and wound suppuration, etc.) are observed, it is necessary to timely remove the sutures, strengthen the dressing, and carry out adequate drainage. The secretions can be obtained for smear examination or bacterial culture, and the effective antibiotics are selectively used.

6.5 Bloated Skin Flap

6.5.1 Causes

The skin flap includes the skin and the subcutaneous tissue, in order to ensure the blood supply; when the skin flap is formed, a certain thickness of the subcutaneous tissue is often harvested together; therefore, after the skin flap is transferred and healed, there are still some problems such as bloated and uneven skin flap, which affect the appearance and sometimes also affect the function.

6.5.2 Prevention

When the donor site of the skin flap is selected according to the receptor site, it is required to make a comprehensive consideration, and the thickness of the skin flap is also one of the selecting factors. When the skin flap is formed, it should be trimmed as thin as possible under the premise of ensuring its blood supply and survival.

6.5.3 Treatment

After the skin flap or skin tube is transferred to the receptor site, if it is considered that the skin flap is too bloated; the thinning of skin flap can be performed after the skin flap has survived for 3–6 months (degreasing surgery). This operation often needs to be performed twice for the medium-sized skin flap, and the half portion of the skin flap is trimmed thinly every time; this operation often needs to be performed multiple times for the large-sized skin flap, while the small-sized skin flap can be trimmed thinly at a time. When the skin flap is trimmed thinly, the selected incision direction should be consistent with the longitudinal axis direction of the skin flap, and the incision is made along the outer edge of the original incision scar; the sharp dissection is performed according to the horizontal direction; the tissue scissors are used to cut off the scar tissue and part of the adipose tissue under the skin flap. Under the premise that the blood supply is not affected, the dissection is performed in a larger scope and more adipose tissues are removed as much as possible, and a thin layer of homogeneous adipose tissue is usually retained. After complete hemostasis is achieved, the skin flap edge will be properly trimmed, namely, the surrounding scar tissue and excessive skin are cut off. The wound is washed with saline solution and is interruptedly sutured, and a rubber membrane rubber is placed for drainage. A negative pressure drainage tube is additionally placed if necessary, and an appropriate compression bandage is carried out.

6.6 The Skin Wrinkles in the Pedicle

6.6.1 Causes

When the skin flap is in the transfer process, the rotation and distortion of pedicle would lead to skin wrinkle, which is commonly known as “orecchiette” and often affects the appearance; thus, it should be trimmed.

6.6.2 Prevention and Treatment

In the early stage, the blood supply of skin flap is completely provided by the pedicle, and the “orecchiette” should be trimmed according to the principle that the blood supply of the skin flap is affected. The “orecchiette” which does not affect the blood supply of the skin flap should be trimmed at the same time of skin flap transfer; the “orecchiette” which may affect the blood supply of the skin flap will be trimmed after the skin flap has survived for 3–6 weeks. The specific method is that an incision is made at the suture site with wrinkles, then a piece of excessive triangular skin is usually removed, and finally, the wound skin is flattened and sutured. Small skin wrinkles may disappear on their own over time and may not be treated.

6.7 Joint Stiffness

6.7.1 Causes

The joints often need to be immobilized for more than 3 weeks during the period between transplanting the limb skin flap and cutting off the pedicle, and the long-term immobilization can cause joint stiffness.

6.7.2 Prevention and Treatment

For patients with an age greater than 45 years or with joint diseases, the transferring skin flap which requires joint immobilization is generally not selectively used. During joint immobilization, the joins are treated with massage and physical therapy. After the stitches are taken out of the wound, the joint immobilization can be relieved, and the joints are moved slightly during the day. When the pedicle of the skin flap is cut off, the surgeon should passively move the corresponding limb joints appropriately under anesthesia; after the pedicle is cut off, the active exercises should be strengthened. These measures are conducive to preventing joint stiffness and the fast recovery of functions after the joint immobilization is removed.

7 Classification of Myocutaneous Flaps and Their Advantages and Disadvantages

The myocutaneous flap is a composite tissue flap containing skin and subcutaneous adipose tissue, deep fascia, and muscles, which takes the dominant artery and vein of the muscle as the pedicle, takes the muscle as the carrier, and carries the skin tissue on the muscle to be transferred to repair the defects. The development and application research of the myocutaneous flap has a history of nearly a century. The researches on the blood supply scopes of the myocutaneous flaps and the blood supply types of the muscles provide the anatomical basis for clinical application of the myocutaneous flap and promote the development and clinical application of the myocutaneous flap.

7.1 The Blood Supply of the Myocutaneous Flap

The blood supplies of muscles of the myocutaneous flaps mostly come from multiple sources, and there are abundant anastomoses between various branches of arteries, of which the main nutrient artery refers to an artery which has the thickest diameter and can provide the most blood supply to this muscle. In clinics, the nutrient blood vessels are mainly taken as the pedicles for skin flap transplantation. According to the number and the primary and secondary relationship of the blood vessels distributed in the muscles, the muscle blood supply is divided into five types (see detail in Sect. 3.7.2).

The blood supply of the skin on the surface of the myocutaneous flap comes from the perforating branch of myocutaneous vessels, the marginal branch of myocutaneous vessels, and the communicating branch between the subcutaneous vascular network and the blood vessels of the adjacent skin, but comes mainly from the myocutaneous artery perforator of the muscle. The myocutaneous arteries providing blood supply to the muscle come from the segmental trunk artery, and these arteries give off branches step by step after entering into the muscles, anastomose with each other to constitute the blood circulation of the muscles, and participate in the metabolism and nutrition of the muscle tissue; another part of blood vessels pass through the deep fascia in the process of giving off branches, enter into the subcutaneous tissue and skin to form into the perforating branch of the myocutaneous artery, and participate in the composition of subdermal vascular network to feed the subcutaneous tissue and skin above the muscle. Some myocutaneous arteries give off the marginal branches before entering the muscle, and enter into the subcutaneous tissues along the muscle edges, which are also involved in the blood circulation of the skin and subcutaneous tissue above the muscles.

The myocutaneous flap contains two sets of venous return systems, respectively, with shallow and deep depth; these veins have valves in addition to the head vein, in order to control the blood flow direction. The deep set of reflux veins are the accompanying veins of the myocutaneous arteries. There are mostly two reflux veins, and they are the major reflux veins of the myocutaneous flap; the shallow set of reflux veins are located within the subcutaneous adipose tissue layers and afflux into the deep set of reflux veins through the perforating veins. The nutrient arteries of the muscles often come from multiple sources. Of the arteries from multiple sources, the artery which has a larger diameter and can feed the whole muscle is the dominant artery, and the rest of the arteries are the secondary arteries.

7.2 The Classification of Myocutaneous Flaps

7.2.1 The Blood Supply Types of the Myocutaneous Flaps

According to the study of [20], the myocutaneous arteries are the main source of skin blood supply. In the further study of [21] on muscle blood supply, it was considered that the blood supplies of the myocutaneous flaps can be divided into five types.

1. The first type: Only a set of vascular pedicle enters into the muscle (Fig. 3.37), such as tensor fascia lata myocutaneous flap, rectus femoris myocutaneous flap, and medial (lateral) gastrocnemius myocutaneous flap.
2. The second type: A set of major vascular pedicle enters into the muscle close tightly to the terminating end of the muscle, while multiple sets of segmental small blood vessels enter into the muscle close tightly to the beginning end of the muscle (Fig. 3.38), such as the latissimus dorsi myocutaneous flap and the pectoralis major myocutaneous flap. When transplanting, the myocutaneous flap is formed, the secondary artery is ligated, and the major vascular pedicle is retained to guarantee the survival to of the myocutaneous flap.

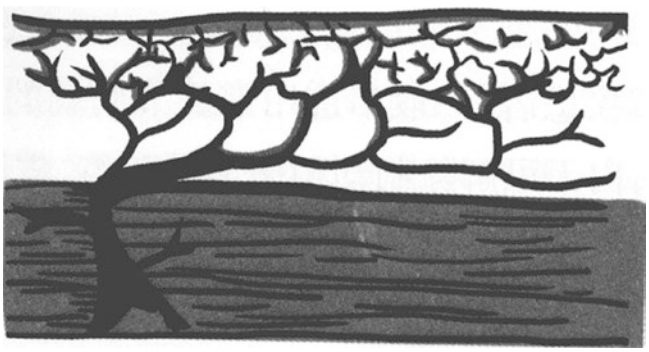

Fig. 3.37 Only one set of blood vessels enters into the muscle

Fig. 3.38 Multiple sets of segmental small blood vessels enter into the muscle

3. The third type: A set of major vascular pedicle and multiple sets of small vascular pedicles enter into the muscle, such as gracilis muscle myocutaneous flap, biceps femoris myocutaneous flap, semitendinosus myocutaneous flap, sternocleidomastoid myocutaneous flap, and peroneus longus myocutaneous flap. Its main vascular pedicle enters into the muscle from one side and provides most of the blood supply to the muscle; multiple sets of small vascular pedicles enter into the muscle from the other side and provide a small part of the blood supply of the muscle. The blood supply of the myocutaneous flap is not affected after the small blood vessels are cut off.
4. The fourth type: Two sets of main vascular pedicles enter into the muscle; each provides a half of the blood supply to the muscle, such as the gluteal myocutaneous flap and gastrocnemius myocutaneous flap (Fig. 3.39).
5. The fifth type: Multiple small blood vessels enter into the muscle, and present segmental distribution, such as the tibialis anterior muscle flap and sartorius myocutaneous flap. When the skin flap is transplanted, the integrity of the muscle and these segmental blood vessels should be maintained, in order to ensure the survival of the myocutaneous flap. If the segmental blood vessels of the muscle come from a well-known artery, and the blood supply of the limb is not affected after the distal end of the artery is cut off, the myocutaneous flap can be used for local transfer or free transplantation.

7.2.2 The Clinical Types of Myocutaneous Flap

1. Pedicled myocutaneous flap: In the periphery of myocutaneous flap, in addition to that the skin, muscles, and major blood vessels are retained in the pedicle, and the other three edges are dissected free.
2. Island myocutaneous flap: The skin in the pedicle of the pedicled myocutaneous flap is cut off to make it island-shaped; thus, it is called the island myocutaneous flap. The muscle pedicle can also be retained, or the part of or the entire muscle pedicle is cut off.
3. Free myocutaneous flap: On the basis of the island myocutaneous flap whose skin and muscle pedicle are completely cut off, the vascular pedicle is cut off again, and then is anastomosed with the blood vessel in the receptor site, which can be used to repair the distal wound.

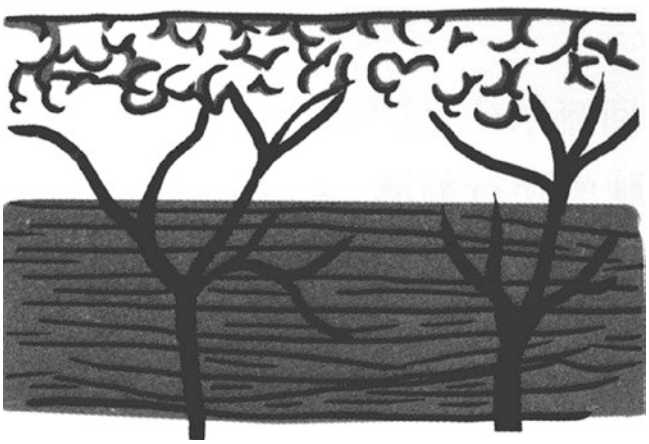

Fig. 3.39 Two sets of main vascular pedicles enter into the muscle

7.3 The Advantages and Disadvantages of the Myocutaneous Flap

7.3.1 The Advantages of the Myocutaneous Flap

1. The myocutaneous flap has a rich blood supply, which can improve the local blood supply in the receptor site after transplantation.
2. Both anti-infectious and biological scavenging effects of the myocutaneous flap are significantly stronger than those of the skin flap.
3. The myocutaneous flap has a larger area and more tissue volume, and it can be used to repair the sunken defect of large area.
4. The myocutaneous flap has a constant anatomy with a thicker vascular pedicle, which can be used for pedicled transfer or free transplantation with blood vessel anastomosis. The whole process of the transfer can often be completed by an operation, and the survival rate is high.
5. The myocutaneous flap can carry the nerves controlling the muscle, which can be anastomosed with the motor nerves in the receptor site, not only to repair the tissue defects but also improve the local functions. It can also carry the bone tissue to repair the wound with bone defects.
6. The myocutaneous flap is soft and pressure and wear resistant, and it is a kind of ideal tissue flap for repairing the bedsores.

7.3.2 The Disadvantages of the Myocutaneous Flap

1. The muscle strength is weakened in the donor site.
2. There is an obvious deformity in the donor site.
3. The myocutaneous flap is bloated in the receptor site.

8 Commonly Used Flaps in Oncoplastic Surgery

8.1 Deltopectoral Skin Flap

8.1.1 Applied Anatomy

The blood supply of the deltopectoral skin flap (Fig. 3.40) comes mainly from the first to fourth perforating branches of the internal thoracic artery and the cutaneous branch of the

Fig. 3.40 The range for harvesting the deltopectoral skin flap (perforating branches of the internal thoracic artery) and the blood supply

thoracoacromial artery. The outer diameter of the second perforating artery is the thickest; thus, the second perforating artery should be preferably selected as the vascular pedicle of the deltopectoral skin flap. The first to fourth perforating branches penetrate out of the intercostal spaces from the sites 1 cm beside the sternum, pass through the pectoralis major muscle and pectoralis major fascia, and run outward 10–12 cm within the subcutaneous superficial fascia. There are a wide range of anastomoses between the various perforating branches, as well as the perforating branches and the cutaneous branch of the thoracoacromial artery.

8.1.2 Indications

The pedicled skin flap or island skin flap transplantation can be performed to repair faciocervical defects and carry out reconstructions of the pharynx and esophagus, and the free skin flap transplantation can be performed to repair the soft tissue defects in the trunk and limbs.

8.1.3 Skin Flap Design

The range of the skin flap: The upper boundary is the lower edge of the clavicle, the lower boundary is the fifth rib, the inner boundary is the parasternal line, and the outer boundary is the shoulder peak. Generally, the length is designed as 20–22 cm, and the width is designed as 10–12 cm. The rotation axis of the skin flap is located in the second to third intercostal space on the outer edge of the sternum.

8.1.4 The Harvesting of the Skin Flap

The outline of the skin flap and the directions of blood vessels are drawn up with methylene blue, and the points where the perforating branches of the internal thoracic artery come out from the intercostal spaces are marked. The skin is incised open from the acromial end to the area under the deep fascia, so that the pectoralis major muscle, deltoid muscle, and platysma myoides are visible. The lateral margin of the skin flap is lifted, and the skin flap is dissected sharply between the surface of the deltoid muscle and deep fascia and inward from the outer edge. The cephalic vein within the deltopectoral groove, the deltoid muscle branch of the thoracoacromial artery, the second and third perforating arteries and veins beside the sternum, and the anterior cutaneous branches of the intercostal nerves should be protected well during the operation.

8.2 Lateral Thoracic Skin Flaps

8.2.1 Applied Anatomy

The blood supplies of the lateral thoracic skin flaps come from the axillary-thoracic cutaneous artery of the axillary artery (15%), the brachial-thoracic cutaneous artery of the brachial artery (37%), the cutaneous artery of the thoracodorsal artery (47%), and the cutaneous artery of the lateral thoracic artery (77%). Body surface projection: The lateral thoracic artery runs downward between the anterior axillary line and the midaxillary line and reaches to the sixth and seventh intercostal space. The axillary-thoracic cutaneous artery runs downward along the midaxillary line or the area slightly in front of this line and reaches to the fourth intercostal space. The cutaneous artery of the thoracodorsal artery runs downward along the posterior axillary line or the area slightly in front of this line and reaches to the sixth and seventh intercostal space. The thoracoepigastric vein runs upward to flow into the axillary vein, then it runs downward to anastomose with the superficial epigastric vein, and finally, it runs forward to anastomose with the perforating branch of the internal thoracic vein. The lateral thoracic artery and thoracodorsal artery are commonly used as the vascular pedicles of the lateral thoracic skin flaps.

8.2.2 Indications

The island flap transfer is applicable to repairs of a larger range of tissue defects in the shoulder, front chest, upper arm, and elbow. The free transplantation with vascular anastomosis is applicable to repairs of the scalp defects with large-area skull exposure and the limb wounds with exposures of bones, joints, tendons, nerves, and blood vessels. The combined skin flap is applicable to repairs of large tissue defects.

8.2.3 Skin Flap Design

The range of skin flap: The upper boundary reaches up to the place where there exist axillary artery pulses; the lower boundary is the eighth intercostal space; the anterior boundary is the lateral edge of the pectoralis major muscle; and the posterior boundary is the front edge of the latissimus dorsi muscle. If the outer edge of the chest is taken as the center to design to the skin flap or the thoracodorsal artery is taken as the axial pattern blood vessel, it is necessary to relocate outward the posterior boundary, and the skin flap is designed taking the front edge of the latissimus dorsi muscle or the running direction of the thoracodorsal artery as the center.

8.2.4 Skin Flap Harvesting

Incise open the skin according to the design drawing line; expose the deep fascia in the thoracic area under the armpit; ligate the cutaneous arteries and veins in the edges of the skin flap. The skin incision reaches the area under the deep fascia, lifts the lower edge of skin flap, and retrogrades upward to look for the vascular pedicle to directly reach the blood vessels. Carefully separate the larger cutaneous arteries and veins which run into the skin flap, or dissect out the lateral thoracic artery, and extend the length of the vascular pedicle, which are conducive to skin flap transfer.

8.3 Lower Abdominal Skin Flap

8.3.1 Applied Anatomy

The blood supply of the lower abdominal skin flap comes from the superficial epigastric artery, and the appearance rate is 97%. Generally, the superficial epigastric artery is given off by the femoral artery at 5 cm under the inguinal ligament, and the outer diameter is about 0.8–1.0 mm. It is usually divided into two branches such as inner and outer branches, which run through the deep layer of abdominal wall superficial fascia. The appearance rate of the medial branch is 68%, and the average outer diameter is 1.0 mm, which is distributed to the ipsilateral medial half of the lower abdomen; the appearance rate of the lateral branch is 66%, and the average outer diameter is 0.9 mm, which is mainly distributed to the ipsilateral outer half of the lower abdomen. The venous blood flows back into the superficial epigastric veins and finally pours into the great saphenous vein (Fig. 3.41).

8.3.2 Indications

The skin flap is for repair of defects in the groin and perineum and the areas in upper limbs such as the hand, wrist, and part forearm.

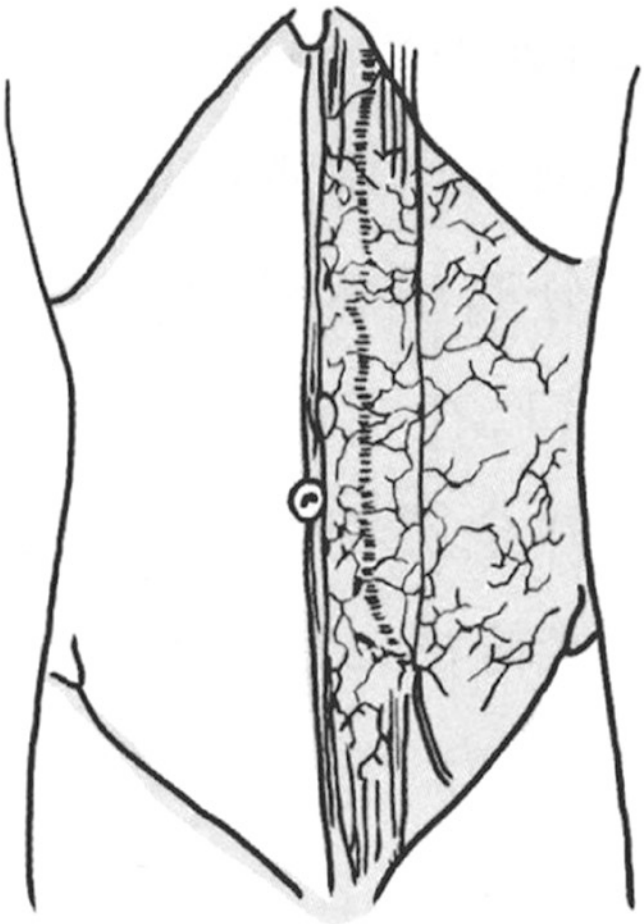

Fig. 3.41 The applied anatomy of the lower abdomen skin flap

8.3.3 Skin Flap Design

The pulsating point of the femoral artery is palpated under the inguinal ligament, and then a connecting line is made between this pulsating point and the navel. This line is the body surface projection line of the superficial epigastric artery, which is the axis line of the skin flap. The size of the harvested skin flap is determined according to the need of the receptor site. In general, the inner boundary does not exceed the abdominal midline, and the upper boundary does not exceed the navel. The range for skin flap harvesting is 28 × 18 cm.

8.3.4 Skin Flap Harvesting

Incise open the skin according to the design drawing line of the skin flap, and expose the superficial epigastric artery within the subcutaneous superficial fascia. Incise open the superficial fascia in the lower abdomen; lift the upper end of the skin flap; dissect the skin flap downward on the ten-

don membrane surface of the obliquus externus abdominis muscle; dissect and expose the trunk of the superficial epigastric artery and the superficial epigastric vein; pay attention to protecting the vascular pedicle of the skin flap during surgery.

8.4 Groin Skin Flap

8.4.1 Applied Anatomy

The superficial iliac circumflex artery is the main blood vessel of the groin skin flap. The trunk length is 1 cm, and the average outer diameter is 1.3 mm. This artery penetrates through the oval fossa and slopes obliquely toward the upper outer side to reach the anterior superior iliac spine, whose branches anastomose with the branches of the superficial epigastric artery along the way to form the superficial arterial network. The average outer diameter of the accompanying veins is 2.1 mm. The venous blood flows back into the great saphenous vein, and the latter is closely accompanied with the superficial iliac circumflex artery, converges into the deep vein, and converges into the femoral deep vein in some patients. Body surface projection: A connecting line is made between the site at 1.5 cm under the starting point of the femoral artery and the anterior superior iliac spine, which is the projection line of the running direction of the trunk of the superficial iliac circumflex artery.

8.4.2 Indications

The island flap transfer can be performed to repair the defects in the adjacent areas such as perineum and the greater trochanter of the femur. The single-pedicle and axial pattern skin flap is mainly used for one-stage repair of extensive and complex emergency trauma in the hand, wrist, and forearm, but it is also used for late repairs of the soft tissue defects caused by burns or trauma and the secondary deformities. Free transplantation can be used for repairs of defects in the limbs, face, and neck. Generally, it is not taken as a first choice.

8.4.3 Skin Flap Design

A connecting line is made between the site at 1.5 cm under the starting point of the femoral artery and the anterior superior iliac spine, which is the projection line of the running direction of the trunk of the superficial iliac circumflex artery, and this line is taken as the axis line to design the skin flap. The range for skin flap harvesting: The upper boundary is the site at 5 cm above the inguinal ligament; the lower boundary is the site at 6–10 cm below the inguinal ligament; the inner boundary is the site at 2–4 cm in the medial side of the pulsating point of the femoral artery; the iliac spine is taken as the axis line of the outer boundary, and a connecting line is made obliquely toward the lateral edge of musculus sacrospinalis, whose length is up to 26 cm.

8.4.4 Skin Flap Harvesting

Lift the skin flap from the distal end, which is not needed to expose the vascular pedicle; or expose the vascular pedicle, and determine the site where the skin flap harvesting is performed after confirming the running direction and variation statuses of the blood vessels.

1. The method with the exposure of the vascular pedicle: Under the inguinal ligament, a 4–6 cm longitudinal incision is made at the site which is located slightly medially to the pulsating point of the femoral artery. Find the great saphenous vein, and then find the femoral artery, the trunk of the superficial iliac circumflex artery running toward the upper outer side, and its deep and shallow main branches along the lateral side of the femoral vein, and confirm the statuses of its branches and whether there is a variation. Draw the outline of the skin flap to be harvested according to the characteristics revealed by the exposed blood vessels. Make an incision in the upper side at first; incise open the full-thickness skin to directly reach the external oblique tendon membrane, and then make a sharp separation close onto it. When the adjacent area of the trunk of the superficial iliac circumflex artery is separated, it is necessary to include the myolemma of the sartorius muscle and some muscle fibers, in order to avoid damage to this blood vessel. After that, a distal incision is made, and the incision plane of the skin flap can be thinner under the condition of clearly observing the running direction of the shallow trunk. The fascia is incised open on the distal side of the site where the superficial main branch penetrates through the fascia lata, and the underneath full-thickness tissue is incised open to directly reach the area under the fascia. The whole skin flap is completely lifted, and only the vascular pedicle is retained. After the receptor site is prepared well, the island flap transfer can be carried out immediately or the vascular pedicle is cut off to perform the free transplantation with vascular anastomosis.
2. The method without the exposure of the vascular pedicle: A dotted line is drawn from the pulsating point of the femoral artery at 1 cm under the inguinal ligament to the anterior superior iliac spine, and then the line turns obliquely to the outer upper side and extends to the level of the navel. A short vertical line is drawn from on this dotted line at the site with a distance of 1 cm from the artery, which is taken as the marker for the superficial out-point where the superficial iliac circumflex artery penetrates through the femoral fascia. Make an incision in the upper side at first, incise open the full-thickness skin to directly reach the deep fascia, and perform sharp dissection along its superficial surface. After the inguinal ligament is exceeded, the superficial main branch can be clearly observed; if there is no anatomic variation, the deep main branch can be ligated at the site where the deep main branch penetrates through the deep fascia; if the dissection exceeds the axis line, after it is

confirmed that the superficial main branch is included in the skin flap, the incisions in the outer and lower sides can be made immediately.

8.5 Anterolateral Thigh Flap

8.5.1 Applied Anatomy

The anterolateral thigh flap takes the descending branch of the lateral femoral circumflex artery (Fig. 3.42) as the vascular pedicle. This blood vessel runs downward the outer lower side between the rectus femoris muscle and vastus intermedius muscle, and runs down outward between the vastus lateralis muscle and the rectus femoris muscle (Fig. 3.43), which gives off four to nine myocutaneous arteries when passing through the midpoint of the connecting line between the anterior superior iliac spine and the outer upper edge of the patella, of which the perforating branch of the first myocutaneous artery is thick and large with an outer diameter of 0.5–1.0 mm, and it is the main blood vessel providing blood supply to the anterolateral thigh flap. A line from the groin midpoint to the midpoint of the connecting line between the anterior superior iliac spine and the outer upper edge of the patella is drawn on the body surface, and the lower two thirds segment of this line is the body surface projection of the descending branch of the lateral femoral circumflex artery. The origin types of various branches of lateral femoral circumflex artery are shown in Fig. 3.44.

8.5.2 Indications

The antegrade transfer of skin flap pedicled with the descending branch of the lateral femoral circumflex artery is used to repair the soft tissue defects in the lower abdomen, buttocks, and hips. The retrograde transfer of retrograde skin flap pedicled with the genicular artery can be used to repair the wounds in the knee joint and its surrounding areas. The free skin flap transplantation with vascular anastomosis is used to repair the distal soft tissue defects.

Fig. 3.42 The blood supply of the anterolateral femoral skin flap (the descending branch of the lateral femoral circumflex artery)

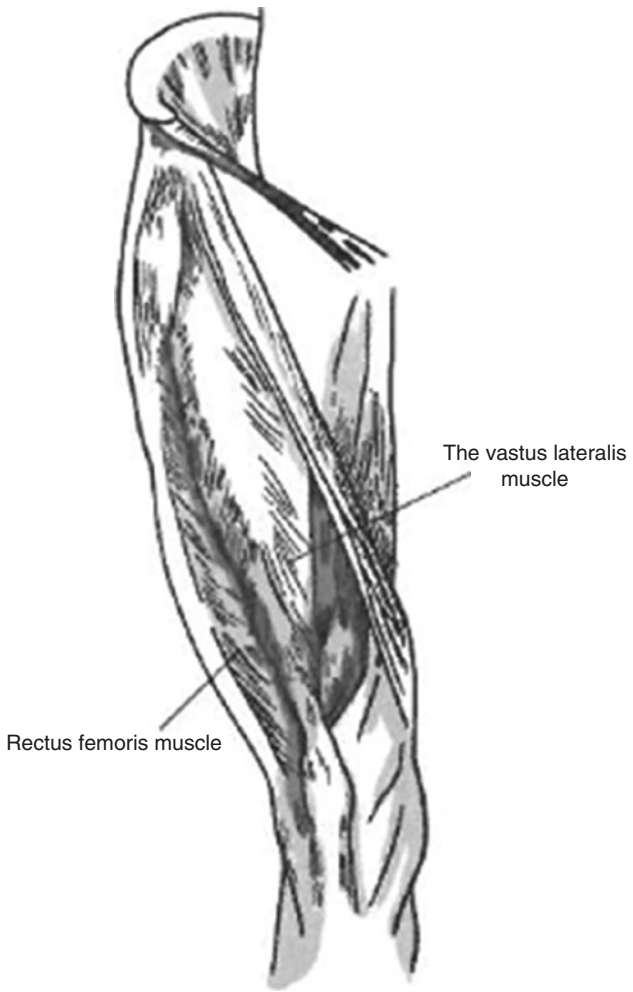

Fig. 3.43 The rectus femoris muscle and the vastus lateralis muscles

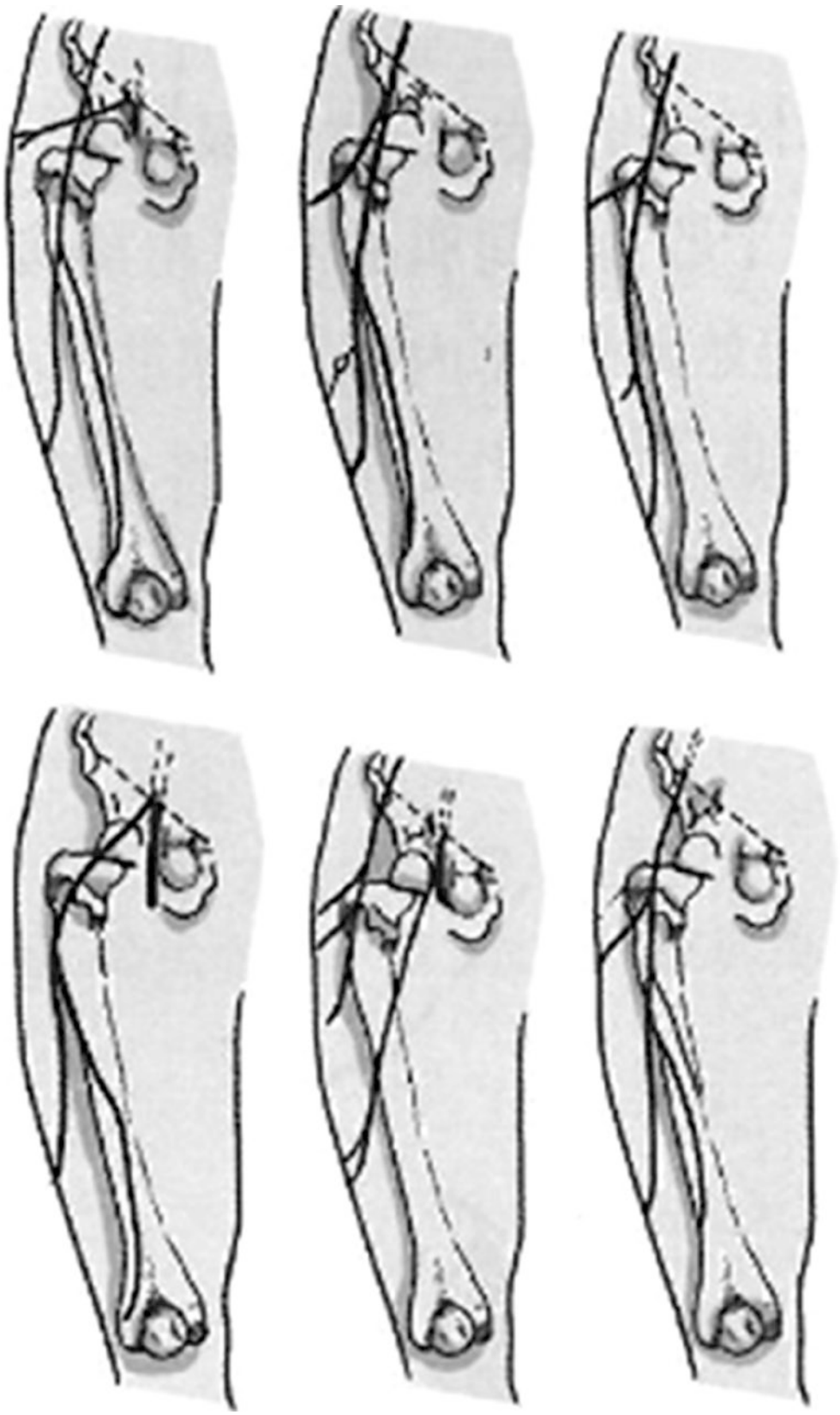

Fig. 3.44 The origin types of various branches of the lateral femoral circumflex artery

8.5.3 Skin Flap Design

The body surface projection of the descending branch of the lateral femoral circumflex artery is marked with the methylrosanilinium chloride, and a circle is made using the midpoint of the connecting line between the anterior superior iliac spine and the outer upper edge of the patella as the center of the circle and with a radius of 3 cm; the myocutaneous perforator and the intermuscular cutaneous branch penetrate superficially into the subcutaneous area mainly within this circular area and concentrate in the outer one fourth area of this circle (Fig. 3.45). The pure skin flap repair or the composite tissue flap with part of the vastus lateralis muscle, femoral fascia, nerves, and blood vessels is designed and made according to the need of repair.

8.5.4 Skin Flap Harvesting

Incise open the skin, subcutaneous fat, and deep fascia along the body surface projection line of the descending branch of the lateral femoral circumflex artery, and extend to the medial side of the skin flap; separate from the lateral side of the rectus femoris muscle to the intermuscular space; separate out the descending branch of the lateral femoral circumflex artery and its accompanying veins within the clearance between the rectus femoris muscle and the vastus intermedius muscle; separate the blood vessel bundle toward the proximal end to its origin area; and then perform skin flap separation under the deep fascia starting from the medial side of the skin flap (Fig. 3.46). To prevent the impact of separation of the fascia from the skin on the blood supply, it is necessary to perform several sutures to fix the edges of the two. The skin flap is lifted outward; when the separation is performed into the marked circular area, attention should be paid to the superficial branch coming out of the deep layer. After that, separate along the vascular pedicle, and identify and dissect the myocutaneous perforators to meet the lifted skin flap to ensure that 2–3 artery perforators are included. Then incise open the lower edge and the outer edge of the skin flap; completely separate and lift the entire skin flap; perform pedicled or free transplantation according to the surgical plan.

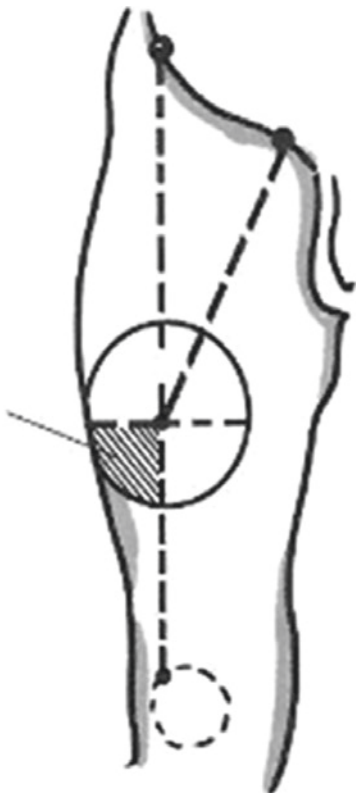

Fig. 3.45 The schematic diagram of the anterolateral femoral skin flap design. The area where the myocutaneous perforator and the intermuscular cutaneous branch penetrate out

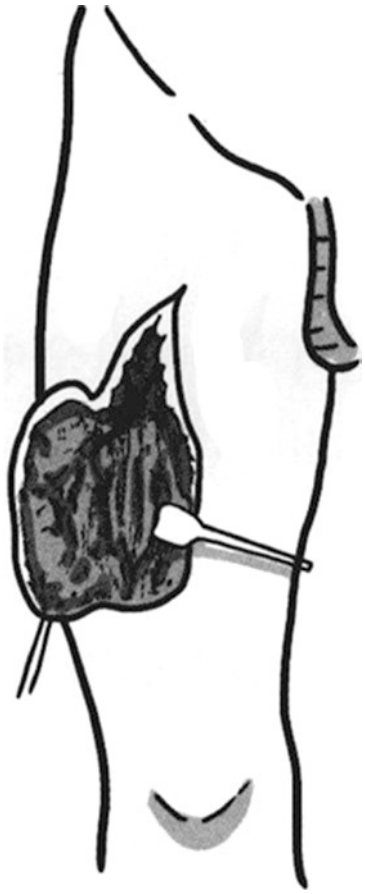

Fig. 3.46 Harvesting of the anterolateral femoral skin flap

8.6 Medial Femoral Skin Flap

8.6.1 Applied Anatomy

The main cutaneous arteries of the medial femoral skin flap (the skin flap with the cutaneous branch of the femoral artery) are originated from the medial wall of the main artery, and 1–3 cutaneous arteries have accompanying veins, which run obliquely downward to the inner side along the deep surface of the sartorius muscle, and penetrate out of the medial side of this muscle to reach the skin in the medial femoral region. The outer diameter of the starting area of the blood vessel is 1.0–1.2 mm, and the vascular pedicle length is 2.1–2.2 cm. The saphenous vein passes through the skin flap.

8.6.2 Indications

The skin flap has fine texture, moderate thickness, and hidden location and can carry sensory nerves, which is a good skin tissue flap to repair the skin tissue defects of medium size in sites such as the head and neck, chest and abdomen, perineum, feet, and hands.

8.6.3 Skin Flap Design

An incision is made at 2 cm outside of the middle 1/3 connecting line from the place in groin where the femoral arterial pulsation is mostly obvious to the medial side of the knee joint, and the incision is parallel to connecting line and has a length of 10 cm. The cutaneous artery is usually dissected out at first, then the skin flap is designed, and the area for skin flap harvesting is 17 × 7 cm.

8.6.4 Skin Flap Harvesting

Incise open the skin, subcutaneous fat, and femoral fascia; separate out the shallow surface of the sartorius muscle to its medial side; pull open the muscle outward to expose the trunk of the femoral artery and its branches within the medial femoral intramuscular septum; carefully separate the main cutaneous arteries in the medial thigh and their accompanying veins and the medial femoral cutaneous nerves. Incise open the skin flap according to the design scope of the skin flap; lift the skin flap on the deep surface of the femoral fascia, and include the femoral fascia into the skin flap. The pedicled transfer or free transplantation can be performed (Fig. 3.47).

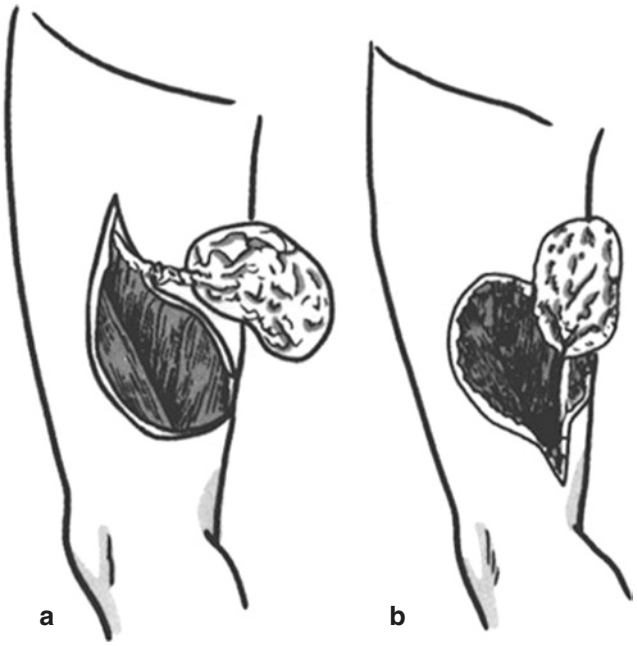

Fig. 3.47 Schematic diagram of the medial femoral skin flap formation. (**a**) Medial femoral skin flap formation. (**b**) Medial femoral retrograde skin flap formation

8.7 Medial Knee Skin Flap

8.7.1 Applied Anatomy

The saphenous artery in the medial knee skin flap (saphenous arterial skin flap) originates from the descending genicular artery; after being given off at a level of 13 cm above the knee, it passes through the adductor canal and runs downward with the saphenous nerve to reach the level of the knee joint and penetrates superficially into the subcutaneous area, then runs in the medial calf, and gives off branches along the way to feed the skin tissues. Its accompanying veins and the saphenous vein can be used as the returning veins. The outer diameter of the beginning part of saphenous artery is about 1.7 mm, and the range for skin flap harvesting starts from the upper site at 10 cm above the knee to the lower site at the junction of the middle and lower third of the medial calf.

8.7.2 Skin Flap Design

A marker line which is parallel to the longitudinal axis of the lower limb is made in the middle of the medial side of the knee joint, and this line is the designed axis line of the skin flap. According to the need of repair of the receptor site, the skin flap can be designed in the areas at 5 cm away along both sides of the axis line and within the range from the upper site at 10 cm above the knee to the lower site at 20 cm below the knee (Fig. 3.48).

8.7.3 Skin Flap Harvesting

Incise open the skin in the proximal side of the skin flap at first; incise open the deep fascia along the front edge of the sartorius muscle; separate out the saphenous blood vessels and the saphenous nerves from the intermuscular space between the sartorius muscle and the medial vastus muscle. Incise open the front edge of the skin flap, and lift the skin flap backward under the deep fascia. When the separation and dissection are performed, several sutures are made to

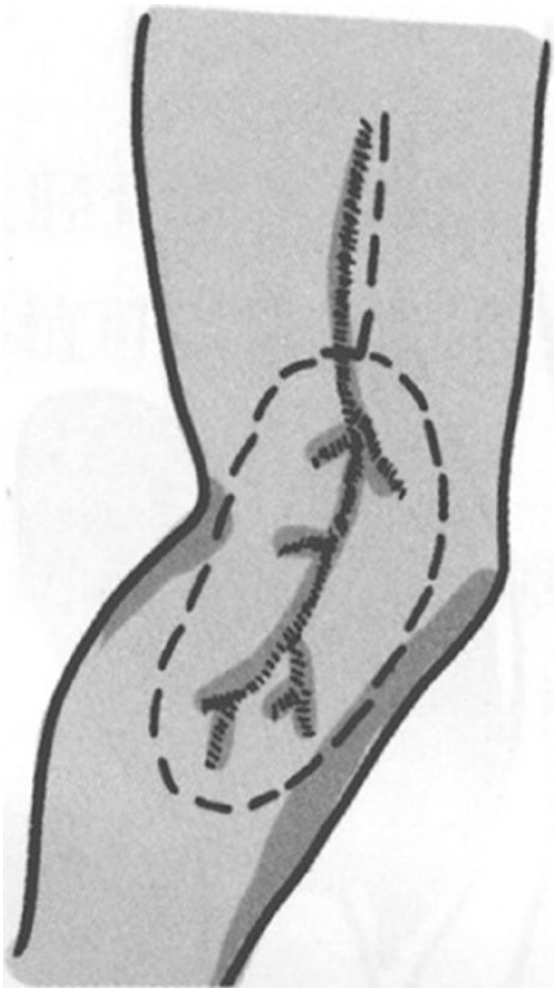

Fig. 3.48 Schematic diagram of the range of the saphenous arterial skin flap in the medial upper calf

temporarily fix the edges of the deep fascia and the skin. Incise open the distal side and posterior side of the skin flap, separate the skin flap to the pedicle, and completely lift up the entire skin flap.

8.8 Medial Crural Skin Flap

8.8.1 Applied Anatomy

The medial crural skin flap (posterior tibial arterial skin flap) takes the posterior tibial artery as the pedicle, which can be used for retrograde or antegrade transfer. The outer diameter of the posterior tibial artery is 2.5–3.5 mm, which runs downward within the intermuscular space, and the upper segment is located in the deep surface of the soleus muscle, so the location is deeper; the middle segment is located between the flexor digitorum longus and soleus muscle, penetrating superficially out between the medial malleolus and the Achilles tendon, which is divided into the medial plantar artery and the lateral plantar artery when reaching the deep surface of ligamentum laciniatum. The lateral plantar artery anastomoses with the deep plantar branch of dorsalis pedis artery to form into the arcus plantaris. In the process of traveling, the posterior tibial artery gives off the muscular branches and the cutaneous branches along the way; the latter are most commonly given off in the vicinity of the junction of the middle and lower segments. The returning veins of skin flap include not only the great saphenous vein but also two veins accompanying the artery. The blood refluxes toward deeply into the posterior tibial vein, and the remaining shallow subordinate branches join into the great saphenous vein in the superficial fascia. The saphenous nerve passes through the skin flap area, and this nerve runs accompanying the great saphenous vein.

8.8.2 Indications

The anterograde transfer of pedicled skin flap can be used to repair the defects around the knees, and the retrograde transfer of pedicled skin flap can be used to repair the defects in ankles and foots. The free transplantation with vascular anastomosis can be used to repair the distal defects or ulcers.

8.8.3 Skin Flap Design

A connecting line is made from the medial malleolus of tibial condyle to the midpoint between the medial malleolus and the Achilles tendon; the middle and lower segments of this line are the body surface projection line of the sites for various cutaneous branches of the posterior tibial artery to penetrate superficially out of the fascia, and this line is taken as the axis line to design the skin flap. The range for skin flap harvesting starts from the upper site at the junction of the upper and middle third of the calf to the lower site at the level above the medial malleolus, and the two sides are the anterior and posterior median lines.

8.8.4 Skin Flap Harvesting

A longitudinal incision is made between the medial malleolus and the Achilles tendon. The incision starts up from the lower edge of the skin flap and reaches down to the site above the ligamentum laciniatum. The skin is incised to reach the deep fascia; the posterior tibial artery and vein are separated out from the loose tissue between the Achilles tendon and the medial malleolus; the separation is performed along the proximal blood vessel to the lower edge of the skin flap. The incision is extended along the posterior edge of the skin flap up to its upper end; the skin is incised to reach the deep fascia directly; several sutures are made to temporarily fix the edges of the deep fascia of skip flap and the skin. The dissection is performed under the deep fascia and close to the myolemma of the gastrocnemius muscle to directly reach the medial edge of the soleus muscle. Two to seven cutaneous

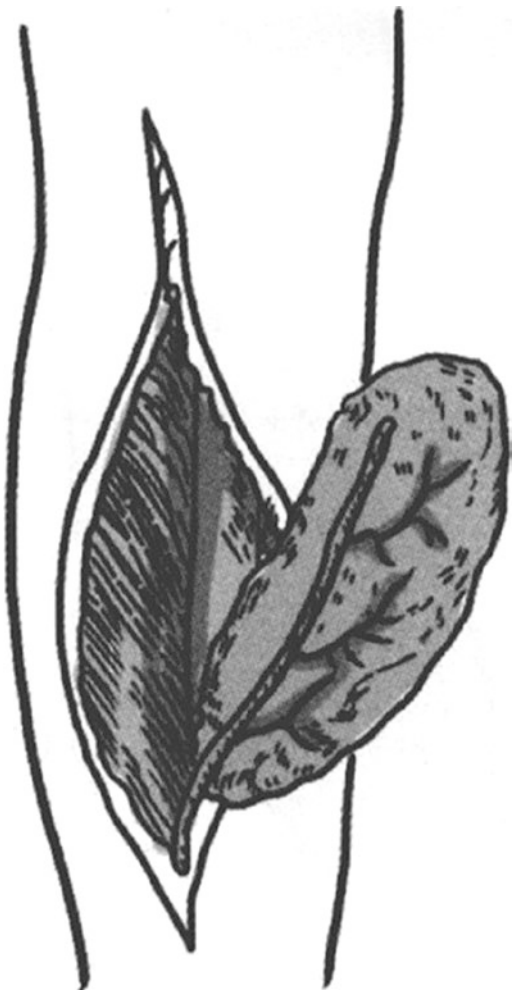

Fig. 3.49 Schematic diagram of the formation of the retrograde skin flap in the medial calf

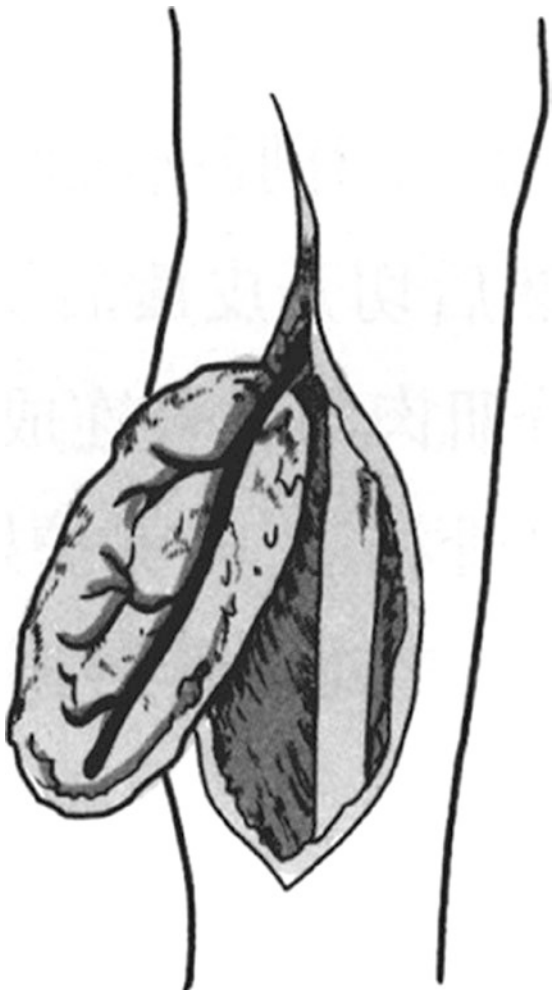

Fig. 3.50 Schematic diagram of the formation of the anterograde skin flap in the medial calf

arteries are observed in the vicinity of the body surface projection line of the sites for the cutaneous branches of the posterior tibial artery to penetrate superficially out, and the outer diameter is 0.5–2.0 mm, which pass through the intermuscular space between the soleus muscle and the flexor digitorum longus and penetrate superficially out of the deep fascia in the calf. Pull the muscle toward the rear to expose the intermuscular space between the soleus muscle and the flexor digitorum longus; separate the posterior tibial artery and vein to the proper length in the intermuscular space; ligate and cut off the posterior tibial artery and vein; retain the tibial nerve. Then incise open the skin and fascia at the front edge of skin flap, and separate and lift up the skin flap to form the skin flap with the vascular pedicle at the lower end for retrograde transplantation (Fig. 3.49).

If it is needed to the form the skin flap with the vascular pedicle at the upper end, the dissection is continuously along the proximal blood vessel in the intermuscular space between the soleus muscle and the flexor digitorum longus to the site above the middle segment of the calf vein. The blood vessel gradually runs into the deep surface and doesn't give off the cutaneous branches again. After dissecting the blood vessel to the desired length, ligate and cut off the posterior tibial artery and vein at the lower end of the skin flap, and lift the skin flap to form the skin flap with the vascular pedicle at the upper end for anterograde transplantation (Fig. 3.50).

8.9 Lateral Crural Skin Flap

8.9.1 Applied Anatomy

The lateral crural skin flap (fibular skin flap) takes the peroneal artery as the vascular pedicle, which does not sacrifice the major arterial trunks of the lower extremity. The area of the skin flap is large, which can carry some muscles and fibula, and can be used not only for pedicled transfer but also for free transplantation. After being given off from the posterior tibial artery, the peroneal artery clings closely to the posterior

tibial muscle to run downward and outward, and runs in the clearance behind the fibula, in front of the posterior tibial muscle and beside the outer lateral surface of flexor hallucis longus; it gives off muscular branch, fibular nutrient artery, arciform artery, communicating branch, and perforating branch along the way. Of which, the appearance rate of the superficial peroneal artery given off at 4.7 cm below the capitula fibula is 100%, and the outer diameter at the start point is 1.0 mm, which passes through between the extensor digitorum longus and the long fibular muscle, penetrates out of the deep fascia at the midpoint of the lateral side of the calf, and then is divided into two branches such as deep and shallow branches. The shallow branch is shorter and is distributed in the middle segment of the lateral calf skin; the deep branch is long and thin, which continues to run forward and gives off branches such as peroneal longus muscle branch and superficial peroneal nerve branch along the way, whose terminal branch and shallow branch, the cutaneous branch of the anterior tibial artery and the cutaneous branch of peroneal artery perforator, form a rich anastomotic network in the lateral side of the calf. In addition, the peroneal artery branch also gives off a number of larger cutaneous arteries within the range of 9–20 cm below the fibular head and penetrates superficially into the subcutaneous area along the clearance between the edge of the fibula and the soleus muscle. These branches anastomose with each other and also have rich traffic anastomoses with the adjacent branch arteries.

8.9.2 Indications

The anterograde transfer of pedicled skin flap can be used to repair the skin tissue defects in the knee and tibialis anterior area. The retrograde transfer of pedicled skin flap can be used to repair the skin tissue defects in the ankle and the lower segment of the calf. The free transplantation with vascular anastomosis can be used to repair the distal skin tissue defects of medium size.

8.9.3 Skin Flap Design

A connecting line is made from the capitula fibula to the lateral malleolus, and this connecting line is the body surface projection of the clearance between the muscles in the lateral side of the calf; in addition, the midpoint of this connecting line is the main site where the cutaneous artery penetrates superficially into subcutaneous area. Therefore, when the free skin flap is designed, it is appropriate to take this site as the center. When the pedicled skin flap is designed, the center should be located slightly backward; and the small saphenous vein is included into the skin flap. The range for skin flap harvesting in adults is 30 × 16 cm.

8.9.4 Skin Flap Harvesting

Incise open the anterior edge of the skin flap to directly reach the deep fascia, and separate the posterior lateral edge side of skin flap under deep fascia. When the separation is performed close to the midpoint of the intermuscular space of the lateral muscles, attention should be paid to observe the cutaneous branches or myocutaneous branches penetrating out from the intermuscular space or the soleus muscle. Of which, the thickest blood vessel is selected as the center of the skin flap, and the skin flap design is adjusted. The skin around the skin flap and the deep fascia are incised open according to the design; the separation is performed toward the central part of the skin flap under the fascia; the muscle belly is separated along the area around the selected blood vessel; 0.5 cm muscle sleeve is retained; the surrounding small blood vessels are ligated to directly reach the trunks of the peroneal artery and vein.

1. When the anterograde transfer is performed, the separation is continued along the proximal end of the vascular trunk to an appropriate length, in order to facilitate the transfer.
2. When the retrograde transfer is performed, the main trunks of peroneal artery and vein are ligated and cut off, and the separation is carried out along the main trunks of the blood vessels to the distal ends to reach the area near to the ankle joint, in order to prepare for the transfer.
3. When the free skin flap is formed, the muscular branches given off from the vascular trunks are ligated. The separation is carried out along the vascular trunks to the proximal ends which are given off from the posterior tibial artery and vein, and the vascular trunks are taken as the vascular pedicle. After the receptor site is well prepared, the vascular pedicle is cut off.
4. The size of the skin flap and the length of the fibula are determined and designed according to the range of the skin or mucous membrane defects and the length of the bone defect. The skin flap is designed in the outside of the middle segment of the fibula, and the intermuscular space between the lateral soleus muscles is included in the skin flap. Enter from the incision in the front edge of the skin flap; after reaching the fibula, 0.5 cm of long fibular muscle sleeve is retained, and the intermuscular space between the long and short peroneal muscles is protected. The pretibial muscle group is pulled apart and the interosseous membrane is incised open. The fibula is cut off in the predetermined bone cutting site at the lower end of the fibula bone, and the distal peroneal artery and vein are also ligated and severed at this site. Then the posterior edge of the skin flap is incised open, and the integrities of the muscle sleeves and the intermuscular space between the lateral soleus muscles are retained with the same method. Therefore, the skin flap is connected with some muscles and the fibula as a whole through the intact intermuscular space. The broken ends

of fibula are pulled outward, and the upper interosseous membrane is cut off continuously to expose the proximal peroneal artery and vein and make them connected with the fibula, and then the arciform artery given off by the peroneal artery is protected. The fibula is cut off at the designed upper end, the proximal peroneal artery and vein are further separated to the site where the peroneal artery is given off from the posterior tibial artery, and then the peroneal artery and vein are ligated and severed. The superficial peroneal nerve is separated and cut off in the neck of the capitula fibula. So far, the fibular skin flap is completely separated.

8.10 Anterolateral Crural Skin Flap

8.10.1 Applied Anatomy

The anterolateral crural skin flap is the intermuscular septum blood vessel flap pedicled with the superficial peroneal artery. The artery is originated from the anterior tibial artery at 4.6 cm under the capitula fibula, which runs downward between the long peroneal muscle and extensor digitorum longus in the anterolateral side of the calf and runs along with the superficial peroneal nerve closely. This artery penetrates out of the intermuscular space at 14 cm under the capitula fibula and runs downward within the deep fascia, and then penetrates superficially out of the deep fascia at 22 cm under the capitula fibula and enters into the skin flap, and the outer diameter of the blood vessel is about 0.8–1.0 mm. In the subcutaneous area, the superficial peroneal artery from the anterior tibial artery is widely anastomosed with the intermuscular septum cutaneous artery from the anterior tibial artery and the intermuscular septum cutaneous artery from the peroneal artery. The trunk of the peroneal artery can also be used as the vascular pedicle, thus increasing the area of the skin flap in the donor site and the length of the vascular pedicle.

8.10.2 Indications

The anterograde pedicled transfer can repair the skin soft tissue defects in knee and anterior tibial area. The retrograde pedicled transfer can repair the skin soft tissue defects in ankle and the lower segment of the calf. The free transplantation with vascular anastomosis can repair the distal skin tissue defects of medium size.

8.10.3 Skin Flap Design

The anterolateral intermuscular septum in the calf, namely, the connecting line between the capitula fibula and lateral malleolus, is taken as the axis line. In clinic, the skin flap of 25 × 10 cm is harvested within the range of 9–28 cm below the capitula fibula tip according to the size and location of receptor site.

8.10.4 Skin Flap Harvesting

According to the axis line of the anterolateral intermuscular septum in the calf, the surrounding skin of the skin flap is incised open to reach underneath the deep fascia along the drawing line; expose the long and short peroneal muscles and the extensor digitorum longus muscle in the lateral side of the calf. Put forward the extensor digitorum longus, and find out the superficial peroneal nerve and peroneal artery and vein within the anterolateral intermuscular septum in the calf. Dissect downward along the peroneal artery and the superficial peroneal nerve to reach the skin flap, and then incise open the posterior edge of the skin flap and separate forward the whole skin flap, and separate the superficial peroneal artery pedicle proximally to the beginning part, so as to form the island skin flap which takes the proximal blood vessel as the pedicle. It is noted that the cutaneous arteries included in the skin flap should be protected during the surgery.

8.11 Medial Malleolus Skin Flap

8.11.1 Applied Anatomy

The blood supply of the medial malleolus skin flap is the posterior tibial artery, which gives off two cutaneous arteries between flexor digitorum longus and triceps surae muscle at 4 and 6.5 cm above the medial malleolus to feed the medial lower third of skin in the calf. The skin flap takes the two cutaneous arteries as pedicles to form into the medial malleolus skin flap, which can be used to repair the distal wounds in ankle and the calf. The skin flap contains the great saphenous vein and the saphenous nerve.

8.11.2 Skin Flap Design

A connecting line is made between the medial condyle and medial malleolus, which is taken as the axis line of the skin flap. The axis of the skin flap is generally at 7 cm above the medial malleolus, and the proximal end of the skin flap up can reach the site at10 cm below the knee. The range for skin flap harvesting is designed according to the size of the wound in the receptor site.

8.11.3 Skin Flap Harvesting

Incise open the skin and subcutaneous superficial fascia to reach to the deep fascia in the calf according to the design drawing line, and expose the great saphenous vein, saphenous nerve, and the lower end of the tibia. Lift the front edge of the skin flap under the deep fascia, and separate the skin flap backward to the posterior edge of the tibia and the surface of the flexor digitorum longus. Pay attention to the cutaneous artery and vein which penetrate out of the deep fascia in the posterior edge of the flexor digitorum longus. Incise open the deep fascia closely clinging to the edge of the tibia, and pull the flexor digitorum longus forward, and expose the posterior tibial

artery and vein as well as the cutaneous artery and vein which feed the skin flap. Then lift the skin flap forward from the incision site in the posterior edge of skin flap under the deep fascia, and dissect the tibial nerve and the cutaneous artery given off from the deep layer of the skin flap.

8.12 Lateral Malleolus Skin Flap

8.12.1 Applied Anatomy

The blood supply of the lateral ankle skin flap is the peroneal artery, which penetrates through the interosseous membrane in the calf at 5 cm above the lateral malleolus and then is divided into two cutaneous arteries such as the ascending and descending branches. The ascending branch passes through the deep fascia between the short peroneal muscle and extensor digitorum longus and runs upward in the subcutaneous tissue to provide blood supply to lateral skin in the lower calf; the descending branch runs downward and anastomoses with the cutaneous branch of the lateral anterior malleolar artery. Both cutaneous arteries have two accompanying veins. The superficial peroneal nerve passes through the skin flap from the superficial part of the extensor digitorum longus to reach the dorsum of foot, and the nervus cutaneus dorsalis lateralis pedis and the small saphenous vein pass through under the lateral malleolus.

8.12.2 Indications

It is used for repair of adjacent tissue defects or repair of distal defects.

8.12.3 Skin Flap Design

The skin flap is designed between the tibia and fibula in the lower calf; at first, Doppler ultrasound is used to detect the point where the peroneal artery perforator penetrates out of the lateral supramalleolar island flap at the site 5 cm above the lateral malleolus, and this point is taken as the axis of the skin flap. The upper boundary of the skin flap reaches up to the middle part of the calf, and the lower boundary reach down to the tip of the lateral malleolus.

8.12.4 Skin Flap Harvesting

Incise open the front edge of skin flap along the design drawing line of the skin flap; lift the skin flap backward to the clearance between the extensor digitorum longus and the short peroneal muscle under the deep fascia; find out the perforating branch of the peroneal artery and the ascending branch of the lateral malleolus cutaneous artery in the intermuscular space. It is visible that the superficial peroneal nerve travels passing obliquely through the skin flap at the front upper side of the lateral malleolus and on the surface of the extensor digitorum longus surface, and attention should paid to protecting them during the surgery. Pull forward the extensor digitorum longus and superficial peroneal nerve to expose the lower end of the tibia, the lower end of the fibula, the interosseous membrane in the calf, the perforating branch of the peroneal artery, and the skin flap artery. Incise open the posterior edge of skin flap, then dissect forward to completely separate the skin flap, and pay attention to protecting the vascular pedicle.

8.13 Medial Plantar Skin Flap

8.13.1 Applied Anatomy

The posterior tibial artery and vein and the tibial nerve enter into the planta pedis through the malleolar canal, and the posterior tibial artery is divided into the medial plantar artery and lateral plantar artery at the site where the abductor muscle is originated. The lateral plantar vein and the lateral plantar nerve run along the artery with the same name. The medial plantar artery and vein pass through the deep surface of the abductor muscle and run forward and give off several muscular and cutaneous branches to provide blood supply to the medial plantar muscles and skin.

8.13.2 Indications

The pedicled transfer can repair the heel defects. The free transplantation can repair the defects in the palm and thumb web.

8.13.3 Skin Flap Design

The body surface projection line of the running direction of the medial plantar artery is taken as the axis line of the skin flap, which is harvested on this axis line, and the range is generally 11 × 7 cm. The front end of the skin flap should not exceed the head of metatarsal bone in the plantar weight-bearing area. The medial boundary of the skin flap is the medial edge of planta pedis, and the lateral boundary has a distance of 1.5 cm from the outer edge of the foot (Fig. 3.51).

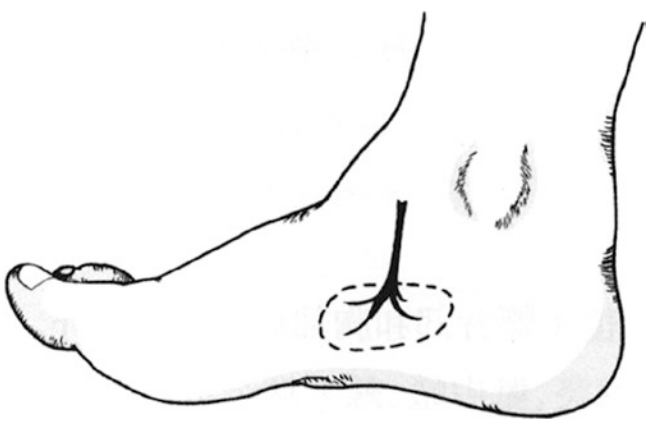

Fig. 3.51 Schematic diagram of medial plantar skin flap

8.13.4 Skin Flap Harvesting

Incise open the skin on the lower end of the malleolar canal along the body surface projection line of the posterior tibial artery and the medial plantar artery; dissect out the posterior tibial artery and vein; make the distal incision of the skin flap in the proximal end of the metatarsal head; incise open the skin and plantar aponeurosis; find out the medial plantar artery, vein, and nerve in the clearance between the plantar abductor muscle and plantar flexor digitorum; lift the skin flap to separate retrogradely to the beginning part of the medial plantar artery; form the plantar medial island skin flap which takes the medial plantar artery and vein as the pedicle. It is supposed to avoid damage to the cutaneous artery when pulling the skin flap.

8.14 Radial Forearm Skin Flap

8.14.1 Applied Anatomy

The blood supply of the radial forearm skin flap is mainly the cutaneous branch of the radial artery (Fig. 3.52). The overall length of the radial artery is about 22 cm, and it is the main arterial trunk of the radial forearm skin flap. The radial artery is covered up by the brachioradialis in the upper two thirds of the forearm, which is known as the covered part; the lower one third is located between the brachioradialis tendon and the radial wrist flexor tendon, which is known as the exposed part. The exposed part of the radial artery is about 10 cm in length, the outer diameter is 2.5 mm, it has more cutaneous branches with an average of 9.6 branches (4–18 branches), the covered part has less cutaneous branches with an average of 4.2 branches (0–10 branches), and the outer diameter is generally less than 0.5 mm. The skin flap mostly takes the cephalic vein as the returning vein trunk, followed by two smaller accompanying veins of the radial artery. The cutaneous arteries of the exposed part of the radial artery and the upper covered part are visible in the superficial fascia in the palmar side of the forearm; the cutaneous arteries of the ulnar artery, the anterior interosseous artery, and the lower end of the humeral artery are in turn visible in the ulnar side of the forearm. Various cutaneous arteries anastomose with each other within the subcutaneous area in the palmar side of the forearm to form a rich vascular network.

8.14.2 Indications

Retrograde transfer of island skin flap can be used for repair of soft tissue defects in hand, especially for repair of the thumb web defect and thumb reconstruction. The free transplantation can be used for repair of distal defects and organ reconstruction.

8.14.3 Skin Flap Design

The range for skin flap harvesting in the radial forearm: The upper boundary reaches up to the cubital crease of the elbow joint; the lower boundary reaches down to the transverse wrist crease on the palmar side of the wrist joint, with an extensive area of maximally up to 35 cm × 15 cm. This skin flap can be used not only for free skin flap transplantation but also for retrograde transfer of vascular pedicled skin flap displacement.

8.14.4 Skin Flap Harvesting

The radial forearm skin flap takes the radial artery, radial vein, cephalic vein, and lateral antebrachial cutaneous nerve as the pedicle. Incise open the skin on the radial and ulnar edges of skin flap along the design line and separate toward the direction of the radial artery and vein on the surface of the deep fascia and forearm flexor. Some protective soft tissues around the blood vessel bundle should be appropriately retained, so as not to damage the cutaneous branch given off by the main trunk of the radial artery. According to the location and the wound size of the receptor site, the transposition skin flap pedicled with the upper or lower end of the radial artery can be formed, and the free transplantation skin flap can also be formed.

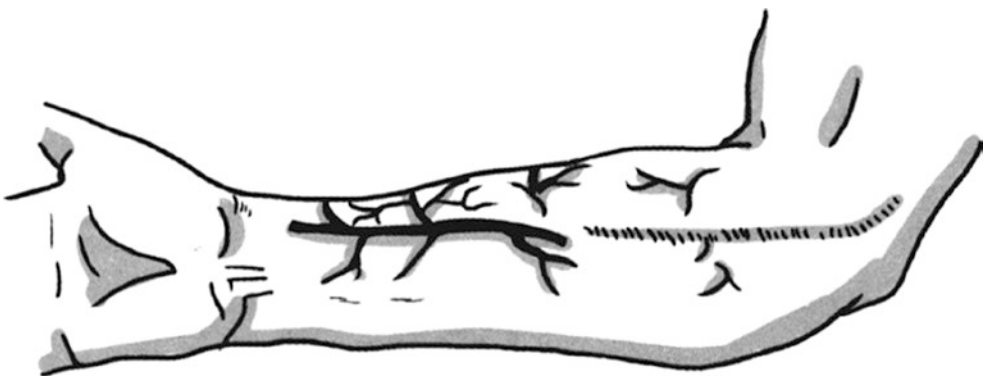

Fig. 3.52 The forearm radial artery and its cutaneous branch

8.15 Latissimus Dorsi Myocutaneous Flap

8.15.1 Applied Anatomy

The latissimus dorsi muscle is the biggest platysma in the whole body, which is located in subcutaneous areas of the lower back and the posterolateral chest, and presents as a triangular-shaped muscle having a broad rounded apex and a narrow base, whose aponeuroses originate from the spinous processes of six thoracic vertebras and all lumbar vertebras, the sacral crest, supraspinous ligament, and the rear part of the iliac crest and stop at the crest of the lesser tubercle of the humerus. The blood supply of the latissimus dorsi muscle comes from the thoracodorsal artery of the subscapular artery. The length of the thoracodorsal artery is 8.4 cm (4–13 cm) with an outer diameter of 3 mm. There is usually an accompanying vein with an outer diameter of about 4 mm, and the vascular anatomy is relatively constant. The upper boundary of the latissimus dorsi myocutaneous is located at 3 cm above the inferior angle of scapula flap; the lower boundary is located at 5 cm above the iliac crest; the inner boundary is located at 5 cm on the outer side of the spinal midline; the outer boundary is located at 5 cm away from the outer edge of the latissimus dorsi muscle.

8.15.2 Indications

Anterograde transfer: The latissimus dorsi myocutaneous flap can be transferred upward to the head and neck area; forward to the contralateral breast area, ipsilateral upper arm, and forearm; and backward to the contralateral back. Retrograde transfer: The latissimus dorsi myocutaneous flap can be transferred downward to the sacroiliac area. It is a commonly used myocutaneous flap. It can also carry the thoracodorsal nerve to repair the function of the receptor site. Therefore, it has a wider range of indications.

1. The patients with a large area of skin tissue defects and deep tissue defects which need to be repaired with tissue augmentation
2. The patients with skin tissue defects and muscle defects with a need for functional reconstruction
3. Breast reconstruction
4. Repair of wounds with poor blood supply, such as chronic ulcers

8.15.3 Myocutaneous Flap Design

The methods for latissimus dorsi myocutaneous flap transplantation, the specific location, and range of harvesting are determined according to the size, characteristics, and location of the wound (Fig. 3.53), and the methylrosanilinium chloride is used to mark the incision line of the myocutaneous flap.

Fig. 3.53 The body surface projection of the latissimus dorsi myocutaneous flap

8.15.4 Myocutaneous Flap Harvesting

Incise the skin tissues from the underarm and along the front edge of the latissimus dorsi muscle; expose the front edge of the latissimus dorsi muscle; bluntly dissect out the intermuscular space of the serratus anterior muscle, and find the thoracodorsal vascular pedicle; incise open the skins and muscles, respectively, from the front and back edges of the latissimus dorsi muscle according to the design size. Because the skin is supplied with blood by the perforating branch of the perpendicular muscular artery, therefore, the skin on the latissimus dorsi muscle is harvested together with the muscle, in order to prevent separation of the skin and the muscle, and several sutures are performed to fix the skin edges with the muscle. If a more

Fig. 3.54 The harvesting of the latissimus dorsi myocutaneous flap

serious sunken defect is repaired, the needed skin area is small, and the needed muscle area is large, it is necessary to form a skin island and a wider latissimus dorsi muscle on the surface of latissimus dorsi muscle. At first, incise open the skin along the edge of the designed skin flap, and dissociate the skins around the outside of the skin flap from the muscle membrane surface; then expose the edge of the latissimus dorsi muscle, and carry out dissociation according to the conventional method. The separation and dissection are performed in intermuscular space between the latissimus dorsi muscle and serratus anterior muscle in the deep layer (Fig. 3.54). The separation is easier; when the muscular branch of the serratus anterior muscle is encountered in the upper part, it is cut off and ligated; when reaching near the armpit, the surgeon can see the dorsal thoracic artery, vein, and nerves which run and cling to the deep surface of the latissimus dorsi muscle. According to the required length of the vascular pedicle, separate upward to the subscapular artery through the armpit and along the neurovascular bundle, and then ligate the circumflex scapular artery.

8.16 Pectoralis Major Myocutaneous Flap

8.16.1 Applied Anatomy

The pectoralis major muscle is located in the anterior chest, and looks like fan-shaped, which originates from the medial half clavicle, sternocostal part, and abdomen and stops at the crest of the greater tuberosity of the humerus. The arteries of the pectoralis major myocutaneous flap come mainly from the pectoral branch (the outer diameter is 1.8 mm, and the distance between the starting point and the muscle hilus is 8 cm) and the deltoid branch (the outer diameter is 1.9 mm, and the length is 4.7 cm) of the chest shoulder peak artery (the outer diameter is 2.8 mm, and the length is 1 cm), the pectoral branch of the axillary artery, the anterior intercostal artery, and the perforating branch of the internal thoracic artery. In addition, the arteria thoracica suprema and the lateral thoracic artery also participate in the blood supply of the pectoral muscle. The veins of pectoralis major myocutaneous flap run along the arteries of the same names, mainly including the deltoid branch (the outer diameter is 2.4 mm, and the length is 3.4 cm), the clavicular branch (the outer diameter is 1.6 mm and the length is 1.4 cm), and the pectoral branch (the outer diameter is 2.1 mm, and the length is 3.7 cm). The anterior thoracic nerve is a major nerve controlling the pectoralis major myocutaneous flap. The body surface projection of the thoracoacromial artery: A connecting line between the shoulder peak and the xiphoid process is made, and the middle third of this line is the body surface projection of the pectoral branch (the upper pectoral branch) of the thoracoacromial artery. The lower half of the connecting line between the shoulder peak and the nipple is the body surface projection of the lower pectoral branch.

8.16.2 Indications

The pedicled transfer can be used to repair the soft tissue defects in the head, face, mouth floor, oropharynx, upper arm, and shoulder. The free myocutaneous flap transplantation can be used to repair the distal defects.

8.16.3 Myocutaneous Flap Design

It is designed according to the body surface projection of the thoracoacromial artery. The range for the harvesting of pectoralis major myocutaneous flap: The upper boundary is the clavicle, the inner boundary reaches the outer edge of the sternum, the outer boundary reaches the anterior axillary line, and the lower boundary reaches down to the xiphoid level.

8.16.4 Myocutaneous Flap Harvesting

It is designed according to the direction of the body surface projection, and the incision lines of the myocutaneous flap and the pedicle are drawn according to the shape and size of the defect. A transverse incision of 3–4 cm is made from the coracoid process to the inner side at 1 cm under the collarbone to reach to the middle one third of the clavicle. Then, a longitudinal incision is made downward to the upper edge of the myocutaneous flap to underneath of the fascia. The clavicular portion of the pectoralis major muscle is pulled to both sides, and the anterior thoracic nerves given off by the brachial plexus are visible. The thoracoacromial artery is found at the upper outer side of the incision and is protected. The skin and the pectoralis major muscles are incised open along the designed incision line, and the skin edge and the fascia are sutured close. The skin flap is separated under the inner fascia of the pectoralis major muscle. The beginning part of the muscle is cut off, and the separation is performed from the bottom up to the pedicle.

8.17 Rectus Abdominis Myocutaneous Flap

8.17.1 Applied Anatomy

The rectus abdominis muscles look belt-shaped and are located on both sides of the abdominal midline, and the upper part is wide and the lower part is narrow. This muscle originates from the xiphoid process of sternum and the front of the fifth to seventh rib cartilages and stops at the pubic symphysis and pubic crest. The rectus abdominis muscle inhabits in the rectus sheath. The anterior wall of the rectus sheath is intact, and the posterior wall of the rectus sheath is damaged beneath the semicircular line. The semicircular line is located at 5.8 cm under the flat umbilicus and 9.6 cm from the upper edge of the pubic symphysis. This area has defects due to the posterior wall of the rectus sheath; therefore, it should be specially noted that the abdominal internal organs are not damaged.

The blood supply of the rectus abdominis myocutaneous flap mainly comes from the superior and inferior epigastric arteries and veins as well as their branches. Because the blood supply of the myocutaneous flap belongs to multi-source, in addition to the main blood supply, other blood vessels such as the intercostal arteries and the blood vessels in superficial part of abdominal wall also participate in the blood supply (Figs. 3.55 and 3.56)

The upper part of the rectus abdominis muscle is provided blood mainly by the superior epigastric artery. The superior epigastric artery is one of the terminal branches of the internal thoracic artery, which extends downward from the internal thoracic artery at the intersection of the xiphoid and the costal arch, and runs downward along the rectus abdominis muscle, then enters into this muscle from behind and runs down within this muscle, and anastomoses with the branches of the inferior epigastric artery near the navel. Of the starting points of the superior epigastric artery, namely, the bifurcation point of the superior epigastric artery (the end branch of the internal thoracic artery) and musculophrenic artery, the starting points which are at the corresponding levels of fifth, sixth, and seventh costicartilages account for 8.8%, 17.6%, and 29.4%, respectively; the starting points which are at the corresponding levels of the fifth, sixth, and seventh intercostal spaces account for 8.8%, 32.5%, and 2.9%, respectively. The outside diameter of the superior epigastric artery (the starting point) is 2.1 mm (1.5–3.0 mm), and the outside diameter of the superior epigastric artery at the right side is greater than that on the left side. The lower part of the rectus abdominis muscle is provided blood mainly by the inferior epigastric artery. The inferior epigastric artery is given off from the anteromedial side of the external iliac artery, runs toward the upper inner side in an arciform shape, enters into the muscle through the sheath of rectus abdominis muscle, and anastomoses with the superior epigastric artery. The total length between the starting point of the inferior epigastric artery and the site where it enters into the muscle is about 10 cm, and the outer diameters at three sites such as the starting point, the outer edge of the sheath of rectus abdominis muscle, and the muscle hilus are 3.0 mm, 2.4 mm, and 1.9 mm, respectively. The starting point of this artery has variations, the arteries starting from the anterior wall of the external iliac artery account for 14.7%, the ones starting from the medial wall of the external iliac artery account for 85.3%, and the ones starting from the site above the inguinal ligament account for 38.2%; the average distance from the starting point to the inguinal ligament is 0.9 cm, the ones which are at the corresponding level of the inguinal ligament account for 58.8%, and the ones starting from the femoral artery beneath the inguinal ligament account for 3%. There are interlinked thicker branches between the superior epigastric artery and inferior epigastric artery.

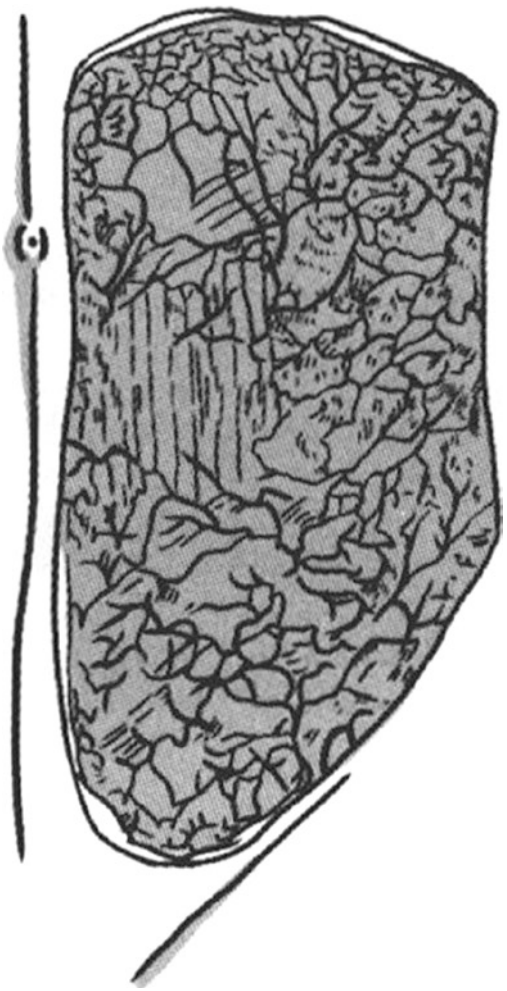

Fig. 3.55 The blood supply in the area of the rectus abdominis muscle

The body surface projections of the superior and inferior epigastric arteries: A connecting line is made from the site at

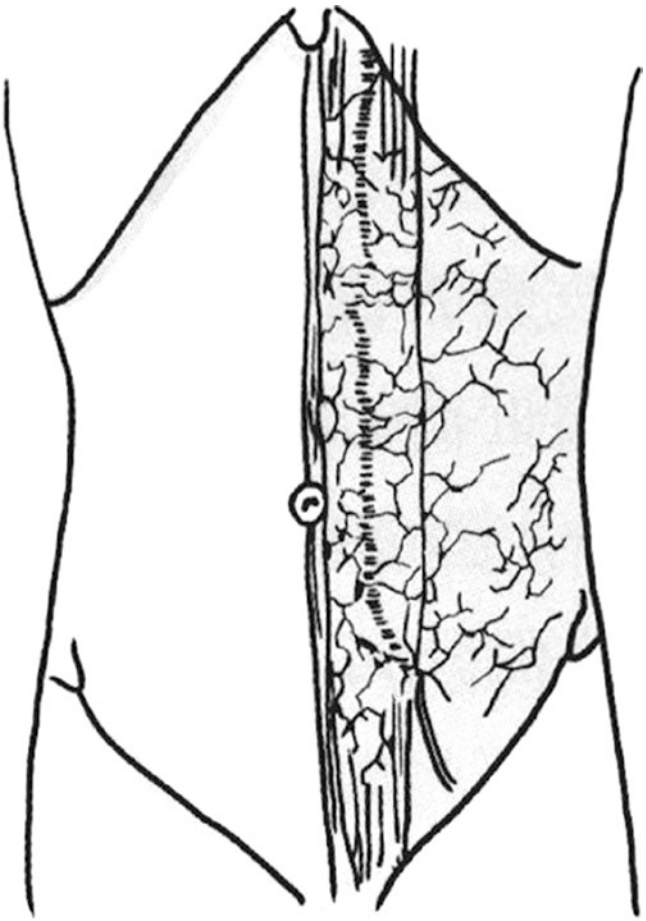

Fig. 3.56 The blood supply of the rectus abdominis myocutaneous flap

3 cm beside the xiphoid to the site at 4 cm beside the pubic symphysis, which is the body surface projection of the superior and inferior epigastric arteries. The terminal branches of the two blood vessels communicate with each other at 4 cm above the navel.

8.17.2 Indications

The rectus abdominis myocutaneous flap takes the superior epigastric vessels or inferior epigastric vessels as the pedicle, and it can be used for pedicled transfer or free transplantation with vascular anastomosis. However, it cannot be used for functional reconstruction due to the fact that the anterior branch of segmental spinal nerve is small. The superior epigastric vessels or inferior epigastric vessels are selected as the pedicle according to the repair needs; the myocutaneous flap pedicled with the superior epigastric artery can be used for repair of the chest wall defects and breast reconstruction; the myocutaneous flap pedicled with the inferior epigastric artery can be used for repair of soft tissue defects in the lower abdomen and perineum; the transverse rectus abdominis myocutaneous flap in the lower abdomen pedicled with the contralateral superior epigastric artery is often used to repair the soft tissue defects of large area. The distal defects can be repaired with free transplantation with vascular anastomosis.

8.17.3 Myocutaneous Flap Design and Harvesting

Because there are interlinked thicker branches between the superior epigastric artery and inferior epigastric artery, the range for myocutaneous flap harvesting can reach the whole rectus abdominis muscle. The upper boundary is at the level of the xiphoid; the lower boundary reaches the pubic symphysis; the inner boundary is the anterior median line of the abdominal wall; the outer boundary is at 3 cm on the outside of the rectus abdominis muscle. The ipsilateral or contralateral vertical rectus abdominis myocutaneous flap, transverse rectus abdominis myocutaneous flap, transverse upper rectus abdominis myocutaneous flap, transverse lower rectus abdominis myocutaneous flap, and rectus abdominis myocutaneous island flap can be designed and formed according to the repair needs of the receptor site.

1. Vertical rectus abdominis myocutaneous flap: The vertical rectus abdominis myocutaneous flap refers to the vertical myocutaneous flap which takes the rectus abdominis muscle at one side as the pedicle and includes the skin tissues on its surface, and the whole rectus abdominis muscle can be harvested. Its blood supply mainly comes from the superior and inferior epigastric arteries and their branches, and the blood supply is rich, and it is suitably used for breast reconstruction and repairs of tissue defects in the thoracoabdominal wall and four limbs.
   (a) Myocutaneous flap design: The range for myocutaneous flap harvesting reaches up to the xiphoid and reaches down to the site 4 cm above the pubic symphysis. Both sides are the inner and outer edges of the rectus abdominis muscle. The area of myocutaneous flap available for harvesting is 15 × 30 cm. The skin flap is designed according to the repair needs in clinic, and the superior epigastric artery or the inferior epigastric artery can be taken as the pedicle.
   (b) Myocutaneous flap harvesting: Incise open the skin tissue, fascia, and the anterior layer of the sheath of rectus abdominis muscle along the design line. If the superior epigastric artery and vein are taken as the pedicle, the rectus abdominis muscle is transversely cut off at the distal end of the myocutaneous flap, and the inferior epigastric artery and vein are ligated and cut off. The separation and lifting are performed from distal to proximal with a finger within the loose connective tissue between the deep surface of the rectus abdominis muscle and the posterior layer of the sheath of the rectus abdominis muscle; at the same time of the separation, the temporary suture fixation

is performed for the skin and muscle to prevent damage to the myocutaneous perforating branches until the separation reaches up to the pedicle of the myocutaneous flap. The superior epigastric artery and vein can be clearly seen in the pedicle. If it is transferred as island flap, the muscle and skin tissues at the proximal end of the myocutaneous flap are cut off after the vascular pedicle is separated; if it is transferred as pedicled peninsular flap, it may not be necessary to separate the blood vessel.

The defects in the rectus abdominis muscle and the anterior layer of sheath of rectus abdominis muscle due to the myocutaneous flap harvesting should be repaired. The anterior layer of contralateral sheath of rectus abdominis muscle contralateral rectus sheath can be incised open from its outer edge, and the separation is performed from the superficial surface of rectus abdominis muscle. Its medial edge is taken as the pedicle, which is turned over by 180 degrees to cover the posterior layer of sheath of the rectus abdominis muscle left in the donor site, and it is sutured and fixed onto the obliquus externus abdominis muscle; the aponeurosis of the obliquus externus abdominis muscle can also be treated with relieving tension and separation and then is advanced to repair the wound. The skin graft is harvested additionally and transferred to repair the skin defects.

2. Transverse upper rectus abdominis myocutaneous flap: The transverse upper abdominal myocutaneous flap pedicled with the rectus abdominis muscle on one side is harvested, whose axial artery is the superior epigastric artery. The myocutaneous perforator of the superior epigastric artery has plenty of communicating anastomosis with the ascending branch of the inferior epigastric artery and the branches of the lateral intercostal artery, and therefore, the blood supply of the transverse upper abdominal myocutaneous flap is very rich, and the area available for harvesting is large. Thus it is suitable for repair of large-scale defects.
   (a) Myocutaneous flap design: The range for designing a myocutaneous flap starts up from the upper surface of the xiphoid process and reaches the anterior axillary line on both sides; the lower boundary reaches down to the level of the navel, and the maximum area can be up to 30 × 30 cm. During clinical application, the rectus abdominis muscle on one side is selected as the pedicle at first, and then the size and shape are determined according to need, and the methylrosanilinium chloride is used to mark the skin incision line of the myocutaneous flap.
   (b) Myocutaneous flap harvesting: Incise open the skin tissue around the myocutaneous flap along the design line, and separate and lift up the skin flaps at both sides of the rectus abdominis muscle on the shallow surface of the obliquus externus abdominis muscle, until the inner and outer edges of the rectus abdominis muscle at one side which is taken as the pedicle are reached. Incise open rectus abdominis anterior sheath and its both sides; bluntly dissect between the deep surface and posterior sheath of the rectus abdominis muscle; cut off the rectus abdominis muscle from the incision at the lower edge of myocutaneous flap; ligate and cut off the inferior epigastric artery and vein. The full-thickness continuous suture of skin, the anterior layer of rectus abdominis sheath, and the myolemma of the rectus abdominis muscle are performed, and then the myocutaneous flap is lifted from the distal end to the pedicle flap and the nerve fibers which enter in the muscle from the outside. The superior epigastric artery and its accompanying veins should be protected during the operation. If it is necessary to perform the free transplantation with vascular anastomosis, the vascular pedicle will be separated upward, and the beginning part of the rectus abdominis muscle is cut off. The length of vascular pedicle of myocutaneous flap is harvested according to the need to anastomose the blood vessels in the receptor site.

   The donor site wound repair is performed referring to the harvesting method for vertical rectus abdominis myocutaneous flap.

3. Transverse lower rectus abdominis myocutaneous flap: The lower part of the rectus abdominis muscle at one side is taken as the pedicle to harvest the transverse lower abdominal myocutaneous flap, whose axial artery is the inferior epigastric artery. When the pedicled transfer is performed, the inferior epigastric artery can be taken as the pedicle, and the superior epigastric artery can also be taken as the pedicle.
   (a) Myocutaneous flap design: The range for myocutaneous flap harvesting starts under the navel level. Both sides reach to the sites at three horizontal fingers away from the medial side of anterior superior spine, and the lower boundary is determined depending on the need of repair in receptor site. The maximum area available for myocutaneous flap harvesting is 20 × 15 cm. The shape and area of the myocutaneous flap are determined according to the need of repair in receptor site, and they were marked with methylrosanilinium chloride. This myocutaneous flap can be used for free transplantation to repair the tissue defects at distal sites; it can also be used for pedicled transfer to cover the wounds in sites such as the perineum, iliac crest, and anterior superior iliac spine.
   (b) Myocutaneous flap harvesting: Incise open the skin and subcutaneous tissue according to marks; separate from

the outside toward the rectus abdominis muscle at one side which is selected as the pedicle up to its inner and outer edges; then cut off the rectus abdominis muscle from upper edge of the myocutaneous flap; ligate and cut off the epigastric artery and vein; dissociate in loose tissue in the deep surface of the muscle; lift the myocutaneous flap toward the pedicle. The donor site wound repair is performed referring to the method for vertical rectus abdominis myocutaneous flap.

4. The rectus abdominis myocutaneous island flap pedicled with the contralateral superior epigastric artery
   (a) Myocutaneous flap design: The range for myocutaneous flap harvesting on the lower abdomen is drawn according to the running directions of blood vessels and the situation of soft tissue defects, and the incision line of the pedicle is the connecting line from the site at 3 cm on the lateral side of xiphoid process to the upper edge of the myocutaneous flap.
   (b) Myocutaneous flap harvesting: Incise open the skin around the myocutaneous flap, subcutaneous tissue, and rectus abdominis anterior sheath according to the design incision line. It is noted that 1 cm wide medial rectus abdominis anterior sheath is retained, which is conducive to postoperative repair. Dissociate the rectus abdominis muscle out of the rectus abdominis posterior sheath with fingers from the outside to the inside, and be careful not to damage the inferior epigastric artery which is located in the deep surface of the muscle. Cut off the rectus abdominis muscle and the inferior epigastric artery at the semilunar line, and carefully dissociate the myocutaneous flap upward to the site under the costal margin.

8.18 The Peritoneal Skin Flap with the Inferior Epigastric Artery and Vein

8.18.1 Applied Anatomy

The paraumbilical peritoneal composite flap is actually two flaps fed by different perforators of the inferior epigastric artery, which is made up of the paraumbilical skin flap and the rectus abdominis musculoperitoneal flap. The main blood supply of the paraumbilical skin flap comes from the lateral perforating branch of the inferior epigastric artery which passes through the rectus abdominis anterior sheath near to paraumbilical area. The rectus abdominis musculoperitoneal flap is supplied with blood by the branch which is given off by the inferior epigastric arteries before entering into the rectus abdominis muscle. The inferior epigastric artery is given off from the medial wall of the external iliac artery at 1 cm above inguinal ligament, which runs obliquely toward the upper inner side behind the transverse fascia; after crossing the lateral edge of the rectus abdominis muscle, it runs upward behind the muscle and enters into the sheath of rectus abdominis muscle in the front of the semicircular line, then runs upward between the posterior lobe of sheath of rectus abdominis muscle and the muscle, and forms into terminal branches in the paraumbilical area and anastomoses with the superior epigastric artery and the lateral cutaneous branches of intercostal artery [12].

8.18.2 The Design and Harvesting of the Peritoneal Skin Flap

The inner boundary of the skin flap is at 1 cm beside the navel. The upper boundary of the skin flap reaches up to the site at 3 cm above the navel level, and a rectangle skin flap can be formed. Incise open the outer edge of the skin flap to the superficial surface of aponeurosis of the obliquus externus abdominis, and separate the skin flap toward the navel. It is observed that two to three larger perforating branches pass through the anterior sheath into the skin flap in the superficial surface of the rectus abdominis anterior sheath. At the moment, it is appropriate to incise open the additional incision designed according to the body surface projection of the inferior epigastric artery beneath the skin flap; cut off the anterior sheath at 1 cm beside the perforating branch downward to the lower part; separate outward its anterior; expose the outer edge of the rectus abdominis muscle, the inferior epigastric vessels, and posterior sheath; incise open part of the rectus abdominis muscle along the perforating branch, and dissect out the branch to the general trunk; and identify and dissect out the branches of the inferior epigastric artery and vein entering into the posterior sheath and peritoneum. The posterior sheath and peritoneum according to design are incised open, and then the posterior rectus sheath-peritoneal flap with required size is harvested to be attached onto the vascular pedicle; at the same time, the paraumbilical skin flap is passed out of the clearance between the rectus abdominis muscles under the intercostal nerve, and the composite flap is formed as single-pedicle double skin flaps. After the vascular pedicle is ligated and cut off, the stratified suture of the peritoneum, rectus abdominis muscle, anterior sheath, and abdominal skin is performed, and the abdominal belt is used for pressure dressing. During the surgery, attention should be paid to protecting the 10th, 11th, and 12th intercostal nerves entering obliquely into the rectus abdominis muscle from the outer upper side, and it is avoided to cut them off to lead to corresponding dysfunctions.

8.18.3 The Advantages and Disadvantages of Peritoneal Skin Flap

1. Advantages:
   (a) The same vascular pedicle can be used to form the single-pedicle double skin flaps, and the cheek after reconstruction can basically recover its unique structure in which the outer surface is the skin and the inner surface is mucosa.

(b) The rectus abdominis muscle and anterior sheath are still reserved in the donor site, and the main barrier structure of the abdominal wall is retained, which significantly reduces the possibility of the abdominal wall bulging and abdominal wall hernia.
(c) It provides a method for repair of the red lip defect in the lip and cheek complex defects. In the previous literatures, fewer methods can be used to repair the red lip defect in the lip and cheek complex defects, and the skin flap is mostly used to reconstruct the shape of oral fissure, and it is difficult to adopt the commonly used methods such as tongue flap and adjacent mucosal flap to repair this type of defects.
(d) The peritoneal skin flap with the inferior epigastric artery and vein has delicate skin surface and a lighter skin color, and it is more suitable for repair of facial soft tissue defects. At the same time, the vascular pedicle of the skin flap is longer and up to 10–13 cm; the diameters of blood vessels are also larger, which are conducive to anastomosis. Furthermore, since the skin flap is not needed to be folded in the application, the harvested skin flap is relatively small, and the donor site can be directly closed and sutured.

2. Disadvantages: In clinical observation, we also note that some peritoneal skin flaps have the following disadvantages:
(a) Due to posterior sheath and peritoneum defects, the likelihood of the emergence of the abdominal wall dehiscence in donor site during perioperative period is increased. Therefore, when the harvested rectus abdominis musculoperitoneal flap is more than 4 cm wide, it is best to repair the donor site of the peritoneum with a patch to reduce the tension of peritoneum. At the same time, the abdominal belt is retained at local site for more than 3 weeks.
(b) At 3 weeks after the rectus abdominis musculoperitoneal flap is transferred, its surface color becomes faint and looks yellowish white, at the same time, an apparent shrinkage occurs, which may be related to a lack of submucosal structures underneath its surface. In order to avoid the occurrence of the phenomenon of limited mouth opening, it is appropriate to advise the patients to carry out mouth-opening exercise in early period of postoperation. The problem of how to prevent the contracture of the peritoneal skin flap needs further discussion.

8.19 Trapezius Myocutaneous Flap

8.19.1 Applied Anatomy

The trapezius muscle is located under the skin in the neck and back and is a triangular platysma. The trapezius muscle starts from the external occipital protuberance, the superior nuchal line, the nuchal ligament, and all thoracic spinous processes and stops at the outer one third of the clavicle, shoulder peak, and spina scapulae. It is controlled by the accessory nerve and the cervical spinal nerves 3 and 4. The cutaneous sensation in the trapezius region is controlled by the cutaneous branch of the rami posteriores nervorum thoracicorum The blood supply of the trapezius myocutaneous flap mainly comes from the transverse cervical artery given off by the subclavian artery, and the occurrence rate of only one transverse cervical artery is 75%, and the occurrence rate of two transverse cervical arteries is 25%. The vascular pedicle length is 5 cm. The outer diameter is 2.3 mm, and the average outer diameter of the accompanying veins is 3.4 mm, which run into the subclavian vein or the external jugular vein (Fig. 3.57).

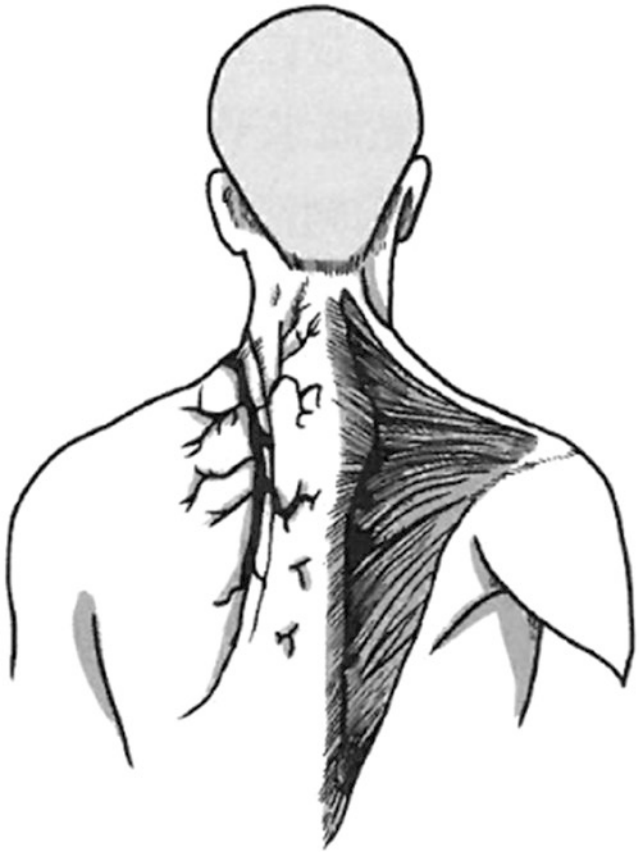

Fig. 3.57 Blood vessel distribution of trapezius muscle

8.19.2 Indications

The myocutaneous flap is used to repair the tissue defects in the neck, parotid, and maxillofacial areas.

8.19.3 Myocutaneous Flap Design

The trapezius myocutaneous flap is generally divided into upper trapezius myocutaneous flap, the middle trapezius myocutaneous flap, and the lower trapezius myocutaneous flap. The upper boundary can reach up to the superior angle

of scapula; the inner boundary is located at 1 cm on the outer side of the spinous processes of thoracic vertebra; the lower boundary reaches down to the level of the tenth spinous process of thoracic vertebra; the outer boundary reaches the outer edge of the trapezius muscle.

8.19.4 Myocutaneous Flap Design Harvesting

Incise open the skin and subcutaneous deep fascia to reach the surface of the trapezius muscle according to the designed range of the skin flap; cut off the aponeurosis of the trapezius muscle starting from the spinous process of thoracic vertebra. The edge of the skin flap is sutured with the skin together to avoid avulsion of the skin of the myocutaneous flap from the trapezius muscle. After that, separate the skin flap from the lower part to the upper part; ligate and cut off the muscular branch of the posterior intercostal artery and the muscular branch of the intercostal nerve; expose the erector spinae muscles and the rhomboideus major. Lift the trapezius myocutaneous flap upward continuously; expose the descending branch of the transverse cervical artery which feeds the trapezius muscle and its two accompanying veins and the accessory nerve which controls the trapezius muscle. The inside edge of the scapula and shoulder blade levator scapula in the upper corner can be observed in the deep surface of the surgical field. It can be observed in the medial edge of scapula that the branches of the subscapular artery and the branches of posterior intercostal artery anastomose each other with the descending branch of the transverse cervical artery.

8.20 Gluteus Maximus Myocutaneous Flap

8.20.1 Applied Anatomy

The gluteus maximus muscle is one of the hip abductor muscles, and is located under the skin in the hip, whose shape presents as an irregular square flat muscle; the short tendon starts from the bone surface behind the posterior gluteal line of the ilium, the outer surface of the sacrum and coccyx, and the sacrotuberous ligament; the muscle belly goes downward and is connected continuously with the terminal tendon, which presents as a flat, thick, and tough aponeurosis. The arteries of the gluteus maximus muscle include the inferior gluteal artery, the superior gluteal artery, and the first perforating branch of the femoral profound artery, and the blood supply mainly comes from the inferior gluteal artery and the superior gluteal artery. The former starts from the lower anterior section of internal iliac artery, passes through the infrapiriformis foramen to reach the hip, and gives off branches to the lower and middle part of the hip. The outer diameter of the inferior gluteal artery at the site passing out the infrapiriformis foramen is 3.52 mm (0.5–5.1 mm), and the length is about 4.2 cm. The surface projection of the inferior gluteal artery: A vertical line from the iliac crest is made to be connected to the ischial tuberosity, which locates at the intersection point of the middle and lower one third of this connecting line. It is an average distance of 12 cm from the iliac crest and a distance of 5.4 cm from the ischial tuberosity. The branches of the inferior gluteal artery anastomose with the first perforating branch of the femoral profound artery and the superior gluteal artery.

The superior gluteal artery is the major blood vessel supplying blood to the gluteus maximus muscle; after given off from the internal iliac artery, it passes through the suprapiriform foramen to reach the hip, and then it is immediately divided into two branches such as superficial and deep branches. The deep branch runs through the deep surface of the gluteus medius muscle and gives off branches to feed the gluteus medius muscle and the gluteus minimus muscle; the superficial branch mainly feeds the gluteus maximus muscle and runs through the deep surface of this muscle and gives off branches to be distributed in the upper parts of gluteus maximus muscle and has branches anastomosing with the inferior gluteal artery. The outer diameter of the superior gluteal artery at the site passing out of the suprapiriform foramen is 3.1 mm (0.5–5.9 mm). The outer diameter of superficial branch of the superior gluteal artery is 2.4 mm, and the main branch length is 3.2 cm. The surface projection of the superior gluteal artery: the midpoint of the vertical connecting line from the iliac crest to the ischial tuberosity. The deep branch of the superior gluteal artery is not related to the blood supply of the gluteus maximus muscle, but only its superficial branch has practical significance in the application of the gluteus maximus myocutaneous (muscle) flap. The superior gluteal artery can be used as the vascular pedicle of upper part gluteus maximum myocutaneous flap.

8.20.2 Indications

The myocutaneous flap can be used for repair of sacral pressure ulcers and tissue defects in adjacent area and carrying out breast reconstruction.

8.20.3 Myocutaneous Flap Design

1. The range for gluteus maximus myocutaneous flap harvesting: The gluteus maximus myocutaneous flap is divided into the upper part gluteus maximum myocutaneous flap and lower part gluteus maximum myocutaneous flap. The pivot point of the upper part gluteus maximum myocutaneous flap is the point of intersection of the straight line which is located at 6 cm beside the spine and is parallel to the spine and the connecting line between the posterior superior iliac spine and the femoral great trochanter. The pivot point of the lower part gluteus maximum myocutaneous flap is located in site at

6 cm below the pivot point of the upper part gluteus maximum myocutaneous flap. The range for myocutaneous flap harvesting is 8 × 15 cm, which slants toward the lower outer side.

2. The body surface projections of the superior and inferior gluteal arteries: The point of intersection of the middle and upper one third of the connecting line between the posterior superior iliac spine and the femoral great trochanter is the point where the superficial branch of the superior gluteal artery penetrates out, and the middle one third of the this line is the body surface projection of the superior gluteal artery. The inferior gluteal artery is located at 0.6 cm below the superficial branch of the superior gluteal artery and is parallel to the running direction of the superior gluteal artery.
3. Application mode of gluteus maximum myocutaneous flap: The commonly used mode of gluteus maximum myocutaneous flap is the local rotation advancement, which is used to repair the bedsores in lumbosacral area. This myocutaneous flap can also be used for free transplantation with vascular anastomosis.

8.20.4 Myocutaneous Flap Harvesting

1. Myocutaneous flap design the superior gluteal artery is taken as the axis to design the skin flap. At first, a connection line between the posterior superior iliac spine and femoral great trochanter is drawn with methylrosanilinium chloride, and the point of intersection of the upper and middle one third of the connecting is the axis point. The distance from the axis point to the most distal point of the skin flap should be slightly larger than the distance from the axis point to the most distal point of the defect. The size and shape of the distal end of the skin flap after rotation should be able to close the wound well.
2. Expose the superficial branch of the superior gluteal artery: Incise open the skin on the upper outside of the hip along the design line; find out the clearance between the gluteus maximus muscle and gluteus medius muscle, and perform the blunt dissection in this clearance; find out the superficial branch of the superior gluteal artery. Make an underneath incision within the skin flap according to the running direction blood vessel, and split off the gluteus maximus muscle along the muscle fibers between the superior gluteal artery and inferior gluteal artery.
3. Lift up the skin flap: Track inward along the blood vessel in the deep surface of the muscle; carefully separate the superficial branch of the superior gluteal artery as the vascular pedicle; make an inner incision; form the island myocutaneous flap pedicled with the superficial branch of the superior gluteal artery (Fig. 3.58).

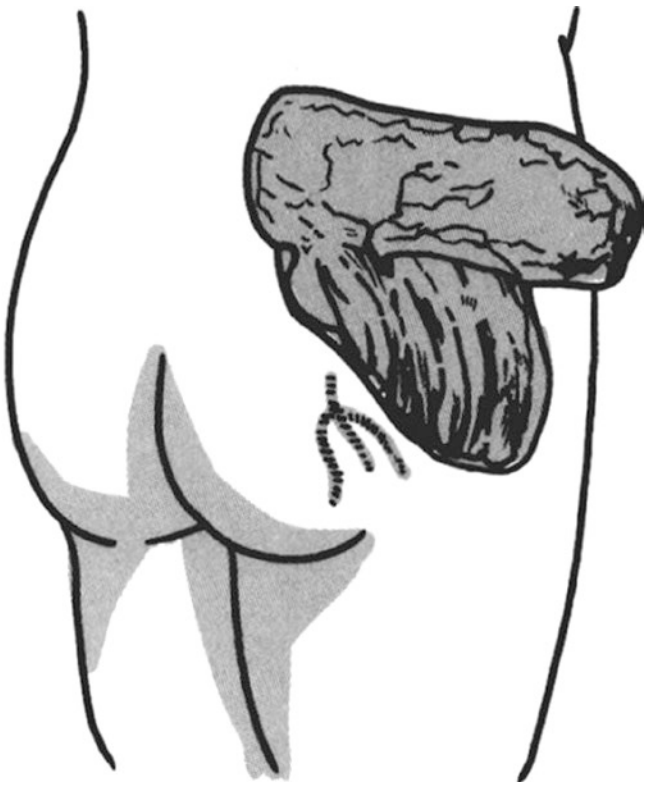

Fig. 3.58 The harvesting of the gluteus maximus myocutaneous flap

8.21 Tensor Fascia Lata Myocutaneous Flap

8.21.1 Applied Anatomy

The tensor fasciae latae muscle is located at the anterolateral side of the thigh between the sartorius muscle and gluteus medius muscle. It starts from the anterior superior iliac spine, then the muscle belly turns into iliotibial band at the junction of the upper and middle one third of the thigh, and it runs down and stops at the lateral condyle of tibia. The arteries of the tensor fasciae latae muscle mostly come from the femoral profound artery and the ascending branch of the lateral femoral circumflex artery (81.82%) and can also come from the transverse branch, the deep branch of the superior gluteal artery, or deep circumflex iliac artery. The average length of the ascending branch of lateral femoral circumflex artery is 4.4 cm, and the outer diameter of the beginning part is 2.7 mm. The body surface projection of the root of this artery is located at the site where can be reached by traveling 9.6 cm vertically down from the anterior superior iliac spine and then 4.9 cm horizontally and inwardly, which is a mark for looking for the lateral femoral circumflex artery. The point where the blood vessel enters into the muscle is below the pubic tubercle level (account for 61.3%), and each artery has two accompanying veins.

8.21.2 Indications

It is used to repair the hip bedsores and lower abdominal wall defect and soft tissue defects on the medial and lateral sides of the thigh.

8.21.3 Myocutaneous Flap Design

The skin flap is designed in the rear of the connecting line from the anterior superior iliac spine to the outer edge of the patella. Generally, the upper boundary reaches up to the site at 2 cm above the anterior superior iliac spine; the front and back boundaries can exceed the front and back edges of the tensor fascia lata muscle by 2 cm; the lower boundary reaches the site at 5 cm above the knee. The maximum range for harvesting is 15 × 40 cm.

8.21.4 Myocutaneous Flap Harvesting

Incise open the skin and superficial fascia according to the drawing line, and expose the fascia lata and cutaneous arteries. The pedicle of the skin flap is located at the superficial surface of the anterior superior iliac spine. At first, cut off the muscle belly of the tensor fascia lata muscle and the transitional area of iliotibial band; lift up the distal end of the tensor fascia lata myocutaneous flap; bluntly dissect upward between the tensor fasciae latae muscle and the rectus femoris muscle, and then dissect and expose the ascending branches of the lateral femoral circumflex artery and vein and the muscular branch distributed to the tensor fascia lata muscle at the front of the vastus lateralis muscle at 6–9 cm under the anterior superior iliac spine. After that, pull inward the rectus femoris muscle and the sartorius muscle; further expose and separate out the vascular pedicle of the tensor fasciae latae muscle and make it extended appropriately (Fig. 3.59). Intraoperatively, it is noted that the muscular branch of superior gluteal nerve entering into the posterior edge of the tensor fasciae latae muscle and the deep branch of the superior gluteal artery should be not damaged.

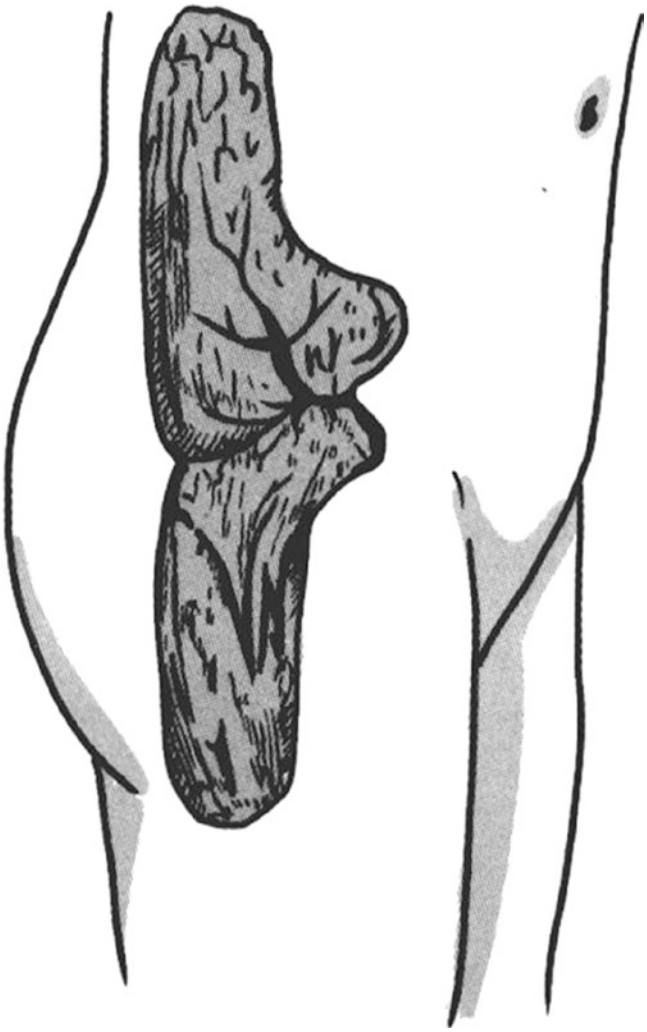

Fig. 3.59 Harvesting of tensor fascia lata myocutaneous flap

8.22 Sartorius Myocutaneous Flap

8.22.1 Applied Anatomy

The sartorius muscle is located under the skin on the anterior and medial side of the thigh and is the longest belt-shaped muscle in the whole body. It starts from the anterior superior iliac spine and stops at the tibial tuberosity. The muscle fibers travel obliquely from the outer upper side to the inner lower side. The muscle belly is 40–60 cm long, 2.5 cm wide, and 1 cm thick. The blood supply to this muscle shows a segmental distribution, and it comes from the branches of the femoral artery, femoral profound artery, lateral femoral circumflex artery, and descending genicular artery from top to bottom, of which there is a larger arterial branch entering into this muscle at 8 cm under the inguinal ligament with an outer diameter of 1.3 mm, and the pedicle length is 6.5 cm, which feeds the proximal end of the sartorius muscle with about 15 cm long range and gives off myocutaneous arteries to feed the skin on the surface of the sartorius muscle. This artery is called as the dominant blood vessel in clinic. It has one to two accompanying veins, and this muscle is controlled by one to three femoral nerve branches.

8.22.2 Indications

The upper half of the sartorius myocutaneous flap pedicled with the proximal end of the dominant blood vessel is used to repair the defects in the areas of the trochanter and pubis. The upper half of the sartorius myocutaneous flap pedicled with the distal end of the dominant blood vessel is used to repair the wounds in areas of the knee, popliteal space, and upper tibia.

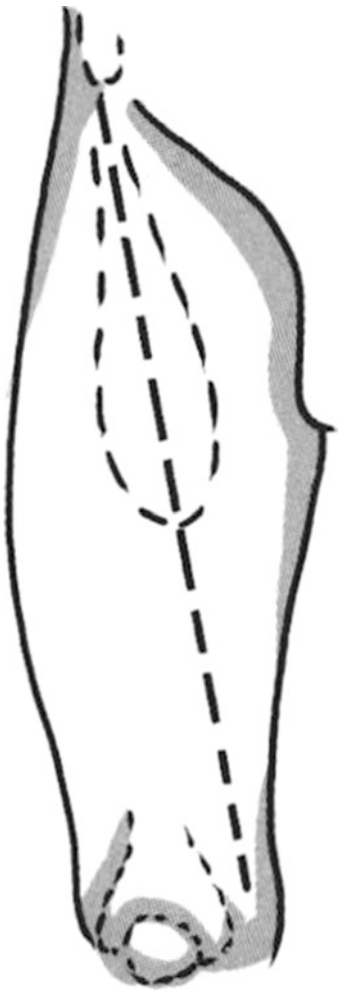

Fig. 3.60 The schematic diagram of the incision design of the sartorius myocutaneous flap

8.22.3 Myocutaneous Flap Design

The body surface projection of the sartorius muscle is taken as the axis line of the sartorius myocutaneous flap. The boundary of the skin flap maximally reaches up to the site at 3–5 cm above the anterior superior iliac spine; the medial boundary can reach the midline in the front side of the thigh, and the lateral boundary reaches to the front edge of the tensor fasciae latae muscle. The donor site of the skin flap can be designed in a range of 6 × 16 cm (Fig. 3.60).

8.22.4 Myocutaneous Flap Harvesting

Incise open the skin and subcutaneous superficial fascia under the anterior superior iliac spine, and expose the fascia lata in the front side of the thigh. Cut off the fascia lata in the front side of the thigh, and expose the sartorius muscle, the rectus femoris muscle, and the femoral nerve at the inner edge of the sartorius muscle, and the muscular branches from different sources are observed at the inner edge of the sartorius muscle from top to bottom. When the outer edge of the sartorius muscle is separated, it is noted that the lateral femoral cutaneous nerve under the anterior superior spine should not be damaged. Cut off the sartorius muscle exposed at the distal incision of the myocutaneous flap; lift up the sartorius myocutaneous flap at the superficial part of the rectus femoris muscle; separate from the lower inner side to the outer upper side, and dissect out the vascular nerve pedicle containing the dominant blood vessels of the sartorius muscle and the sartorius branch of the femoral nerve in the adjacent area at 8 cm under the inguinal ligament. Sometimes in order to make the rotation angle larger, the starting point of the proximal skin and muscle can be cut off to form an island flap for transfer.

8.23 Cutaneous Iliac Flap

8.23.1 Applied Anatomy

The deep iliac circumflex iliac artery is one of the major blood supply sources of the ilium, and it originates from the femoral artery (40.5%) or external iliac artery (59.5%). The beginning part is located within a range from 1.3 cm above the inguinal ligament to 2.4 cm below the inguinal ligament, and the average outer diameter of the beginning part is 2.8 mm. After being given off, the vascular pedicle runs through the deep surface of the abdominal wall muscle, between the superficial layers of the transverse fascia and from the behind of the inguinal ligament obliquely toward the outer upper side, and it is divided into the ascending branch and the terminal branch at the site with a distance of about 3 cm from the medial side of the anterior superior iliac spine, and the ascending branch runs upward between the transverse subabdominis muscle and the obliquus internus abdominis muscle to feed the abdominal wall muscles; the terminal branch runs close to the site at 2 cm under the internal lip of the iliac crest, travels backward in an arc shape between the iliac fascia and the iliac muscle, and gives off a number of branches along the way to supply blood to the anterior iliac crest and the superficial skin, which become the nutrient blood vessels of the anterior iliac crest. The average length of the vascular pedicle is 6.2 cm (4.1–8.1 cm). The deep circumflex iliac artery has one to two accompanying veins, and the two veins converge into a trunk before running into the external iliac vein with an outer diameter of 2–4 mm.

8.23.2 The Design and Harvesting of the Skin Flap

The connecting line from the midpoint of the inguinal ligament (the site with arterial pulses) to the edge of the inferior angle of scapula is taken as the axis line; the anterior iliac

crest (the estimated harvesting area of the ilium bone flap) is taken as the center; the range for skin flap harvesting is marked more than 1–2 cm exceeding the need of repair of the skin and bone defects in the receptor site. Make an incision from the middle of the iliac crest, along the inner edge of the skin flap and reaching obliquely to the midpoint of the inguinal ligament where there exist the femoral artery pulses and extending 3 cm longitudinally downward along the direction of the femoral artery, and then incise open the skin, subcutaneous tissues, and deep fascia. Find and protect the lateral femoral cutaneous nerve at 2.5 cm under the anterior superior iliac spine. Incise open the aponeurosis of the obliquus externus abdominis muscle and obliquus internus abdominis muscle, and flip them up from the outer one third of the inguinal ligament and the area near to the anterior superior iliac spine. The deep circumflex iliac artery and its accompanying veins with their directions parallel to the inguinal ligament can be observed in the sunken fascia space at the junction of the transverse fascia and the fascia iliaca. Separate the deep circumflex iliac blood vessel bundle toward proximally to the initiation site, and cut off and ligate the branches given off along the way. Incise open the aponeurosis of the obliquus externus abdominis muscle, obliquus internus abdominis muscle, and transverse subabdominis muscle layer by layer on the upper edge with a distance of 2–3 cm from the internal lip of iliac crest; the deep fascia and the subcutaneous part of skin flap are sutured with a number of stitches to prevent separation; the linkage between the skin flap and the iliac crest is protected to ensure the blood supply of the skin flap. Separate 2 cm backward paralleling to internal lip of iliac crest and then along the separated vascular pedicle in the posterior edge toward the direction of the front part of the iliac crest, and cut off and ligate the vascular branches entering into the abdominal muscles. Protect the trunk of the deep circumflex iliac blood vessel bundle and the terminal branches entering into the ilium to the back edge of the ilium to be harvested; during the separation, pay attention not to damage the iliohypogastric nerve and the ilioinguinal nerve located between the obliquus externus abdominis muscle and the obliquus internus abdominis muscle. Expose the ilium under the periosteum according to the length of the bone defect; cut off the bone block with a bone knife; carefully cut off the iliac muscle connected with the inner plate; protect the deep circumflex iliac blood vessel; cut off the blood vessel in the starting site of the vascular pedicle to make the bone flap completely free. After the donor site wound is washed, the transverse subabdominis muscle and the transverse fascia which have been cut off are sutured with the iliac muscle and the fascia of the iliac muscle, and the obliquus internus abdominis muscle and the obliquus externus abdominis muscle in the site where the ilium is harvested are sutured with the gluteus muscles and the femoral fascia in the outside. Suture the aponeurosis of obliquus externus abdominis and the obliquus internus abdominis muscle above the outer one third of the inguinal ligament which have been cut off and turned up to prevent the occurrence of abdominal wall hernia.

9 Perforator Skin Flap

The concept of perforator skin flap began in the late 1980s of the twentieth century. Koshima et al. firstly reported in 1989 that the free skin flaps pedicled with myocutaneous perforator vessels were used to repair the groin defects and the tongue defects [13, 14]. Since 1997, the symposium on perforator skin flap has been held internationally once every year. After a dozen years of development, now the application of the perforator skin flap has matured, and it has been widely used in clinic.

9.1 The Names Associated with Perforator Skin Flap

9.1.1 The Relevant Names

In order to standardize the related names of the perforator skin flap, facilitate the academic communication and promote the development of perforator skin flap, Some domestic experts on the basic and clinical researches of the perforator skin flap held a seminar on the perforator skin flap in Yinchuan of Ningxia from July 30 to August 2, 2010, who culminated in consensus on the naming of the perforator skin flap names and related names.

1. Perforator skin flap: The perforator skin flap refers to the axial pattern skin flap which takes the cutaneous perforator vessel with a small diameter as the pedicle to get the blood supply directly rather than taking the deep main vessel as the pedicle to get the blood supply; otherwise, it will be no different from the traditional axial pattern skin flap. Its sources include myocutaneous and septocutaneous perforator vessels. The skin flap supplied with blood by the septocutaneous perforator vessel is called the septocutaneous perforator skin flap, and the skin flap supplied with blood by the myocutaneous perforator vessel is called the myocutaneous perforator skin flap.
2. Perforator vessel: The perforator vessel refers to the small blood vessel which is given off by the source vessel and then runs through the deep fascia to reach the subcutaneous tissue and skin, including the septocutaneous perforator vessel and the myocutaneous perforator vessel. The former passes through the intermuscular septum (space) and the deep fascia to reach the subcutaneous tissue and skin, and the latter passes through the deep muscles and the deep fascia to reach the subcutaneous tissue and skin.
3. Perforasome: The perforasome refers to the maximum anatomic area wherein each perforator vessel and its branches

can be distributed, namely, the maximum range which is available for the harvesting of this perforator skin flap.
4. Perforator vessel anastomosis: The perforator vessel anastomosis refers to the anastomosis between the adjacent perforator branches. It has three types such as real anastomosis, obstructive anastomosis, and potential anastomosis.
5. Chain-linked vascular plexus: The chain-linked vascular plexus refers to the vascular anastomosis with features such as all linked with one another with a certain direction which is formed due to the fact that in the process of the perforator vessels passing through the deep fascia to travel to the superficial layers, the adjacent perforators give off branches and anastomose with each other.
6. The dynamic territory of the perforator vessel: There is a balance point of blood flow pressure at the boundary between donor sites of adjacent perforator vessels; when the perforator vessels in one side are occluded or blocked to lead to a decreased blood flow pressure, the blood flows of the perforator vessels in another one side will cross over the original site of the anastomosis to provide blood supply to the side with the low blood flow pressure and, thus, crossing the anatomical donor site. Namely, it means the skin flap survival area in clinic.
7. Potential boundaries of the perforator vessel: It refers to the harvesting area of skin flap which is expanded beyond the limit of hemodynamic range, but the whole of skin flap can still survive.
8. External pressurization and internal pressurization of the perforator skin flap: When a large area of skin flap exceeding an angiosome is harvested, in order to ensure its survival, the vascular anastomosis must be carried out in the most distal side to establish the ancillary blood circulation. If the perforator vessels in the distal side are anastomosed with the blood vessels in the receptor site located outside of the skin flap, it is called the external pressurization (including artery and vein, single artery, single vein); if the perforator vessels in the distal side are anastomosed with the other branches of its own vascular pedicle in the proximal side, it is called the internal pressurization.

9.1.2 Naming Principles

The following naming principles were proposed in the 2001 international symposium on naming of perforator skin flap:

1. Generally, the perforator skin flaps are named according to the "source artery + perforator skin flap," such as inferior epigastric artery perforator skin flap, thoracodorsal artery perforator skin flap, and superior gluteal artery perforator skin flap.
2. If the source artery gives off more than one perforator vessels, the perforator skin flaps are named according to the methods such as "anatomic site + perforator skin flap" and "deep muscle + perforator skin flap." For example, the lateral femoral circumflex artery gives off multiple perforator vessels, and the names of its perforator skin flaps include the tensor fascia lata perforator skin flap and anterolateral thigh muscle perforator skin flap.

9.2 The Distribution of Perforator Skin Flap

Taylor et al. carried out a detailed study on the cutaneous arteries of the human body using angiographic techniques, proposed the concept of the angiosome, and calculated out that there is an average of 374 perforator vessels with a diameter $\geq$ 0.5 mm in the human skin, and nearly 40 perforator skin flaps can be harvested. Yang Daping et al. carried out radioactive imaging anatomy and computer image processing in ten fresh corpses, and the observation results showed that there are a total of 128 angiosomes in the human skin and 440 perforator vessels with an outer diameter $\geq$ 0.5 mm, and the average outer diameter is 0.7 mm, of which the ratio of the myocutaneous perforator vessel to the septocutaneous perforator vessel is 3:2. There are 20 perforator vessels at each side of the head and neck area, including 7 in the head, 5 in face, and 8 in neck. There are 60 perforator vessels at each side of the body trunk, including 13 in the chest, 17 in abdomen, 21 in back, and 9 in waist. There are 49 perforator vessels in the upper limb on each side, including 22 in the shoulder and arm, 24 in elbow and forearm, and 3 in wrist and hand. There are 91 perforator vessels in the lower limb on each side, including 21 in hip, 34 in thigh, 30 in calf, and 6 in ankle and foot. The rule is as follows:

1. There are myocutaneous perforator vessels in the body trunk, and their running distances and distribution ranges in the skin are greater than those of the perforator vessels in the limb skin.
2. There were intermuscular septal perforator vessels in the limb skin, which are mainly distributed in the surfaces of the deep fascias and the areas around the cutaneous nerves and the superficial veins.
3. The number of the perforator vessels per unit area is inversely proportional to the mobility degree of the skin; the diameters and the running distances of the perforator vessels are in direct proportion to the mobility degrees of the skins and are in direct proportion to the donor areas of the perforator vessels [15–17].

9.3 The Advantages and Disadvantages of the Perforator Skin Flap

Compared with the traditional flap, one of the advantages of the perforator skin flap is the arbitrariness of the donor site; as long as there exists a perforator vessel, this perforator vessel can be taken as the pedicle to form the skin flap; secondly,

the harm to the donor site is reduced, because only the perforator vessel and skin in the donor site are harvested, while the other tissues such as muscle, deep fascia, and nerves are retained, and the wound can usually be closed and sutured directly; thirdly, the harvested skin flap is thin, so that the receptor site will be not so bloated, and this is conducive to the functional activities.

The main disadvantage of perforator skin flap is the instability of the perforator vessels, and therefore before the surgery, the techniques such as duplex Doppler ultrasound and CT angiography should be adopted to determine the points where the perforator vessels penetrate out and their running directions, whereby the axis line and the maximum safe harvesting area are designed. Secondly, the perforator vessels are thin and small, and are likely to be injured during surgery, or the vascular spasm and embolism may appear; thus, the incidence rate of the vascular crisis is higher than that in the conventional flaps; the operation is relatively complex, and a longer time is required to make the skin flap. Therefore, it is required that the surgical doctors have more skilled, precise, and deft anatomical techniques, and the postoperative intensive care is carried out.

9.4 Perforator Skin Flap Commonly Used in Clinics

The perforators flaps used in clinics mainly include two forms for pedicled transfer and free transplantation. The perforator skin flap has the following characteristics: (1) It has a constant blood supply; (2) it has more than one perforator vessels with a diameter ≥0.5 mm; (3) it has a vascular pedicle of sufficient length; and (4) its donor site can be closed and sutured directly.

9.4.1 Thoracic Dorsal Artery Perforators Flap

The thoracic dorsal artery perforator flap is evolved on the basis of the latissimus dorsi myocutaneous flap, and it was reported by Angrigiani et al. in 1993. It is supplied with blood by the myocutaneous perforator of the thoracodorsal artery. It doesn't carry the latissimus dorsi muscle and the thoracodorsal nerve and can be used for pedicled or free transplantation to cover the wounds in the torso and limbs, and it can also carry the scapula to repair the mandibular defects [18].

The thoracodorsal blood vessel is originated from the subscapularis artery, which enters into muscle from the deep surface of the latissimus dorsi muscle and is divided into the horizontal branch at the medial side and the vertical branch at the outer side. Of which, the vertical branch runs downward with a distance of 2–3 cm from the outer edge of the muscle. The blood supply of thoracic dorsal artery perforator flap comes from the distal end of the vascular trunk, which can also come from the vertical branch. The first perforator vessel is located at 6–8 cm under the posterior wall of the axilla. There are three perforator vessels emanating from the vertical branch; the interval is 1.5–4 cm; each perforator vessel runs obliquely for 3–5 cm to penetrate through the muscle to reach the skin. The diameter is 0.3–0.6 mm, and each perforator vessel has two accompanying veins.

Generally the first perforator vessel is taken as the center to design the skin flap. The long axis of the skin flap is parallel to the outer edge of the latissimus dorsi muscle. The width of the skin flap can reach to 8–12 cm, and the length can maximally reach to 25 cm. The first perforator vessel can be detected at 6–8 cm under the posterior wall of the axilla and at 2–4 cm within the outer edge of the latissimus dorsi muscle with Doppler flowmetry.

9.4.2 The Deep Inferior Epigastric Artery Perforator Flap

The deep inferior epigastric artery perforator (DIEAP) flap was reported by Koshima et al. as early as in 1989, and it is further improved on the basis of transverse rectus abdominis myocutaneous flap.

The inferior epigastric artery is originated from the external iliac artery above the inguinal ligament, runs toward the inner upper side to enter into the sheath of rectus abdominis muscle through the semilunar line, and runs upward in the deep surface of the rectus abdominis muscle. The inferior epigastric artery gives off 2–3 terminal branches at the level of the navel and anastomoses with the superior epigastric artery at the level of a tendinous intersection above the navel. Along the way, it gives off segmental arteries outward to anastomose with the intercostal arteries and gives off myocutaneous perforators simultaneously to provide blood supply to the abdominal skin [19].

Alexandre et al. observed that the perforator vessels penetrate out of the rectus abdominis anterior sheath and are often vertically arranged in two rows. One row is located at the outer one third of the rectus abdominis muscle, and another row is located at the inner one third of the rectus abdominis muscle; 66% of perforator vessels are located in the medial row, 34% of perforator vessels are located in the outer row. Heitmann et al. found that in the abdominal wall on each side, there are always 1–3 perforator vessels with a diameter greater than 1 mm, of which three perforator vessels account for 10%, two perforator vessels account for 67.5%, one perforator vessel accounts for 22.5%. Halloek recommended that the positioning range of the inferior epigastric artery perforator is as follows: A vertical line is made, respectively, at 1 cm and 6 cm on the outer side of the abdominal midline; then a horizontal line is made, respectively, at 2 cm above the navel and 4 cm under the navel; and the perforator vessels on each side are located roughly in corresponding rectangles. The ultrasound, color Doppler ultrasound, CT angiography, three-dimensional imaging, and

other technologies can help locate the positions of the preoperative perforating branches.

The perforator vessel is taken as the center to design the skin flap, which is spindle-shaped or oval. Both lateral boundaries reach to the anterior superior iliac spine. The upper boundary is located at 2–3 cm above the navel, and the lower boundary can reach to the site above the pubic tubercle. When the skin flap is harvested, it is lifted up from the surface of the tendon sheath of the obliquus externus abdominis muscle firstly on the outer side of the skin flap to expose the myocutaneous perforator beside the navel, then the rectus abdominis anterior sheath is incised, and finally the perforator vessels are bluntly dissected and traced to the trunk of the inferior epigastric artery.

9.4.3 Hip Perforator Flap

The hip perforator flap was firstly reported by Granzow et al. in 1993. It is widely distributed, whose blood supply is provided mainly by the superior gluteal artery, the inferior gluteal artery, the fourth lumbar artery, and (or) the descending branch of the iliolumbar artery, and the vast majority of them are myocutaneous perforators. There are a total of 20 to 25 myocutaneous perforators and intermuscular septal perforators in the entire gluteal region, where it is the most densely populated area of perforator vessels in the covering tissues of the human body. Hu Siwang et al. reported that there are 5 ± 2 superior gluteal artery perforators with a diameter ≥ 0.5 mm; the distribution area of perforator vessel is 69 ± 56 cm^2; the blood supply area of each perforator vessel is 21 ± 8 cm^2; there are 8 ± 4 inferior gluteal artery perforators with a diameter ≥ 0.5 mm; the distribution area of perforator vessel is 177 ± 38 cm^2; the blood supply area of each perforator vessel is 24 ± 13 cm^2. The positioning of hip perforator flap is carried out, mostly taking the superior gluteal artery perforator as the pedicle in the inner two thirds of the connecting line between the posterior superior iliac spine and the femoral great trochanter.

9.4.4 Radial Artery Perforator Flap

The radial artery runs between the brachioradialis muscle and the flexor carpi radialis muscle; then it gives off a larger constant perforator at about 6–8 cm above the radial styloid process with a diameter of 0.6–0.8 mm, which is called the dorsal superficial branch of the radial artery; and the radial artery is divided into the thin and short ascending branch and the thick and long descending branch at about 6 cm above the radial styloid process. About ten tiny fasciocutaneous perforators given off by the descending branch are mutually anastomosed around the radial styloid process and form a dense vascular anastomosis net.

The axis line of the skin flap is the body surface projection line of the radial artery. The rotation point of the skin flap is located at 1.5–2 cm above the radial styloid process, and the pedicle with a width of more than 3 cm is appropriate. Clinically it is used to repair the wound in the hand.

9.4.5 Deep Circumflex Iliac Artery Perforator Flap

The deep circumflex iliac artery originates from the external iliac artery, runs toward the outer upper side along the inguinal ligament line to the anterior superior iliac spine, and runs toward the back upper side along the upper edge of the iliac crest and between the obliquus internus abdominis muscle and the termination point of the transverse abdominal muscle, which gives off 1–2 perforator vessels at 5–10 cm on the rear side of the anterior superior iliac spine and 1.2–3.5 cm above the iliac crest to feed the skin in the region. The inner diameter of blood vessel diameter is 0.7 mm, and the blood supply range is 30 cm^2.

Before surgery, the pen-type Doppler flowmetry is used to detect and mark the perforator vessels between 1.2 and 3.5 cm along the upper side of the iliac crest. The long axis of the skin flap is parallel to the iliac crest, and the front end is 5 cm far from the anterior superior iliac spine. If the deep circumflex iliac artery perforator is taken as the pedicle alone to harvest the skin flap, a skin flap of 10×6 cm can be harvested taking the site at 2 cm above the iliac crest peak as the center; if it is needed to expand the harvesting range, take advantage of the rich anastomoses deep between the deep circumflex iliac artery and the anterior cutaneous branch of the lumbar artery to harvest toward the back upper side in the blood supply area including the lumbar arteries, and a skin flap of 20×10 cm can be harvested.

9.4.6 Anterolateral Shares of Perforator Flap

The skin flap is supplied with blood by the descending branch of the lateral femoral circumflex artery and the perforating branch given off by its accompanying veins; in a few cases, the transverse branch of the lateral femoral circumflex artery, the trunk of the lateral femoral circumflex artery, and the perforating branch of the femoral profound artery provide direct blood supply and nutrition to the skin. Most perforating branches penetrate out of the vastus lateralis muscle, and a few perforating branches penetrate out between the anterior superior iliac spine and the rectus femoris muscle. The descending branch of the lateral femoral circumflex artery runs between the rectus femoris muscle and vastus lateralis muscle toward the outer lower side, which gives off the first perforating branch at the midpoint of the connecting line between the anterior superior iliac spine and the outer upper edge of the patella with an outer diameter of 0.5–1.0 mm, and it is the main blood vessel of the anterolateral thigh flap, and then it gives off the second to ninth perforating branches successively on this connecting line. The vascular pedicle length of the skin flap is 8–12 cm.

In skin flap design, the connecting line from the anterior superior iliac spine to the outer upper edge of the patella is taken as the axis line, and the midpoint of this connecting line is the surface projection of first perforating artery. Before surgery, the Doppler flowmetry is firstly used to detect and mark the position of the first perforating branch of the descending branch of the lateral circumflex femoral artery near the midpoint of the patella-ilium connecting line. The shape and size of the skin flap are determined according to the shape and size of the wound, and this perforating branch is positioned near the center of the upper one third part of the skin flap. If a large area of skin flap is designed, the second and third perforating arteries should be retained. The range for skin flap harvesting: The upper boundary is the distal end of the tensor fasciae latae muscle; the lower boundary is located at 7 cm from upper edge of the patella; the medial boundary is no more than the medial edge of skin flap, and the outer boundary reaches the intermuscular septum.

Incise open the medial edge of the skin flap and vascular pedicle to reach the deep fascia; separate the intermuscular space between rectus femoris muscle and vastus lateralis muscle; detect out the myocutaneous perforator and septocutaneous vessels. Incise open the outer edge and the distal end; lift inward the skin flap under the deep fascia, and carefully find perforator vessels. Detect out the perforator vessel from the muscle along the direction of the perforator vessel, and pay attention to protect to the muscular branch of the femoral nerve. Incise open the proximal end of the skin flap, and separate the lateral femoral cutaneous nerve.

9.4.7 Tensor Fasciae Latae Perforator Flap

The blood supply of tensor fasciae latae perforator flap comes mainly from the lateral femoral circumflex artery. The lateral femoral circumflex artery gives off the ascending branch, the horizontal branch, and the descending branch; the ascending branch gives off muscle or septal perforator to provide nutrition to anterolateral thigh flap or anteromedial thigh flap; the horizontal branch mainly provides nutrition to the tensor fasciae latae muscle and is the main source of blood supply to this muscle. The horizontal branch is divided into the upper branch, the middle branch, and the lower branch at the anteromedial surface of the muscle, providing nutrition, respectively, to the upper, middle, and lower parts of the muscle. All these three branches within the muscle give off perforator vessels to enter into the skin from the front half of muscle, and there are 5–7 perforator vessels with a diameter of 0.8–1.0 mm. The harvesting area for a single perforator skin flap is 9 × 5 cm, and the harvesting area for several perforator skin flaps can be greater than 15 × 12 cm.

The Doppler flowmetry is used to determine the locations of perforator vessels, and the size and scope of the skin flap are determined according to the need of wound repair. A longitudinal incision is made at the front boundary of the skin flap, and the lateral circumflex femoral vessel and the horizontal branch are exposed between the rectus femoris muscle and tensor fascia lata muscle. The perforator vessels are dissected out from the tensor fascia lata muscle along the horizontal branch, the trunk of the horizontal branch and the lateral femoral circumflex artery are dissected toward the proximal end, and the perforator vessel is taken as the center to determine the scope of the skin flap harvesting. If the donor site defect is less than 5 cm, it can be sutured directly; otherwise, it is required to carry out free skin transplantation to repair the wound in the receptor site.

9.4.8 Posterior Tibial Artery Perforator Flap

The posterior tibial artery perforator flap was first reported by Zhang in 1984, and its blood supply comes directly from the intermuscular septal perforator of posterior tibial artery. The posterior tibial artery is generally located at 5–10 cm above the medial malleolus, and it has 3–4 fairly constant perforator vessels with an outer diameter of 0.5–2 mm and 1–2 accompanying veins mostly, in order to provide nutrition to the medial skin in the middle and lower part of the calf. The perforator vessels pass through the deep fascia in the medial calf between the soleus muscle and flexor digitorum longus muscle, when they penetrate superficially out; they are divided into two branches such as anterior and posterior branches. The anterior branch is distributed into the skin at the medial side of the tibia, and the posterior branch penetrates out of intermuscular space to reach the skin The body surface projection of the site where the perforator artery penetrates superficially out of the fascia is on the connecting line from the junction of the middle and upper one third of the medial edge of the tibia to the Achilles tendon midpoint at the posterior edge of the medial malleolus.

Before surgery, the ultrasonic Doppler blood flowmeter is used to detect the site where the perforating branch of the posterior tibial artery penetrates out at the body surface projection area of the perforator artery and marks the site as the rotation point of the skin flap. According to the need of the wound, the rear edge within the tibia is taken as the longitudinal axis line to design the shape and size of skin flap. At first, the front edge of the designed skin flap is harvested; after the perforator vessels are confirmed, the separation is performed toward the deep part of the intermuscular septum to reach the trunk of the posterior tibial artery, and then the skin flap is harvested according to the preoperative design.

9.4.9 Medial Gastrocnemius Artery Perforator Flap

The medial gastrocnemius artery originates from the medial popliteal artery. The trunk runs obliquely toward the inner lower side and enters into the muscle at the deep surface of

the medial head of gastrocnemius muscle, then runs downward along the long axis of the muscle fibers, gives off a few muscular branches and cutaneous artery perforators, and provides nutrition to muscles in the medial head of the gastrocnemius muscle and its surface skin. There are 2–7 perforator vessels, with an average of four perforator vessels, of which a perforator vessel is relatively thick and large. Before surgery, firstly the Doppler flowmetry is used to detect the myocutaneous perforator of the medial gastrocnemius artery in a range between the site with a distance of 10–17 cm from popliteal folds and the site with a distance of 2–5 cm from the posterior median line, and there are mostly 1–4 myocutaneous perforators, which are well marked. A larger myocutaneous perforator is selected as the rotation point of the skin flap, which is designed according to the size and shape of the wound in the receptor site, and attention should be paid so that the perforator vessel is placed in the upper part of the skin flap to increase the rotation distance of the skin flap. It is appropriate to firstly perform inflating homeostasis before surgery to facilitate the identification of the myocutaneous perforator during surgery. At first, incise open the medial edge of the skin flap to the area under the myolemma of medial head of gastrocnemius muscle; lift up the skin flap, and it is observed that the perforator vessel passes out of the medial head of the gastrocnemius muscle and then vertically enters into the deep fascia to reach the skin. Then separate the muscle longitudinally along the perforator vessels; dissect out the medial sural artery, after reaching the requirements of the receptor site; then incise open the surrounding area of the skin flap according to the design. Loosen the tourniquet; after a good blood supply to the skin flap is observed, the pedicle can be cut off, or the skin flap can be transferred to the receptor site through subcutaneous tunnel.

9.4.10 Peroneal Artery Perforator Flap

The peroneal artery perforator flap is located at the outer side of the calf, and the main blood supply comes from septocutaneous perforators of the peroneal artery, which are directly given off by the peroneal artery. There are about 4–8 septocutaneous perforators, of which, the second, third, and fourth septocutaneous perforators are generally larger, and the outer diameters are mostly 0.6–1.0 mm. The peroneal artery perforators are mainly concentrated in the range of 10–20 cm under the fibular head, and the farthest perforator is mostly given off from the site at 5–8 cm above the prominence of the lateral malleolus. The appearance rate of the perforators is 93%, and the perforator pedicle length is 4–6 cm. Various perforators were anastomosed mutually with cutaneous branches of anterior and posterior tibial arteries. Generally the peroneal artery perforator has two accompanying veins.

A connecting line between the fibular head and the external ankle is made before surgery; Doppler flowmetry is used to detect and mark out the points where the perforator vessels penetrate out on this connecting line, respectively, at the 15 and 20 cm under the fibular head and 7 cm above the prominence of the lateral malleolus. One of the points will be selected as the rotation point of the skin flap to design the size and shape of the skin flap according to the need of wound repair. The anterior edge of the design range of the skin flap can reach up to 3 cm in front of the fibula, and the posterior edge can reach the posterior midline of the calf. The surgery is performed under the condition that the air pressure tourniquet is used to stop bleeding and lead to engorgement of perforator vessels of skin flap. Incise open the skin and subcutaneous tissue to reach deep fascia at the posterior edge of the skin flap; lift the skin flap forward; carefully find out the perforator artery given off from the intermuscular septum by the peroneal artery between the soleus muscle and long fibular muscle, which is taken as the rotation point of the skin flap; incise open the periphery of the skin flap; dissect and lift the skin flap distalward under the deep fascia; and it is noted that the fasciocutaneous pedicle with a width of 3 cm is preserved, which is incised and lifted distalward together with the skin flap.

9.4.11 Descending Genicular Artery Perforator Flap

A majority of the descending genicular arteries originate from the femoral artery at a distance of 10.5 ± 1.7 cm from the adductor tubercle, while a minority originate from the popliteal artery and run downward along the front of the adductor magnus tendon. The starting outer diameter is 2.0 mm (1.0–3 mm), and the trunk length is 1.2 + 0.5 cm. It has two accompanying veins, whose outer diameters are slightly thicker than the outer diameter of the artery. The descending genicular artery usually gives off a thick and large saphenous branch and an articular branch. The articular branch runs straight downward between the posteromedial side of the medial vastus muscle and the adductor magnus tendon and gives off the medial femoral muscular branch, the adductor magnus tendon branch, the periosteum branch, and the cutaneous perforator branch. The terminal branch is transitioned to the infrapatellar branch, which passes through the anterolateral side of the great adductor tubercle to the medial meniscus plane, runs horizontally toward the inner lower side of the patella along the surface of the articular capsule in the medial meniscus plane, and anastomoses with terminal ends of the arteria genus inferior medialis to join the genicular articular rete. The cutaneous perforator branch of the descending genicular artery is relatively constant, which gives off numerous small blood vessels to anastomose with the adjacent vascular network around the patella, the perforator vessel of the medial vastus muscle, and the perforator vessels in the anterior and posterior edges of the sartorius muscle to form vascular plexus, greatly increasing the blood supply range of the skin flap and forming the trans-regional

blood supply of skin flap. In the skin flap design, the anterior edge of the sartorius muscle is taken as the axis, and the site at 4 cm above the lower edge of the medial femoral condyle is taken as the rotation point (the point where the cutaneous branch penetrates out). The upper boundary of the harvesting area of the skin flap can reach the midpoint of the inner thigh, and the lower boundary is located in triangle in the medial knee. According to the design line of the skin flap, firstly incise open the anterior edge of the skin flap to directly reach the sublayer of the fascia lata; lift the skin flap backward the point where the perforator vessel penetrates out; carefully dissect the perforator pedicle; and harvest the entire skin flap according to the design.

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Defect Repair After Eyelid Tumor Surgery

4

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There are two types of eyelid tumors such as benign and malignant tumors. The common benign eyelid tumors include eyelid papilloma, calcified epithelioma, keratoacanthoma, adenoacanthoma, dermoid cyst, xanthoma, pigmented nevus, and hemangioma, while the common malignant tumors include basal cell carcinoma, meibomian gland carcinoma, squamous cell carcinoma, malignant melanoma, sebaceous carcinoma, and malignant lymphoma and malignant granuloma, and the sarcoma is rarely seen. The tumors occur mostly in the lower eyelid, especially in the eyelid margin and canthal corner. The surgical resection is the preferred method of treatment [1]. The malignant tumor patients with regional lymph node metastasis should undergo additionally regional lymph node dissection.

The resection range of malignant tumors should be determined according to the pathological types and infiltration situation, and it should generally be at 5–10 mm on the outside of the tumor. The patients usually undergo full-thickness eyelid resection. The patients with suspected malignant lesions or precancerous skin diseases in the eyelid should undergo more extensive resection as early as possible; furthermore, the resection range should include some surrounding normal tissues, and the biopsy and surgery should be completed at one time, so as to avoid the proliferation of cancer and simultaneously avoid the secondary surgery and reconstructive difficulties. The intraoperative histological examination (rapid section) is performed to ensure complete tumor resection.

The eyelid is an organ to protect the eyeball; therefore, all morphological abnormalities due to eyelid tumor resection need to be repaired and reconstructed, and most of the surgeries have plastic properties.

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1 Small Defect Repair

1.1 Direct Suture

This method is suitable for patients with small full-thickness defects of 4–6 mm or defects less than one fourth of the total length of the eyelid or older patients with defects less than or equal to one third of the total length of the eyelid. After local anesthesia, the surgical procedure is as follows:

1. Trim the eyelid margin defect to make it look like fusiform or triangle (Fig. 4.1a, b).
2. Firstly make a suture at the line between the anterior lip and posterior lip within the eyelid to make good alignment of the eyelid margins (Fig. 4.1c).
3. The wound margins are sutured with layered interrupted suture, then the mattress suture or 8 characters suture can be performed, and the skin wound margins are sutured with 5-0 suture line (Fig. 4.1d–g).

1.2 The Method for Vicarious Suture of Anterior and Posterior Layers of the Eyelid

This method is also applicable to the full-thickness defects. The surgical procedure is as follows:

1. Trim the wound margin to make it triangle shaped, and incise open along the dotted line to form two lobes such as the anterior lobe and the posterior lobe (Fig. 4.2a).
2. On one side of the wound, remove downward from the eyelid margin a strip of tissue of eyelid anterior layer with a width of 2–3 mm, and then remove the corresponding tissue of eyelid posterior layer in the opposite wound margin (Fig. 4.2b).
3. Perform a mattress suture; insert the needle, respectively, at the conjunctival surface at one side of the tissue of eyelid posterior layer with both ends of the suture line tissue;

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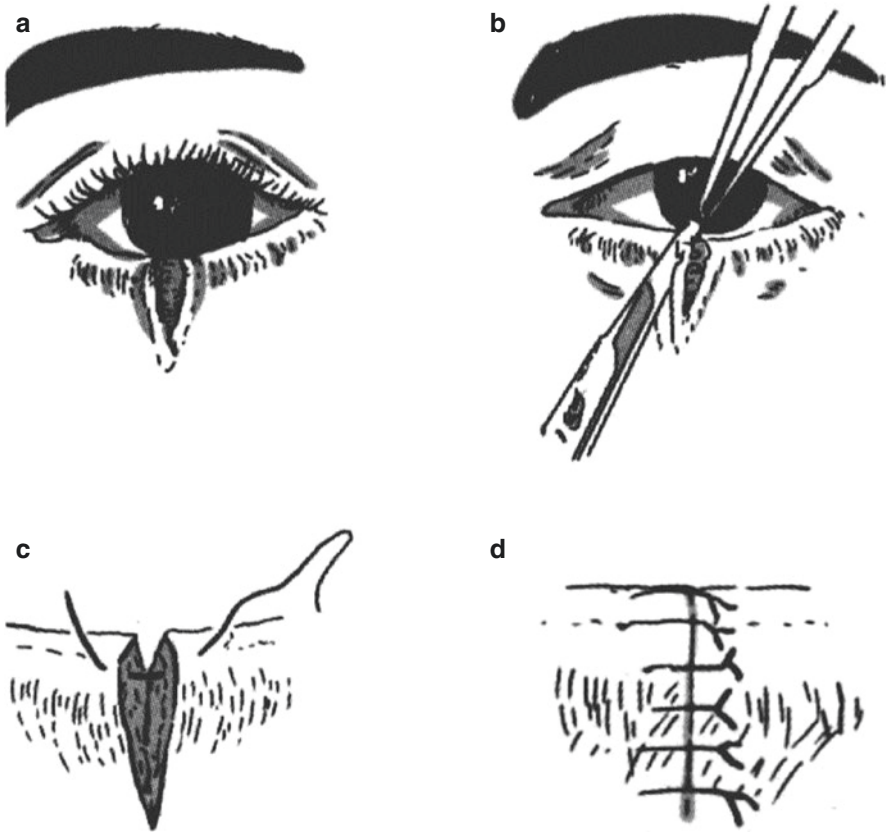

Fig. 4.1 Direct suture. (**a**) Defect after tumor surgery. (**b**) Location. (**c**) Sew up the palpebral margin. (**d**) Completion

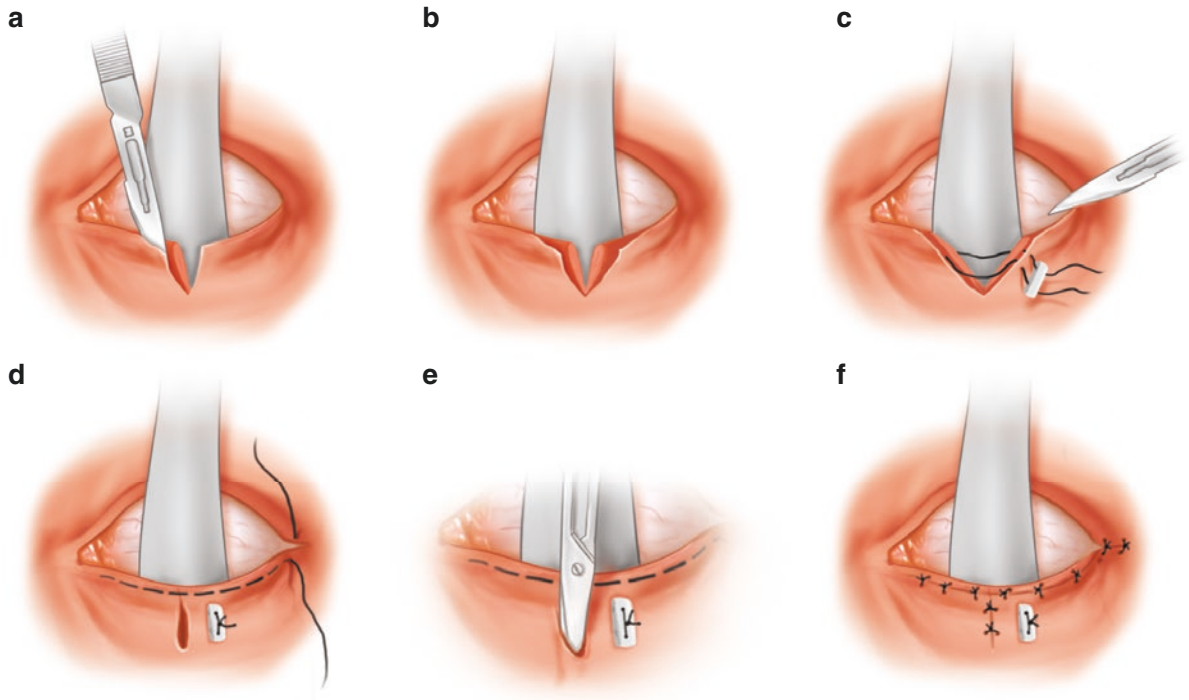

Fig. 4.2 The method for vicarious suture of anterior and posterior layers of the eyelid. (**a**) Incise open the lower eyelid along the dotted line. (**b**) Excise anterior skin layer of eyelid on one side, excise posterior tarsal plate layer of the eyelid on the other side. (**c**) Sew up posterior tarsal plate layer. (**d**) Horizontally sew up the anterior lobe and the posterior lobe. (**e**) Vicarious suture the vertical skin incision. (**f**) Completion

pass through the tarsus, penetrate out of the skin surface on the other side of the anterior layer, and pass through a sheet rubber; and then incise open the lateral canthus by two times the length of the defect according to the size of the defect area (Fig. 4.2c).
4. Ligate the mattress suture line on a small piece of sheet rubber. The suture line penetrates through the deep tissue in the outer canthus, and the interrupted suture is performed (Fig. 4.2d).
5. Perform interrupted sutures in all wound margins. Perform compression bandaging, then carry out dressing every other day, and finally take out the stitches 1 week later (Fig. 4.2e, f).

2 Repair of Medium or Large Upper Eyelid Defect

2.1 Cutler-Beard Method

This method is suitable for long and thin upper eyelid defect, and the surgical procedure is as follows:

1. Cut through the eyelid paralleling to the eyelid margin at the site with a distance 3–4 mm from the lower eyelid margin, and the length is equal to that of the upper eyelid defect. Along both ends of the transverse incision, incise downward the full thickness of the eyelid vertically to the eyelid margin; cut straightly toward the bottom of the lower eyelid dome, and the length is about 15 mm. Finally, the lower eyelid flap is formed (Fig. 4.3a).
2. Separate the skin and subcutaneous tissues from the muscle in the lower eyelid flap, and separate the conjunctiva from the muscle, which leads to complete looseness between the conjunctiva and skin in order to successfully pull it up to the upper eyelid defect. The lower eyelid margin becomes a "bridge" with both ends connected to the canthus.
3. Pull upward the lower eyelid flap from the area under the "bridge"-shaped eyelid margin, and transplant it in the upper eyelid defect (Fig. 4.3b). The conjunctiva is sutured with the muscle and the remaining posterior lobe of upper eyelid, and the skin and muscle are sutured interruptedly. The approximating suture of skin and conjunctiva in the lower eyelid margin wound is performed.
4. The compression bandaging is performed for 2–3 days, and the stitches are taken out 7 days later. After 2 months, at the same height of the healthy eye, the tarsus flaps which are cut off and implanted at the inner and outer canthus are connected, and the wound in the eyelid margin is sutured; the broken end of transplant flap under the "bridge" is restored to its previous position (Fig. 4.3c). The lower eyelid margin incision is separated again, and an apposition suture is performed.

2.2 Composite Transplantation Method

This method is suitable for patients with upper eyelid full-thickness defects, and the surgical procedure is as follows:

1. Take out a full-thickness tissue block in the lower eyelid, whose width doesn't exceed 1 cm, and it shows a triangular shape (Fig. 4.4a).
2. Trim the margin of the upper eyelid defect; after the transplant block is placed, the vicarious suture of anterior and posterior layers of the eyelid is performed. The wound in donor site is closed and sutured directly (Fig. 4.4b, c).

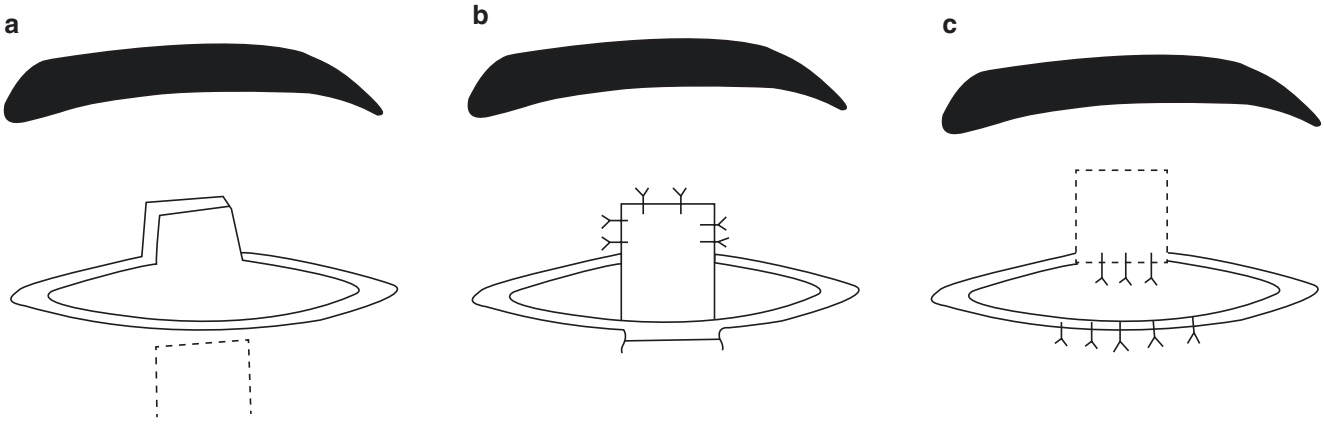

Fig. 4.3 Cutler-Beard method. (**a**) The lower eyelid is cut through transversely at the site with a distance 3–4 mm from the lower eyelid margin, and the lower eyelid flap is formed. (**b**) The lower eyelid flap is passed through the "bridge"-shaped eyelid margin and is transplanted onto the upper eyelid defect. (**c**) The transplant flap is cut off at 2 months after surgery, then the palpebral fissure is made, and the transplant flap under the "bridge" is restored to its previous position

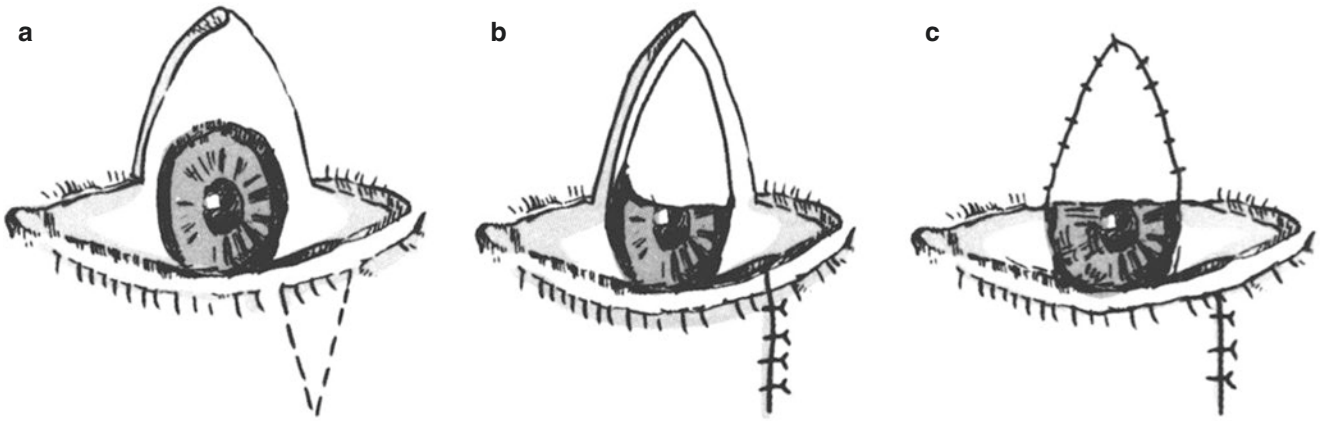

Fig. 4.4 Composite transplantation. (**a**) A full-thickness tissue block in the lower eyelid is taken out according to the *dotted line*. (**b**) The wound in donor site is closed and sutured directly, and the margin of the upper eyelid defect is trimmed. (**c**) After the transplant block is placed in the upper eyelid, the vicarious suture of anterior and posterior layers is performed

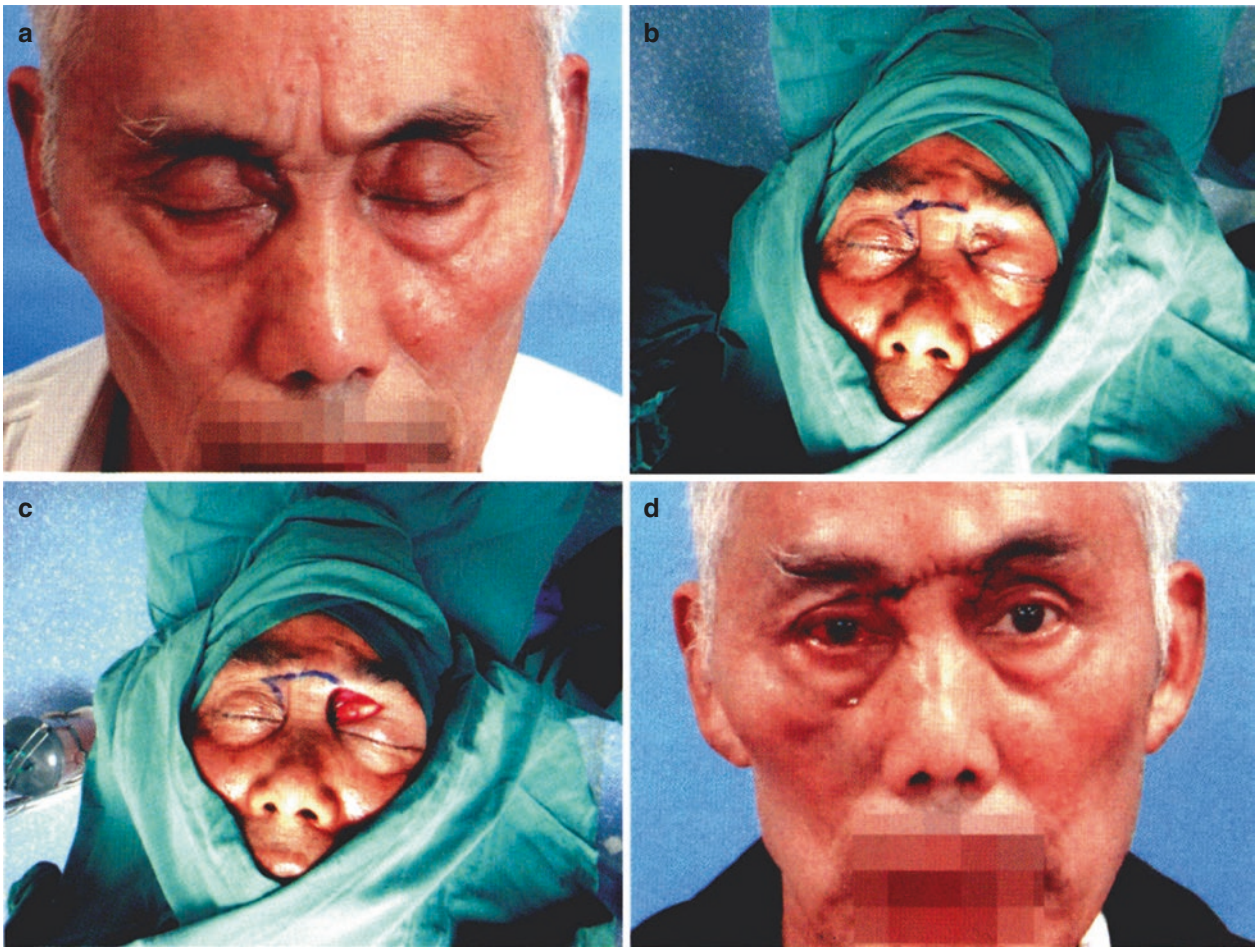

Fig. 4.5 Case I. (**a**) The right upper eyelid basal cell carcinoma. (**b**) The tumor resection range and skin flap design. (**c**) Upper eyelid defect after tumor resection. (**d**) The eyelid shape is good at 10 days after surgery

2.3 Repair Method with the Ortho-position Skin Flap

Case I This is a patient with simple eyelid skin defect, and the defect can be repaired with the ortho-position skin flap (Fig. 4.5).

2.4 Forehead Flap

This method is suitable for the repair of the upper or lower eyelid skin defect due to tumor resection.

The blood supply of the forehead flap includes two systems such as the frontal branch of the superficial temporal

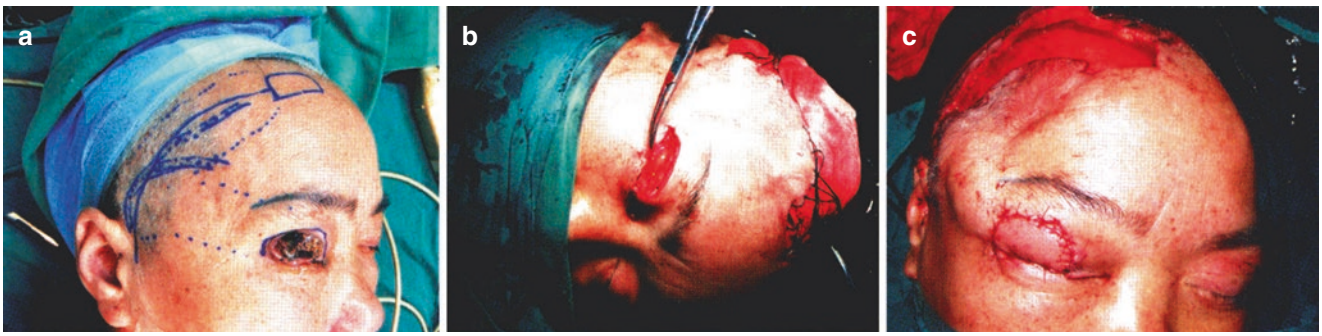

Fig. 4.6 Case II. (**a**) The upper eyelid mass and skin flap design. (**b**) The defect after mass resection. (**c**) The forehead flap is passed through the subcutaneous tunnel to repair the eyelid defect

artery as well as the supraorbital artery and supratrochlear artery, and there is a netlike distribution of rich anastomosis branches between two systems of blood vessels. In general, there are concomitant venous veins of the same name for venous return. Any system of blood vessels can be taken as the supplying vessels, and both can feed and ensure the survival of the skin flap.

The forehead flap can be used for repair of upper and lower eyelid defects, which is appropriate to take the superficial temporal artery as the pedicle for the lower eyelid; the superficial temporal artery or the supratrochlear artery can be taken as the pedicle for the upper eyelid according to the defect site.

Case II This is a patient with upper eyelid defect, and the forehead flap is used for repair (Fig. 4.6).

3 Repair of Medium or Large Lower Eyelid Defect

3.1 Mustard Method

This method is suitable for repair of larger eyelid defects (lower eyelid defect), and the surgical procedure is as follows:

1. At first, a nasal septal cartilage with mucosa is taken according to the size of the lower eyelid defect for repairing the defects in the posterior lobe of the lower eyelid.
2. The incisions are extended, respectively, toward the outer lower side and the inner outer side from the margins of the eyelid defect, and both incisions converge in a place with a height equivalent to twice the height of the defect, and the triangle skin between the incisions is removed.
3. A slightly upwardly curved arcuate incision is made at 2–3 mm above the lateral canthus of upper eyelid, and then the incision is extended to the posterior outer side, turns to the inner lower side at the temple, passes through the area at 15 mm in the front of the auricle, and travels downward and stops at 1–1.5 cm under the earlobe (Fig. 4.7a).
4. The subcutaneous tissue between the lower eyelid defect and the preauricular incision is stripped off to allow it to be moved to the nasal side (Fig. 4.7b).
5. The prepared septal cartilage with mucosa (the mucosal surface faces toward the position of the conjunctiva) is implanted in the defect area of the lower eyelid, and then the cartilage mucosa graft and the skin flap are used together to reconstruct the lower eyelid; at last, the wound is sutured layer by layer (Fig. 4.7c).
6. A light pressure bandage is applied after surgery, the intermittent dressing is carried out, and the skin stitches are taken out on the tenth day.

3.2 Repair Method with the Retroauricular Island Flap Pedicled with the Superficial Temporal Artery

This method is suitable for repair of the whole lower eyelid defect caused by the extensive resection of malignant eyelid tumors [2, 3].

The posterior auricular artery is a relatively constant artery, which has rich anastomoses with the parietal branch of the superficial temporal artery, and such anastomoses provide that the transferred skin flap pedicled with a certain blood vessel cannot be limited to the anatomical basis in the blood supply range of this vascular pedicle. Based on this principle, the reversal flow axial retroauricular island flap pedicled with the superficial temporal artery and vein is designed (also known as the reversal flow axial flap in the mastoid process area at the back auricle), and its venous return direction starts from the posterior auricular vein and runs along anastomosis branches to reach the superficial temporal vein. In addition, the perivascular fascia tissue should be retained during surgery, in which all the venules and the immaturely developed veins have no valves, which can ensure the venous return of the skin flap. Because the superficial temporal and posterior auricular arteries and veins are located in the superficial temporal fascia, when the pedicle is harvested, it is required to ensure the integrity of the superficial temporal fascia. The relatively concentrated

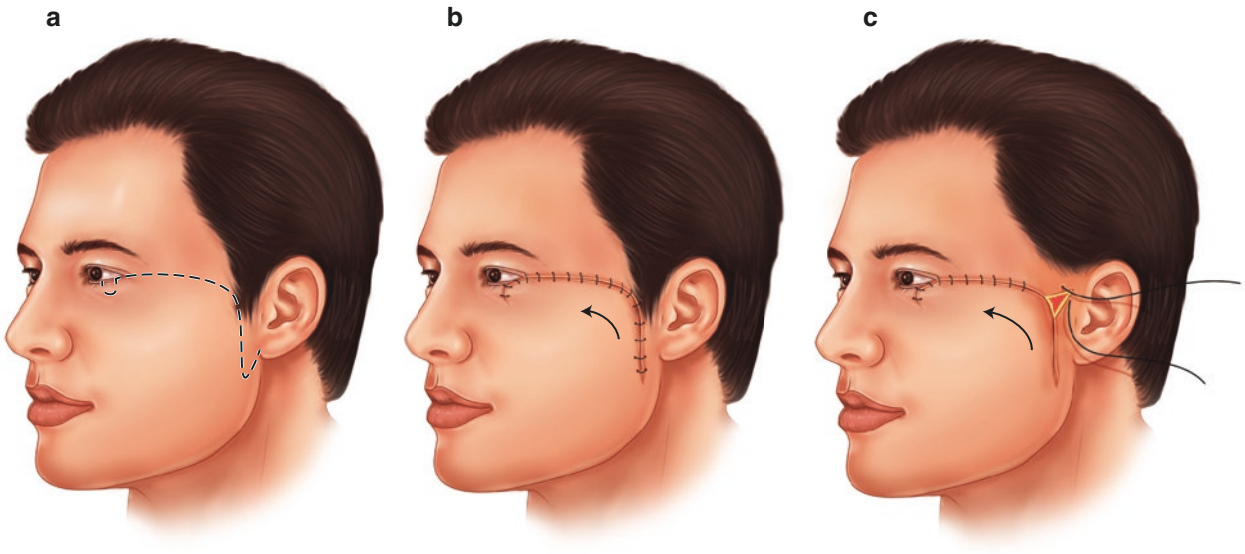

Fig. 4.7 Mustard method for repairing the larger lower eyelid defect. (**a**) The incision line. (**b**) Rotation of the skin flap. (**c**) After the wound is sutured

place of anastomosis points is between the area above the pinna and the parietal protuberance, and the pedicle of the skin flap should include this area.

3.2.1 Surgical Methods

1. Skin flap design. According to the defect area in the lower eyelid, the skin flap to be harvested in the mastoid process area at the back auricle is drawn out, and the positions of the communicating branches between the superficial temporal vessel and its parietal branch and the posterior auricular artery are drawn out in front of the crus of helix and at 2–9 cm above the pinna.
2. Surgical procedure. Incise open the skin and subcutaneous tissue along the drawing line, and expose the communicating branches between the superficial temporal vessel and its parietal branch and the posterior auricular artery. There may be two to four communicating branches, which can also present as reticular anastomoses (usually located on the fascia at 2–9 cm above the pinna with a width of about 3 cm). Expose downward the posterior auricular artery along the communicating branches to directly reach the postauricular flap to be harvested, incise open the skin and subcutaneous tissue according to the draw lines from the distal end and both sides of the skin flap, and expose and ligate the posterior auricular artery. After separating the skin flap at the deep surface of the posterior auricular artery, incise open the fascias on both sides of the posterior auricular artery and the communicating branches upward to reach the superficial temporal artery, and separate and form the island flap under the fascia.

   A subcutaneous tunnel from the wound margin in the crus of helix to defect margin is made, and the island flap is passed through subcutaneous tunnel to reach the defect area under the condition of no tension; the buccal mucosa is transplanted to replace the defected palpebral conjunctiva and reconstruct the conjunctival sac; the wound is sutured layer by layer, and the lower eyelid defect is repaired. Finally, the patient receives a monocular fixation bandaging. The wound in the donor site is directly closed and sutured or is repaired with skin transplantation.
3. Precautions
   (a) The skin flap has a long pedicle and a thin flap with good color, the donor site is concealed, and the curative effect is reliable.
   (b) There may be a variation in positions of the communicating branches between the parietal branch of the superficial temporal artery and the posterior auricular artery; therefore, it is needed to use the blood vessel navigation technology such as Doppler to detect the status of the blood vessels before surgery.
   (c) The position of the parietal branch of the superficial temporal artery is superficial, and the communicating branches are thin and small. Therefore, caution should be paid to ensure that the communicating branches are not damaged during surgery, and it is noted that the vascular pedicle is retained with an appropriate width and is harvested together with the fascia.

3.2.2 Typical Case

1. Case III The patient, female, had recurrence after resection of lower eyelid basal cell carcinoma, and the retroauricular island flap was used to repair the defect after resection of the lower eyelid tumor (Fig. 4.8).
2. Case IV The patient, male, had a total lower eyelid defect due to the resection of lower eyelid basal cell carcinoma, and the defect was repaired with the forehead flap (Fig. 4.9).

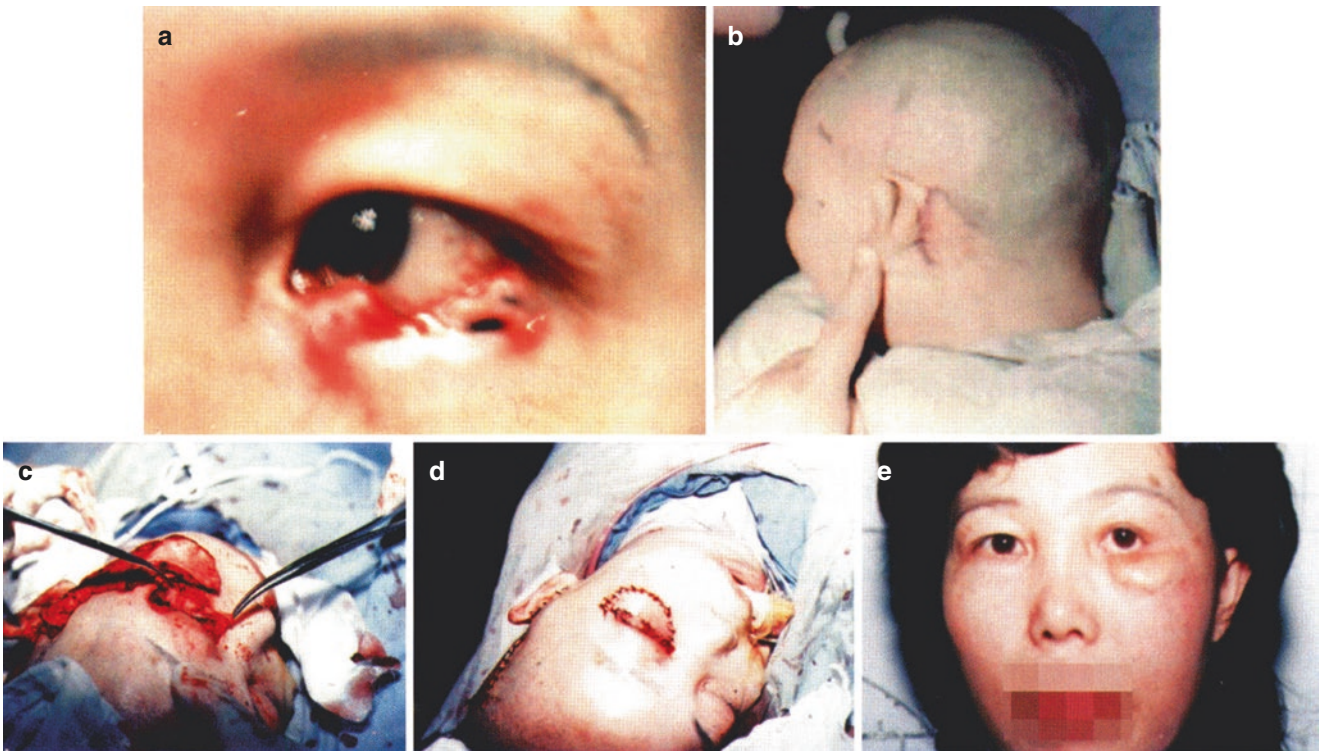

Fig. 4.8 Case III. (**a**) Manifestation of the postoperative recurrence of lower eyelid basal cell carcinoma. (**b**) The donor site of the retroauricular flap. (**c**) Preparation of the retroauricular flap (free oral mucosa was used to repair the defect in the lower eyelid conjunctiva). (**d**) The retroauricular island flap was used to repair the eyelid defect. (**e**) Postoperative rehabilitation condition

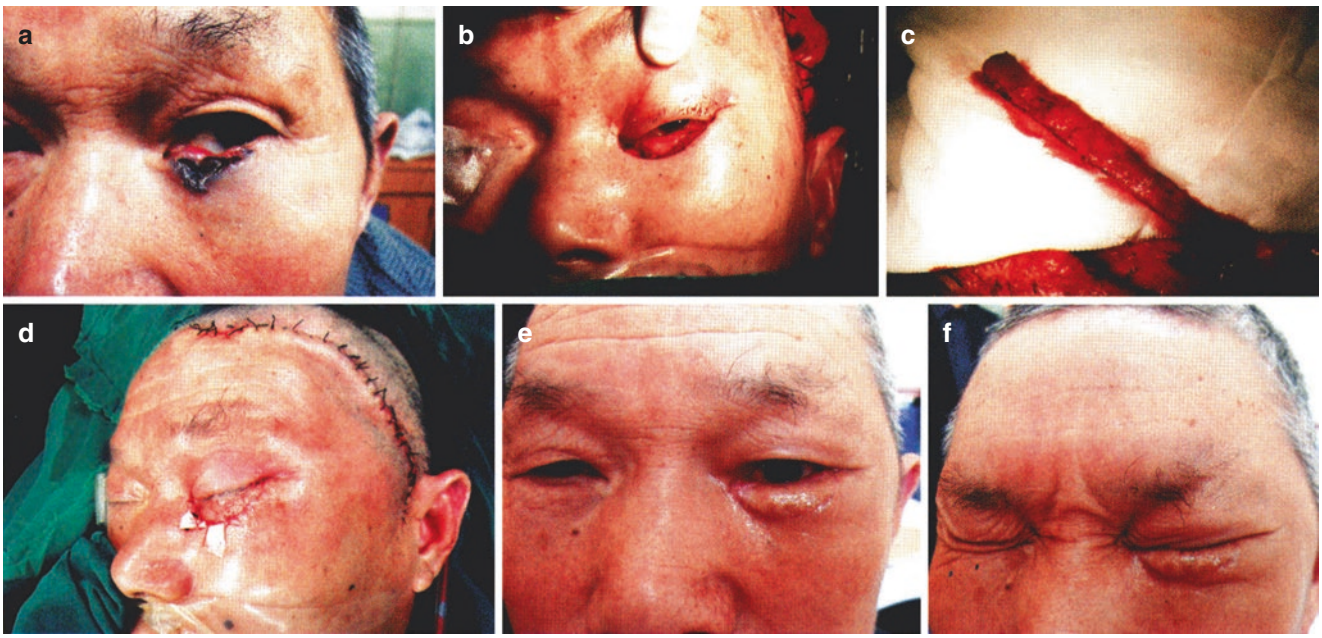

Fig. 4.9 Case IV. (**a**) Manifestation of lower eyelid basal cell carcinoma. (**b**) The defect after resection of lower eyelid mass. (**c**) Preparation of the forehead flap. (**d**) The skin flap was sutured. (**e**) The eye opening showed no ectropion at 2-month eyes after surgery. (**f**) At 2 months after surgery, the eye had a good shape when it was closed

4 Resection and Repair of Canthus Tumors

4.1 Outer Canthus Tumors

If the outer canthus tumor is a benign small tumor, after removal of the tumor, the wound can be repaired with transfer of the temporal skin (Fig. 4.10) or with a free skin flap. The patients with malignant tumor should undergo more extensive resection, and the specific method is as follows:

1. Incise along the drawing line of the safe area around the tumor, and remove the tumor along with the outer canthal ligament (Fig. 4.11a).
2. Incise open the tarsus at 2 mm above the upper eyelid margin and paralleling to the eyelid margin, and separate and strip out an appropriate section of tarsal conjunctival layer at the temporal side, which is sutured with the residual inferior fornical conjunctiva using thin catgut or silk thread and can be taken as the lining of the eyelid to be repaired (Fig. 4.11b).
3. Make a small incision, respectively, at the medial broken ends of the upper and lower eyelids, and separate the skin and muscle layer and the tarsal conjunctival layer. The medial margin of the tarsal conjunctival layer which is transferred from the upper eyelid is wedged into the dissected fracture in the tarsus layer of the lower eyelid with a mattress suture (Fig. 4.11c). This step can also be completed using the thin nylon line to directly perform a continuous suture between the medial margin of the tarsal conjunctival layer which is transferred from the upper eyelid and the broken ends of the lower tarsus (Fig. 4.11d), rather than splitting off the skin and muscle layer and the tarsal conjunctival layer in the broken ends of the medial upper eyelid.
4. Strip the temporal skin off with scissors; strip out a periosteal stripe from the orbital rim slightly under the original outer canthal angle; reverse this periosteal stripe; embed it into the separated fracture in the tarsus layer of broken ends of the upper eyelid with a mattress suture to replace the original outer canthal ligament (Fig. 4.11e).
5. Extend downward the incision along the broken ends of the upper eyelid skin incision, and remove a piece of triangle skin at the medial side of the lower end of this incision. After the skin flap under the tempus is stripped off, it is transferred upward and is interruptedly sutured, respectively, with upper and lower eyelids using a silk thread (Fig. 4.11f).
6. The linkage between upper and lower eyelid is cut off along the eyelid margin 2 months later.

4.2 The Inner Canthus Tumors

The benign and malignant tumors in inner canthus should be treated differently:

1. For small benign tumor in inner canthus or the basal cell carcinoma without invading the deep tissue, after surgical removal of the tumor, the frontonasal flap can be used for V-Y-type suture, and one side of the skin flap is used to cover the surgical wound.
2. For malignant tumors, the upper and lower eyelid full-thickness resection can be performed in the same way as the treatment for malignant tumors in the outer canthus (Fig. 4.12a), then the tarsal conjunctival layer in the upper eyelid is transferred and sutured into the medial lower residual conjunctival stump as the lining, and finally, the full-thickness free skin graft is used to repair the wound (Fig. 4.12b). The skin graft is fixed with a gauze pillow, and a temporary skin closure is made for the upper and lower eyelid margins. In the case that more tissues are removed, frontonasal or forehead flap can be designed to repair the wound, and the lip mucosa is taken as the lining.

   The light compression bandage is performed after surgery, then the skin sutures are removed 7 days later, and the eyelid is cut off 8 weeks later.

5 Repair of Eyelid and Periorbital Defects

If there are larger defects in the eyelids and periorbital soft tissues, it is appropriate to use the forearm free skin flap for repair, and the specific operation steps are as follows.

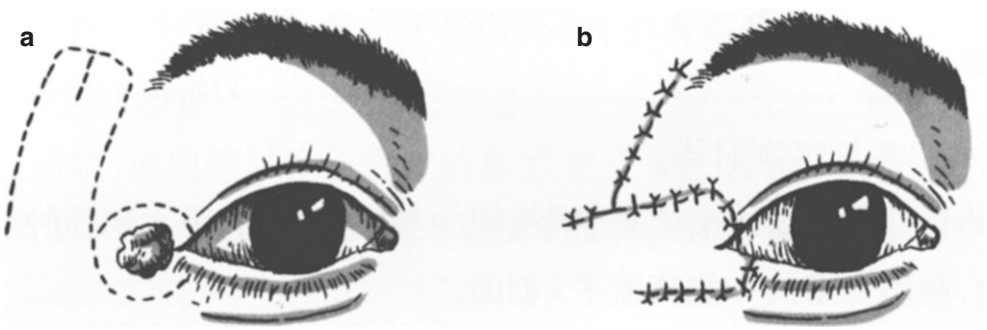

Fig. 4.10 Repairs of defects after resection of outer canthus tumor (using temporal frontal flap). (**a**) Remove the tumor and separate the skin flap. (**b**) Transfer repair of the temporal flap

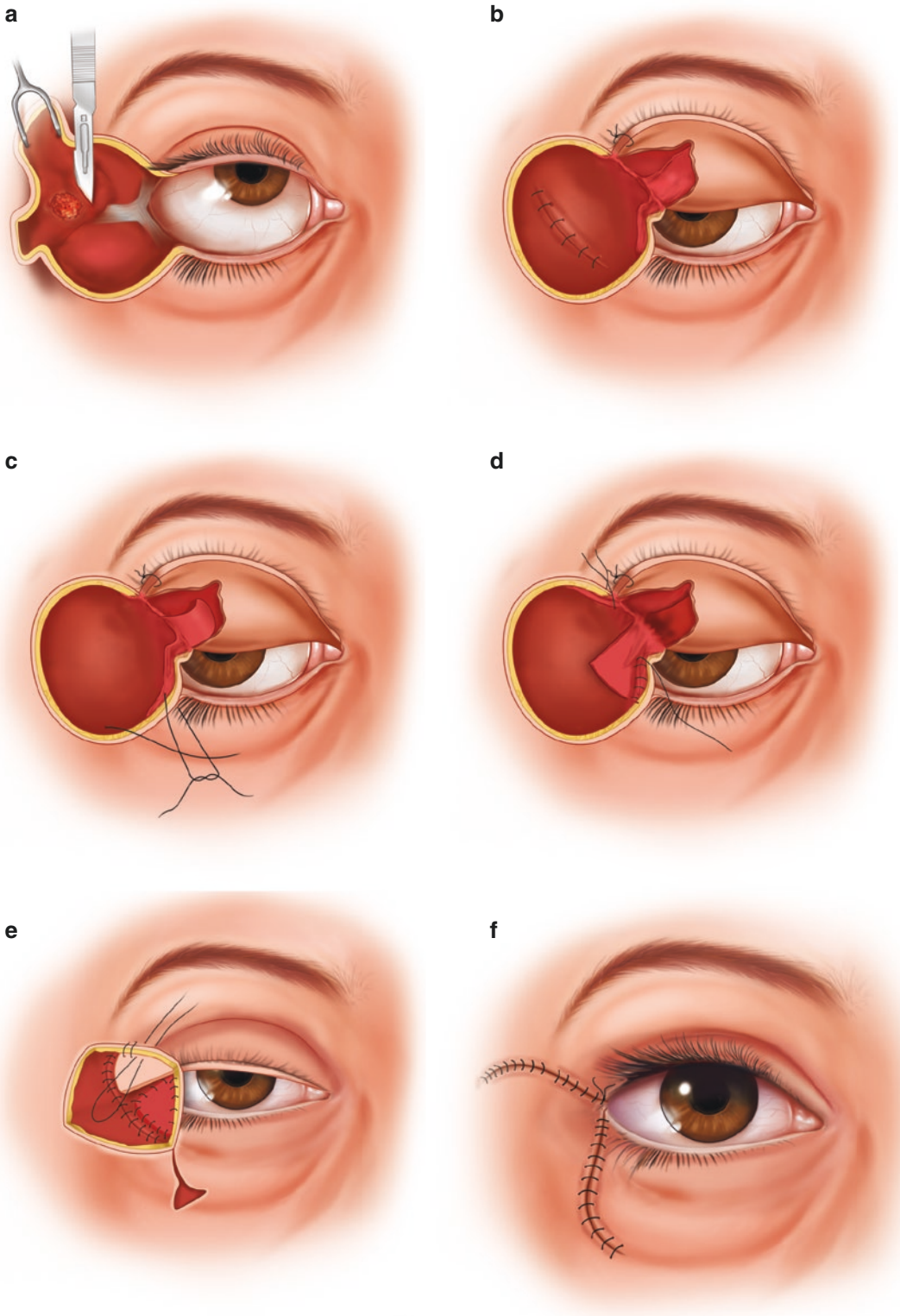

Fig. 4.11 Repair of the defect after extensive resection of outer canthus tumor (the tarsal conjunctival layer is taken as the lining of the lower eyelid, and the temporomandibular flap is used to cover the wound). (**a**) The tumor and the lateral tarsal ligament are removed. (**b**) The outer lining of the upper eyelid is made. (**c**) The tarsal conjunctiva layer is wedged into the dissected fracture in the tarsus layer of the lower eyelid. (**d**) A continuous suture between the medial margin of the tarsal conjunctival layer which is transferred from the upper eyelid and the broken ends of the lower tarsus is performed. (**e**) A periosteal stripe is stripped out to replace the original outer canthal ligament. (**f**) The wound margins of the upper and lower eyelids are interruptedly sutured

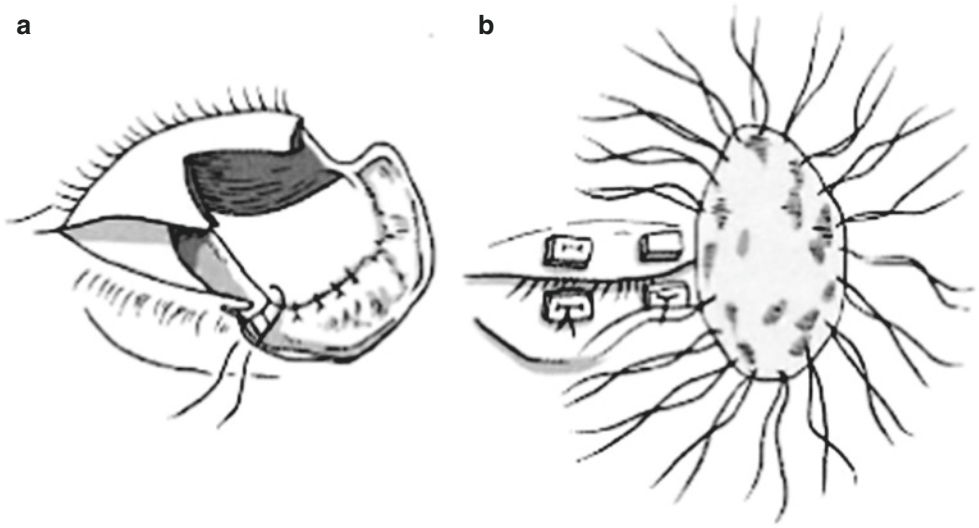

Fig. 4.12 The defect repair after resection of inner canthus tumor (the tarsal conjunctival layer is taken as the lining, and the free skin graft is used to cover the wound). (**a**) The upper and lower eyelid full-thickness resection. (**b**)The wound is repaired with the full-thickness free skin graft

5.1 Design and Preparation of the Skin Flap

The running directions of the radial artery (or ulnar artery), cephalic vein (or basilic vein and the median vein of the forearm), and their tributaries are drawn out, then a skin flap with a longer vascular pedicle and an area 10% greater than that of the receptor site is designed according to the defect shape, and it is marked with the methylrosanilinium chloride. The forearm skin flap is prepared according to the conventional method.

5.2 Expose the Blood Vessels in the Receptor Site

Routinely incise open the skins in front of the antilobium and at the lower margin of the mandible to expose the superficial temporal artery and the external jugular vein, and make a subcutaneous tunnel toward the receptor site.

5.3 Free Flap Transplantation

The vascular pedicle of the forearm skin flap is cut off, it is transplanted into the prepared receptor site and fixed with a number of stitches in the wound margin, and the vascular pedicle is passed through the subcutaneous tunnel. The end-to-end anastomoses between the forearm radial artery and the superficial temporal artery as well as the median vein of the forearm and the superficial cervical vein are performed under the operating microscope or magnifying glass with 8-0 or 9-0 monofilament nylon line, and then the incision in the wound margin of the receptor site is sutured. The rubber sheet is placed inside the wound for drainage, then the bandage is carried out under no tension, and a part of the skin flap is exposed to facilitate the postoperative observation. The donor site is directly closed and sutured or covered with a skin graft.

5.4 Precautions

1. Under the conditions that both the ulnar and radial arteries are normal, this skin flap can be selectively used for free transplantation.
2. It is needed to sacrifice a major artery in the donor site of this skin flap, and the donor site is located in the exposed part of the forearm, which affects the beauty. Currently the area where is more concealed with constant blood vessels and a larger outer diameter is mostly taken as the donor site.
3. If the external maxillary artery and the anterior facial vein are selected as the blood vessels for anastomosis, attentions should be paid to protection of the marginal mandibular branch of the facial nerve. This branch travels within the range of 1 cm above and under the mandibular margin at the anterior edge of the masseter muscle and on the superficial surfaces of the external maxillary artery and anterior facial vein; therefore, it is appropriate to make an incision at 1.5–2 cm under the mandibular margin.
4. According to the actual situation, the eyelid and periorbital defects can also be repaired with the free supraclavicular flap and the temporal myocutaneous flap.

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Defect Repair After Lip Cancer Surgery

5

Wu Hanjiang, Li Zan, and Zhou Xiao

1 Overview

The lip cancers refer to the cancers occurred in the lip vermilion mucosa (the exposed lip vermilion mucosa when the lips are naturally closed) and the joint mucosa in the corner of the mouth (within the range of 1 cm backward from the oral fissure). The cancers occurred in the inner side of the lip mucosa belong to the category of buccal mucosa carcinoma. The vast majority of cancers occurred in the lip vermilion mucosa are squamous cell carcinomas, and most of them are better differentiated; a small part of lip cancers are the basal cell carcinomas, which are caused due to the fact that the lip skin is invaded, and the adenocarcinoma is rarely seen.

The incidence of lip cancer is 1.8/100,000, accounting for 0.6% of the malignant tumors in the whole body and 9.57% of oral and maxillofacial squamous cell carcinoma. About 90% of lip cancers occur in the middle-aged and elderly people over the age of 40, more than half of them occur in the elderly people over the age of 60, and they occur more in men than women. More than 90% of lip cancers occur in the lower lip and occasionally occur in the upper lip. The lip cancers are more likely to occur in the mucosa of the prolabium at the junction of the middle and outer one third of the lower lip, and it is occasionally observed that the lip cancer occurs in the corner of the mouth. Most of lip cancers are solitary, and they have a slow disease progression and a longer disease course of usually 6 months to more than a year. The early lesions are presented as small herpes, induration, uncured chronic ulceration, or limited thickening and hardening of lip vermilion mucosa; the lesion is slowly increased and extended to the lip lump protruding outwardly or the deeper ulcer with a slightly elevated edge; the patients often have no self-conscious symptom and occasionally have mild pain and a little bleeding. Later on, the lesions are extended to the surrounding mucosa and skins, and the deep muscles are violated, and the cauliflower-like mass with edge eversion or crater-like ulcer is formed; the mass surface is covered with a gray-black eschar; the surface is presented as uneven small nodular shape. After the eschar is removed, the erosive wound and a little bleeding can be observed; the pain often occurs and is gradually aggravated. In the advanced stage, the lesion can be spread to the most part of the lip and even the whole lip, buccal cavity, and mandible, and the salivation, eating disorders, and more severe pain will occur [1, 2].

The blood supply of the lip comes, respectively, from the superior and inferior labial arteries and the branch of the facial artery, the labial arteries surround the mouth to form an arterial arch, and, therefore, the lesion in the one side of the lip is supplied with blood by the blood vessel from the middle part and one side of the lip. The sensations in the skin around the lip and at the junction of the skin and mucous membrane are controlled by the branches of the maxillary and mandibular divisions of trigeminal nerve. The movements of the orbicularis oris muscle and the muscle above and under the corner of the mouth are dominated by the branches of the facial nerve.

The lymphatic drainage of the lip has a certain direction; firstly the lymphatic fluid of the lower lip is drained into the lymph nodes in front of the facial blood vessel on the surface of the mandible and the level I lymph nodes and then is drained into level II and III lymph nodes; therefore, the level IV and V lymph node metastases are very rarely seen

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in the patients with lip cancers. The hematogenous distant organ metastases are rarely seen in the patients with lip cancers [3, 4].

2 Repair Method

2.1 V-Shaped Resection of the Lip

2.1.1 Indications

The patients who have lip benign tumors and small and limited lip cancers with a diameter of less than 2 cm or a resection range of no more than one third of the whole lip, which have not invaded the corner of the mouth, can undergo V-shaped resection in most cases.

2.1.2 The Surgical Procedure

1. The routine disinfection and sterile draping are carried out, and the methylene blue is used to draw out the range of the tissues to be removed. The benign tumors can be removed along the incision line drawn at 2 mm from the margin of the tumor; if the cancer is confirmed, the resection should be performed at 0.5–1 cm from the margin of the cancer.
2. The lip clips or fingers are used to pinch the lips on both sides of the incision to reduce the bleeding. The incision line should be V shaped or W shaped, the surgical knife should be at right angle with the skin on the labial surface, the full-thickness skin incision is made, and the lip artery is ligated.
3. After mass resection, 0–1 silk thread is used to suture the mucous layer and muscular layer, and 5–0 silk thread is used to suture the wound margin of the skin. In order to get good results in the lip shape, at first, a suture in the lip prolabium should be accurately performed. When the suture is performed, if the lip tissue has a greater tension, the assistant incisions can be made in the transitional parts at both sides.
4. The wound is covered with dressing, which is removed after 24 h.

2.1.3 Precautions

1. Keep the wound dry and clean. If there is food or escharosis in wound, the wound can be cleaned and treated with 3% hydrogen peroxide solution or 75% alcohol.
2. When the needle pus or surface infection occurs, it may be appropriate to take out some stitches, and the gromwell oil is smeared onto the local area.
3. The antibiotics are applied for 3–4 days.
4. The stitches are taken out after 5–7 days.

2.2 Lip Resection

2.2.1 Indications

It is applicable to the precancerous lesions of the lip, such as leukoplakia of the lip.

2.2.2 The Surgical Procedure

1. The incision of the whole lip is made along the lip vermilion border.
2. The tissue forceps are used to lift the tissues to perform the stealth separation to the underneath of the inner lip mucosa, and the lesion area is totally removed.
3. The inner lip mucosal tissue is migrated forward to be close to the skin margin, and then the interrupted suture is carried out with silk thread.

2.2.3 Precautions

They are the same as the V-shaped lip resection.

2.3 Cross Lip Flap Transfer

The cross lip flap transfer is also known as Abbe-Estlander operation.

2.3.1 Indications

If the lip cancer involves a range of more than 2 cm, after cancer removal, the defect range reaches up to the half of the transverse diameter of the lip; the patient can be treated with this method (this procedure is applicable to the lesions which are located at the middle and outer one third of the upper and lower lips). The skin flap can be designed into a variety of shapes, such as triangles, rectangles, and squares. It is appropriate that the donor site can be directly closed and sutured. The width of lip flap in the donor site is half of the width of the contralateral lip defect.

2.3.2 Surgical Procedures

If the defect is located in the middle of the lip, an additional incision can also be made firstly in one side of the lower lip adjacent to the corner of the mouth, and the lip flap is transferred to the middle part to repair the defect; then the upper lip tissue adjacent to the corner of the mouth is transferred into the lateral lower lip defect and is sutured (Figs. 5.1 and 5.2). This method not only ensures that there is enough tissue to repair the defect in the middle part of the lower lip but also avoids the transfer of the tissue in the middle part of the upper lip, which has the disadvantage of causing damage to the shape of the upper lip and philtrum. The elongation of the oral fissure should be performed at 3–4 weeks after the lip flap is transferred to achieve bilateral symmetry

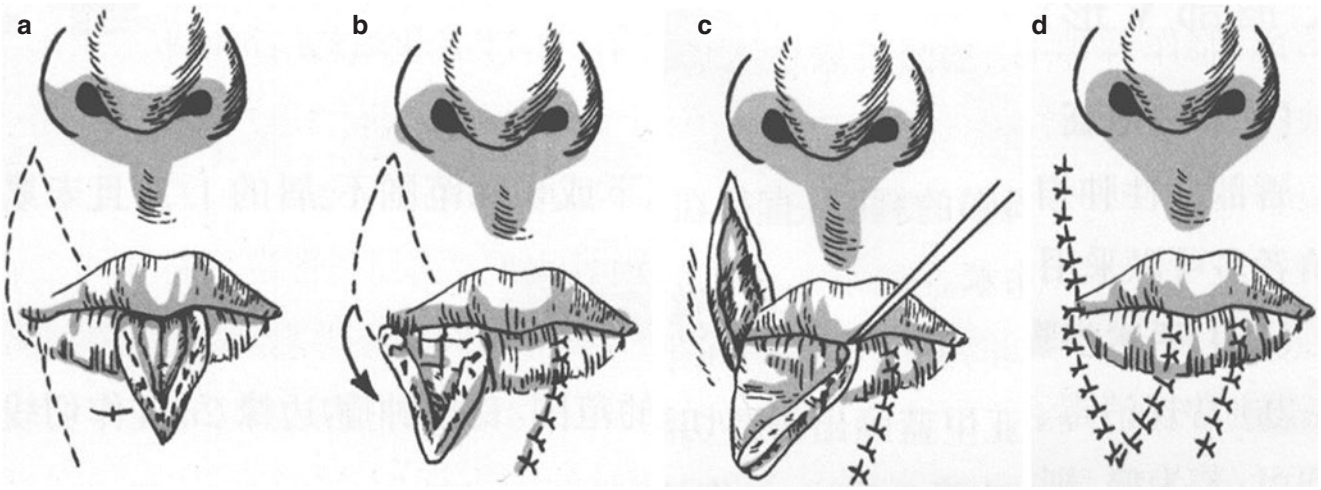

Fig. 5.1 The transfer of cross lip flap to repair the tissue defect in the middle part of the lower lip. (**a**) The defect and incision design. (**b**) The lower lip flap is transferred to the middle part and is sutured. (**c**) The upper lip flap is transferred downward. (**d**) After suture

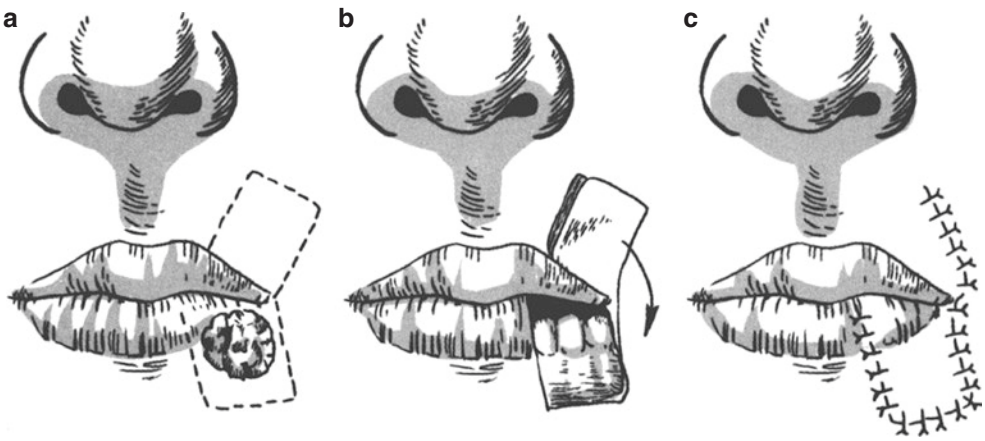

Fig. 5.2 The transfer of cross lip flap to repair the tissue defect after tumor resection in the lower lip. (**a**) Incision design. (**b**) The lesion in the lower lip was removed, and the upper lip was transferred downward. (**c**) After suture

2.4 The Nasolabial Flap Combined with the Vermilion (Mucosa) Sliding Flap or Tongue Flap for Defect Repair After Resection of Lower Lip Cancer

2.4.1 Indications

The lip cancer involves a wider range, the defect range after resection can reach from more than three fourths of the transverse diameter of the lip to the whole lip, and the method is applicable for the upper and lower lip defects.

2.4.2 The Anatomy of the Nasolabial Flap

The nasolabial flap has been used for a long term due to the advantages that it is adjacent to the location of the lip and has a similar color and texture as well as a rich blood supply, and its donor site is relatively hidden. After a piece of the skin of 2–3 cm is harvested in this area, the incision can be closed and sutured directly. The nasolabial flap has a rich blood supply, which comes from multi-sources. There is the inner canthus artery in the upper part, the facial artery in the lower part, the superior labial artery in the inner side, and the transverse facial artery in the outer side. The branches of these blood vessels anastomose each other to form a dense vascular network within the skin and subcutaneous area, which has laid a good vascular basis for the nasolabial flap. The pedicle of the nasolabial flap can be designed at one of the sites such as the inner, outer, upper, and lower sites, and the flap can be designed into the random pattern skin flap and the subcutaneous island pedicle flap.

2.4.3 The Surgical Procedure

1. The routine disinfection and sterile draping are carried out.
2. The vermilion tissue is preserved as far as possible on the premise of ensuring adequate safe incisal margin,

and the range for skin flap harvesting is marked according to the size of the defect after tumor resection. The medial incision of the nasolabial flap should be anastomosed with the nasolabial fold wrinkle. The skin, subcutaneous tissue, and mimetic muscles are incised open layer by layer according to the marker line to form the nasolabial flap pedicled with the facial artery and vein, and the donor site of nasolabial flap is closed and sutured directly. A tunnel between the donor site and the defect site is made; then the skin flap is passed through the tunnel to repair the defect site; finally the bilateral vermilion sliding flaps and the mucosal sliding flap are used to repair the vermilion defect according to the size of the vermilion defect.

3. If the area of the vermilion defect is larger, the tongue flap with a pedicle in the front part can be designed to repair the vermilion defect. Incise from the tip of the tongue and extend the incision toward the both sides along the margin of the tongue to reach the superficial layer of the tongue muscle, the incision length is consistent with the length of vermilion defect, and then a 1.5 cm of sharp dissection is performed toward the direction of the tongue root along the superficial layer of the tongue muscle to form the tongue flap; the lower margin of the tongue incision is sutured with the wound margin in the pedicle of the skin flap. The pedicle of the tongue flap is preserved, and the pedicle is cut off at 2 weeks after surgery (Fig. 5.3).

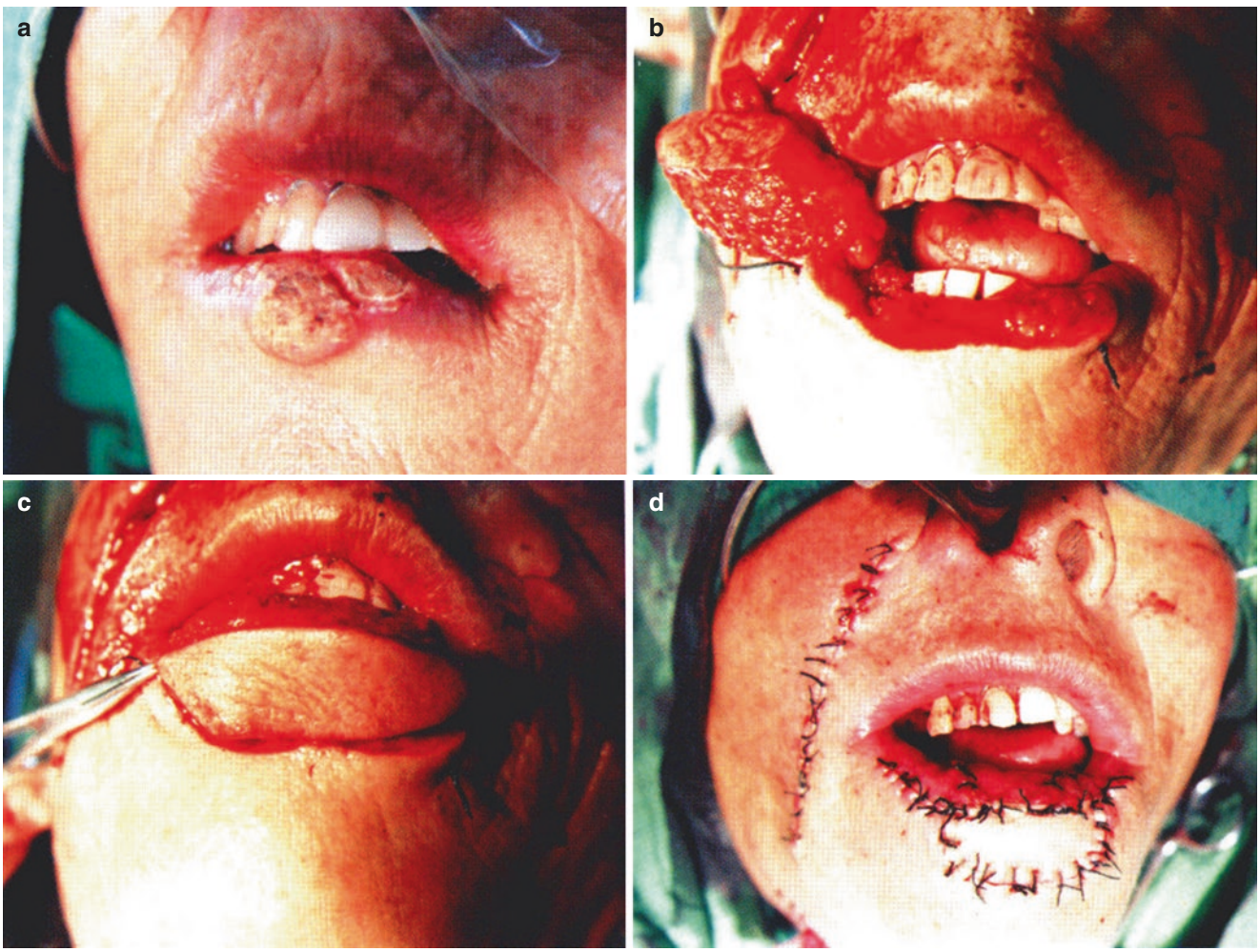

Fig. 5.3 Defect repair after resection of lower lip cancer (the nasolabial flap is passed through the tunnel to repair the lower lip; the lip mucosal sliding flap is used to repair vermilion defect). (**a**) Preoperative situation, the range of the lower lip cancer is more than the three fourths of the transverse diameter of the lip. (**b**) The lower lip defect after tumor resection. (**c**) The nasolabial flap is passed through the tunnel to repair the lower lip defect. (**d**) The lip mucosal sliding flap is used to repair the vermilion defect

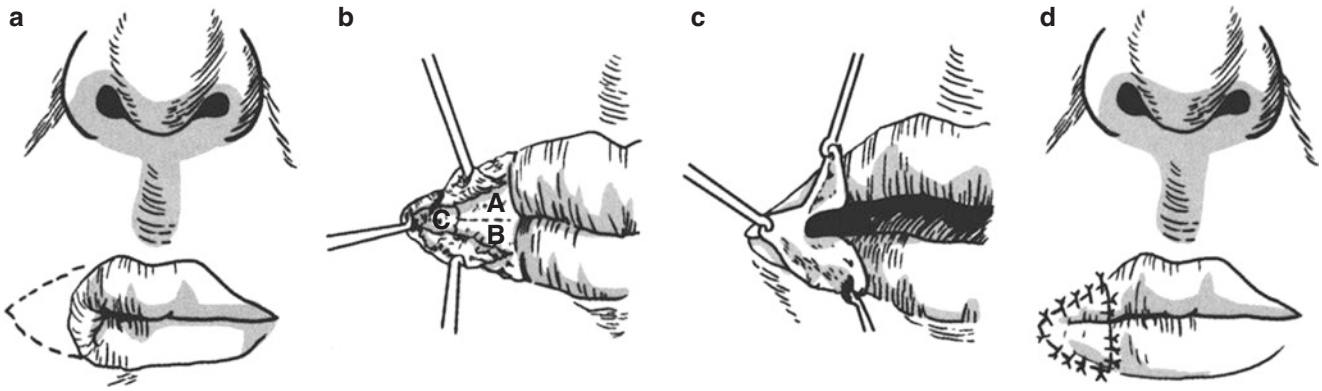

Fig. 5.4 Elongation of the oral fissure. (**a**) Incision design. (**b**) The skin and a part of muscle within the incision are removed. (**c**) The mucosal flap is overturned and sutured with the skin. (**d**) The new corner of the mouth is formed

2.5 Elongation of the Oral Fissure

2.5.1 Indications

The microstomia deformity occurs due to the fact that the normal shape of the corner of the mouth is damaged by the lip surgery. At this time, the elongation of the oral fissure can be performed, in order to make both corners of the mouth symmetrical. Generally, the elongation of the oral fissure is performed at more than 3 weeks after the healing of incision in one-stage operation.

2.5.2 Surgical Procedures

1. The routine disinfection and sterile draping are carried out. Generally in the corner of the mouth, the triangle incision of appropriate length and size is made toward the outside skin and extending along the vermilion border. The unilateral elongation of the oral fissure is performed taking the healthy side as the standard (Fig. 5.4a); if there exist bilateral small mouth deformities, it is needed to determine the new location of the corner of the mouth. Generally a vertical line is drawn downward from the pupil or the point of intersection of inner and middle one third of the palpebral fissure, and then a horizontal line is drawn outward from the oral fissure; the point of intersection of two lines is the location of the corner of the mouth; two connecting lines are made from this point, respectively, toward the upper and lower vermilion borders to form a triangle.
2. The skin, subcutaneous tissue, and a moderate amount of muscle within the triangular incision are removed (Fig. 5.4b), and the mucosa should be fully retained. The triangle mucosa is divided equally along the original oral fissure, and an incision parallel to the oral fissure is made. To make flap A, B, C (Fig. 5.4b), the additional incision is made near the top of the triangle mucosa. These three mucosal flaps are overturned outwardly and are sutured, respectively, with the upper and lower edges of the skin incision (Fig. 5.4c), to form a new labial margin (Fig. 5.4d).

2.6 Sliding Advancement of the Lip and Cheek Tissue Flap

The sliding advancement of the lip and cheek tissue flap is also known as the Burow operation.

2.6.1 Indications

The operation is suitable for patients with a lower lip cancer which involves the middle one third of the lip and does not involve the corner of the mouth and the patients who have a defect of about half of the lip after cancer resection.

2.6.2 The Surgical Procedure

1. The routine disinfection and sterile draping are carried out. At the bilateral corners of the mouth, the methylene blue is used to design two equilateral triangle incisions with two bottoms parallel to the extension lines of the corners of the mouth, and the length of two triangle bottoms should be the width of the lip (Fig. 5.5a).
2. The full-thickness incision is performed at the two triangle bevel edges, only the muscle is cut through and the mucosa is retained at the bottom, and then the skin and muscles inside the triangle are totally removed (Fig. 5.5b).
3. In the lower clypeogenal sulcus wrinkles, a relaxant incision is made parallelly backward; at this time, the remaining lower lip tissue flap is slidingly advanced to the midline, and the layered apposition suture is performed in the midline (Fig. 5.5c).

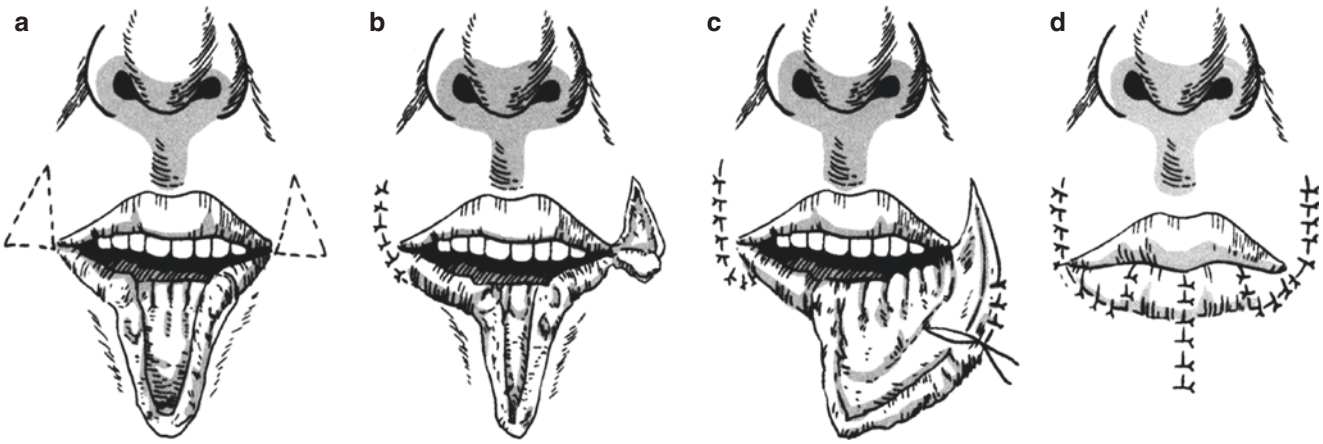

Fig. 5.5 Sliding advancement of the lip and cheek tissue flap for repair of the lower lip defect. (**a**) The defect and incision design. (**b**) The triangle mucosal flap is overturned outward and is trimmed and sutured to form the new lower lip vermilion (**c**)

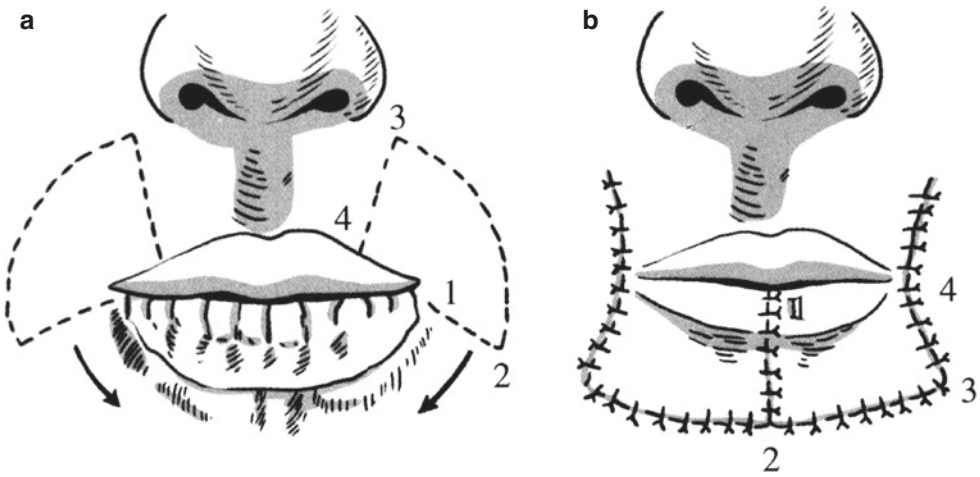

Fig. 5.6 Rotating advancement of the lip and cheek tissue flap for repair of the lower lip defect. (**a**) The defect and the incision design. (**b**) After transfer and suture of the tissue flap

4. The triangle mucosal flap left at both sides of corner of the mouth is overturned outward and is sutured with the skin after trimming to form the new lower lip vermilion border (Fig. 5.5d).

2.7 Rotating Advancement of the Lip and Cheek Tissue Flap

2.7.1 Indications

The operation is suitable for the patients with a lower lip defect of more than two thirds of the lip after cancer resection or the patients with whole lower lip defect.

2.7.2 The Surgical Procedure

1. The routine disinfection and sterile draping are carried out, and the methylene blue is used to design the fixed points. At one side, for example, the point "1" is positioned as far as possible in the site where the remaining lip margin is usable or in the corner of the mouth, and point "4" is positioned at the junction of the upper lip skin and the vermilion mucosa. The distance between point "1"and point "4" should be equivalent to 1/2 of the lower lip after repair; the distance between point "1" and point "2" should be equal to or slightly greater than the distance between point "3" and point "4," and this distance will be the height of the lower lip to be formed; the distance between point "2" and point "3" is generally greater than the distance between point "1" and "4." The same point positioning method is used in the contralateral side (Fig. 5.6a).
2. The full-thickness incision is performed with a sharp knife along the above connecting line, and then two fan-shaped tissue flaps are rotated and advanced toward the inner lower side; the wound margins are sutured with each other at the midline and can be closed and sutured directly by segments and layers (Fig. 5.6b).
3. The precautions are the same as those in V-shaped resection.

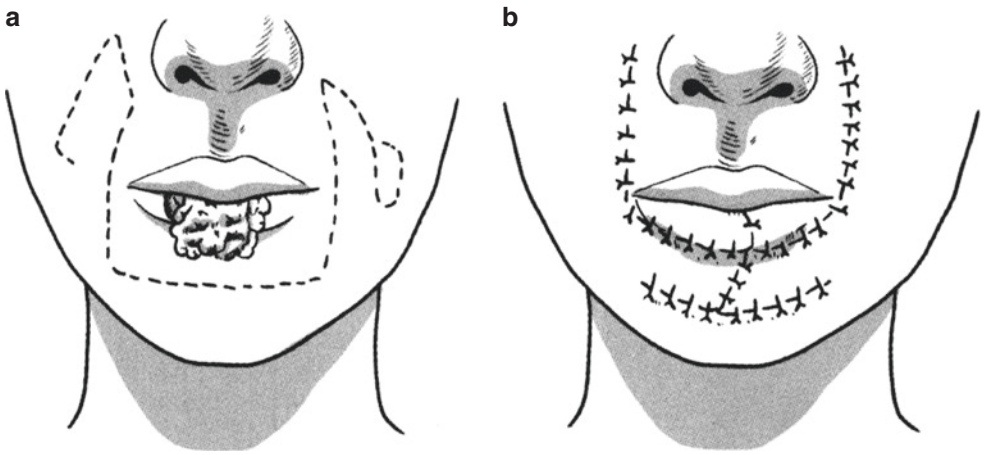

Fig. 5.7 Szymanowski operation. (**a**) Incision design. (**b**) After suture

2.8 Szymanowski Operation

2.8.1 Indications

The invasion range of the cancer comes near or reaches the entire lower lip but does not involve the gingival sulcus.

2.8.2 The Surgical Procedure

Two vertical buccal flaps with pedicles at the bottoms are used to repair the lower lip defect after tumor resection. The pedicle of the skin flap is located below the skin flap, and the width of the skin flap is equivalent to the height of the defect. The medial incision of the skin flap is performed upward along the nasolabial sulcus, and the lateral incision is started from the level of the extension line of the corner of the mouth and is performed upward and ended above or below the level of the medial incision (Fig. 5.7a). If the upper end of the lateral incision of the right buccal flap is located above the medial incision, then the upper end of the lateral incision of the left buccal flap is located under the medial incision and vice versa. Whereafter, an oblique incision is made to connect the vertical incisions. Two oblique incisions should be parallel to each other, which is conducive to defect repair. The tissue flap includes the whole layers of the cheek. When this flap is harvested, a long strip of buccal mucosa on the lateral side of the flap is additionally retained to form the vermilion to reconstruct the lower lip. After the flap is formed, it is rotated to the defect area and is sutured by layers, and the long strip of buccal mucosa is used to form the vermilion to reconstruct the lower lip, and the donor site of the skin flap after undermining dissection is closed and sutured (Fig. 5.7b)

2.9 Repair Method with Forearm Myocutaneous Flexor Carpi Ulnaris Flap

This flap is used to reconstruct the lower lip. Both ends of the muscle bundle can be sutured with the remaining stumps of orbicular muscles in the bilateral corners. Driven by the orbicular muscles of the upper lip, the reconstructed lower lip can have a certain range of motion. In addition to that, the flap has the advantages of the radial forearm flap, the flap has a more delicate texture and less hair, and its position is more hidden, which is one of fairly ideal donor sites for reconstruction of the lower lip.

2.9.1 Indications

This flap is used for repair of whole lower lip defect and the oral and maxillofacial defects.

2.9.2 Skin Flap Design

According to the scope and shape of the lower lip defect, the ulnar artery and basilic vein are taken as the axis to design the skin flap. A rectangular flap can be designed for repair of simple lower lip defect, and it is folded for repair along the longitudinal axis of the blood vessels.

The size of the skin flap is determined based on the width of the upper lip, but it should be increased by 1 cm. Generally the skin flap is designed as 7 × 6 cm; if combined with defects in chin, alveolar crest, and sulcus vestibularis, its width can be increased to 8–9 cm. The length of the flexor carpi ulnaris is 1 cm more than that of the skin flap. The length of ulnar artery pedicle is 6 cm. The length of the basilic vein is 10 cm, so that the pedicle can pass through the tunnel to be anastomosed with the submandibular healthy blood vessels at the either side.

2.9.3 The Surgical Procedure

The surgery is divided into two parts to be performed by different groups of surgeons, and the defect after lower lip cancer surgery is taken as an example.

1. Donor site group. The tourniquet is used for expelling blood; the skin in the distal end of myocutaneous flap (wrist side) is incised open; the basilic vein is ligated and cut off and is sutured and fixed into the subcutaneous tissue of the skin flap. The ulnar artery is dissected out between the flexor carpi ulnaris and flexor digitorum

superficialis muscle; the double threading is performed without ligation. Attentions should be paid to protecting the ulnar nerve beneath the blood vessels. Incise open along the inner and outer edges of the skin flap to reach the area between the deep fascia and the myolemma, and sharply separate toward the central part. Separate the ulnar side to the flexor carpi ulnaris muscle; ligate and cut off the ulnar vascular bundle and the wrist end of the flexor carpi ulnaris muscle, which are sutured and fixed, respectively, into the subcutaneous tissue of the skin flap. Lift the flap with the above three suture lines, dissect the vascular bundle, turn up the myocutaneous flap, and place the myocutaneous flap back to its original place after it is totally turned up. An arc prolonged incision in the elbow end is made between the basilic vein and the ulnar vascular bundle. The basilic vein is dissected out, then the aponeurosis between the flexor carpi radialis muscle and flexor carpi ulnaris muscle is incised open to dissect and separate the ulnar nerve bundles, and its length is determined according to the need. The tourniquet is released, and the thorough hemostasis is carried out. The flexor carpi ulnaris muscle is ligated and cut off at 1 cm (elbow side) at the outer side of the skin flap. In addition to the vascular pedicle, the myocutaneous flap is completely separated and is wrapped with warm and wet saline gauzes and put in the place next to the forearm, then the prolonged incision is sutured, and the forearm wound is repaired with the full-thickness skin graft harvested in the lower abdomen or lateral chest.

2. The receptor site group. The lower lip cancer resection and the lymph node dissection on both sides of the hyoid bone are performed; the submandibular wound on the one side is closed after washing; the facial artery and the vein and the external jugular vein are retained in the contralateral submandibular incision; a subcutaneous tunnel between the submandibular incision and the lower lip wound is made. The submandibular blood vessels are ligated and cut off, and their adventitias are trimmed for anastomosis.

   Finally, the pedicle of the myocutaneous flap is cut off, and the prolonged incision is closed. The myocutaneous flap is transferred into the lower lip defect, and several sutures are performed; the vascular pedicle is passed through the tunnel into the submandibular area. The facial artery, the facial vein, and the external jugular vein reanastomose, respectively, with the broken ends of the ulnar artery, the ulnar vein, and the basilic vein, and the left submandibular wound is covered with the saline gauzes. Both ends of the flexor carpi ulnaris muscle are sutured tip to tip, respectively, with the orbicularis oris muscles in the upper lip at the bilateral corners of the mouth. The myocutaneous flap is folded to close the labiomental wound by layers. The margin of the oral medial flap is sutured with the lingual gingiva, and several transfixion sutures are performed for the skin from the vestibular groove to the submentum to form the shape of the vestibular groove in the medial side of the mouth. Then the left submandibular wound is sutured by layers, and the whole lower lip defect reconstruction is completed.

2.10 Repair Method with Dorsalis Pedis Flap

The dorsalis pedis flap is the skin flap pedicled with the dorsal pedal artery and the great and small saphenous veins. Its advantages are that the artery and vein of the skin flap have constant anatomical locations and are easy to dissect; the vascular diameters are thicker , which is conducive to anastomosis; the subcutaneous fat layer is thinner with compact tissues, which is thin and soft with a certain toughness, easy shaping, and no bloated look after repair; the vascular pedicle is longer , which is adapted to the vascular anastomosis in the distal receptor site; the skin flap contains the branches of the superficial peroneal nerve, and it has a sensory function after transplantation; after the donor site wound is repaired with skin graft, there exists no functional movement disorder; it can combine the extensor hallucis brevis to form the composite tissue flap, which is very beneficial for the prevention of the falling of the tissues. The dorsalis pedis flap area is one of ideal donor sites for repair of the whole lower lip defect. Its disadvantages are that the skin flap has a darker color and the donor site area is subject to certain restrictions. But only in terms of the repair of the lower lip tissue defect the donor site area of the dorsalis pedis flap is sufficient.

2.10.1 Indications

This skin flap is used for repair of the whole lower lip defect and the oral and maxillofacial defects. When the lower lip is repaired, because of the need to prevent the falling and valgus deformity of the lower lip, the effect of the free transplantation of composite skin flap with muscles is comparatively ideal.

2.10.2 Skin Flap Design

Before surgery, it is required to examine the dorsal pedal artery to determine whether there exists the dorsal artery and examine whether the posterior tibial artery is damaged or obstructed, as well as whether there are reflux veins in the dorsum of the foot available for anastomosis. The size of skin flap should be determined according to the need of repair of the receptor site. The length-to-width ratio of the skin flap is generally 13 × 10 cm–14 × 11 cm; the maximum size is less than 15 × 10 cm. When the skin flap is designed, the running direction of the dorsal pedal artery is taken as a basis, the harvesting range of the skin flap is determined by combining the length of the needed vascular pedicle, and finally the skin flap is designed according to the shape of the defect site.

2.10.3 The Surgical Procedure

The repair of the whole lower lip defect is taken for an example, and the surgery is divided into two groups.

1. The donor site group. Incise from the distal end and both sides of the skin flap along the design line of the skin flap, dissect and separate clinging close to the tendon membrane surface, and cut off the dorsal metatarsal veins and ligate them, respectively. Attentions are paid to protecting the great and small saphenous veins and the superficial dorsalis pedis vein. Lift the skin flap from the distal end, because the repair of the lower lip needs the extensor hallucis brevis, so that its muscle tendon can be sutured with orbicularis oris muscle to prevent the falling of the skin flap; therefore, the extensor hallucis brevis tendon should be cut off at the junction area of the extensor hallucis brevis tendon and the extensor hallucis longus tendon, so that the extensor hallucis brevis tendon is included in the skin flap. At the first metatarsal clearance, continuously dissect and separate from the deep surface of the extensor hallucis brevis tendon; pull out the extensor hallucis brevis tendon and the extensor hallucis longus tendon; ligate and cut off the deep plantar branch of the dorsal pedal artery and its accompanying vein from the basilar part of the first metatarsal clearance; separate the skin flap at the deep surface of the dorsal pedal artery. When the skin flap is separated to the proximal end, the skin and subcutaneous tissue in the proximal end are incised open, and the prolonged incision of the dorsal pedal artery pedicle is made to harvest a sufficient length of vascular pedicle. If necessary, extensively incise the extensor retinaculum toward the direction of the calf, and expose the anterior tibial artery upward. The artery and vein pedicle of the entire skin flap are well retained, and all other blood vessels are ligated to wait for cutting off the pedicle.
2. The receptor site group. Resect the lower lip cancer and dissect bilateral lymph nodes above the hyoid bone (or bilateral cervical lymph nodes); retain the facial artery and vein at one side (or external jugular superficial veins); make a subcutaneous tunnel from the lower lip wound to the donor site of the submandibular vessels; trim the vascular adventitia in the donor site for use. The separated dorsalis pedis flap is transplanted onto to the surface of the lower lip defect; the skin flap is folded into the shape of the lower lip defect; after the skin flap at the side of the tongue side is sutured and fixed with the residual lip mucosa, the vascular pedicle is passed from the tunnel to the submandibular region, and the end-to-end anastomoses are performed, respectively, between the dorsal pedal artery and the facial artery as well as the great saphenous vein and the anterior facial vein (or external jugular superficial veins). After the vascular patency is examined, the extensor hallucis brevis and the muscle belly within the skin flap were sutured and fixed, respectively, onto the orbicularis oris muscles at the left and right corners of the mouth, and this plays a role in suspending the reconstructed lower lip. The rest of the wound layer is interruptedly sutured by layers, and the lower lip repair is completed.

3 Typical Patient Cases

3.1 Case I

The patient, male, 42 years old, was found with lower lip ulceration for 3 months. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys. The area of the lower lip ulceration was 1.5 × 1.5 cm, the texture was hard and the surface was covered with eschar, and the tenderness was evident. No obvious swelling lymph nodes were palpated in bilateral cervical regions. Pathology: well-differentiated squamous cell carcinoma. Admission diagnosis: highly differentiated squamous cell carcinoma of the lower lip. The patient underwent V-shaped resection in the lip under the general anesthesia. The postoperative pathology: highly differentiated squalors cell carcinoma (Fig. 5.8).

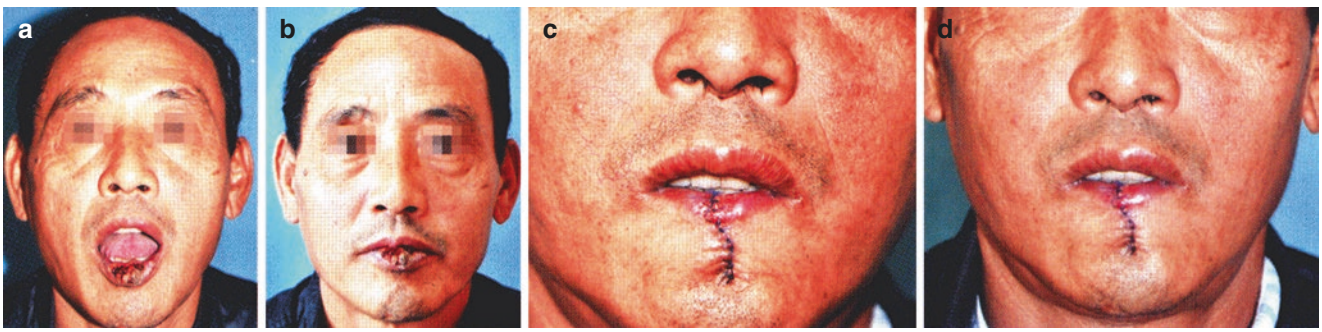

Fig. 5.8 Case I. (**a**, **b**) Before operation. (**c**, **d**) On the sixth day after operation

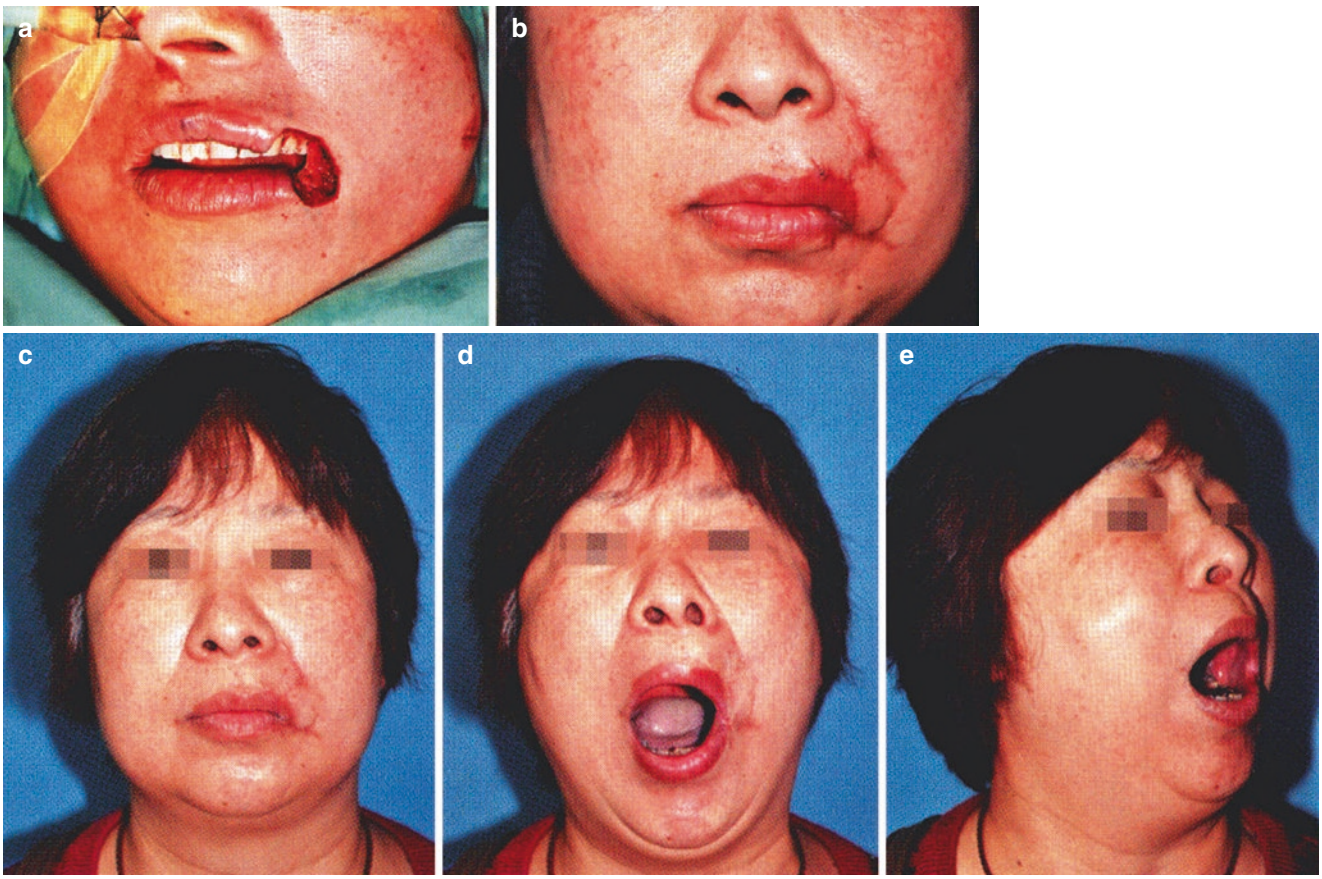

Fig. 5.9 Case II. (**a**) The defects in the upper and lower lips and the corner of the mouth after tumor resection. (**b**) At 2 weeks after operation. (**c**–**e**) At 2 months after operation, the mouth opening was essentially normal

3.2 Case II

The patient, female, 51 years old, was found with the upper and lower lip ulceration near the left corner of the mouth for a month. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys. The area of the upper and lower lip ulceration was 1.0 × 1.0 cm, involving the left corner of the mouth, and no obvious swelling lymph nodes were palpated in bilateral cervical regions. Pathology: highly differentiated squamous cell carcinoma. Admission diagnosis: highly differentiated squamous cell carcinoma of the upper and lower lips. The patient underwent lip cancer resection, nasolabial fold flap repair, and vermilion sliding flap repair under the general anesthesia. Pathology: highly differentiated squamous cell carcinoma (Fig. 5.9).

3.3 Case III

The patient, male, 49 years old, was found with lower lip ulceration for 5 months. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys. The area of the lower lip ulceration was 1.0 × 1.0 cm, and the surface was covered with eschar, which was prone to contact bleeding. No obvious swelling lymph nodes were palpated in bilateral cervical regions. Pathology: highly differentiated squamous cell carcinoma. Admission diagnosis: highly differentiated squamous cell carcinoma of the lower lip. The patient underwent the lip cancer resection and lip cross flap transfer under the general anesthesia. Pathology: highly differentiated squamous cell carcinoma (Fig. 5.10)

3.4 Case IV

The patient, female, 62 years old, was found with a lump in the right upper lip and skin for 3 months. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys. The size of the lump in the upper lip and skin was 1.0 × 1.0 cm, and no obvious swelling lymph nodes were palpated in bilateral cervical regions. Pathology: highly differentiated squamous cell carcinoma. Admission diagnosis: highly differentiated squamous cell carcinoma of the upper lip. The patient underwent the lip cancer resection + nasolabial fold flap repair + vermilion sliding flap repair under the general anesthesia. Pathology: highly and moderately differentiated squamous cell carcinoma (Fig. 5.11).

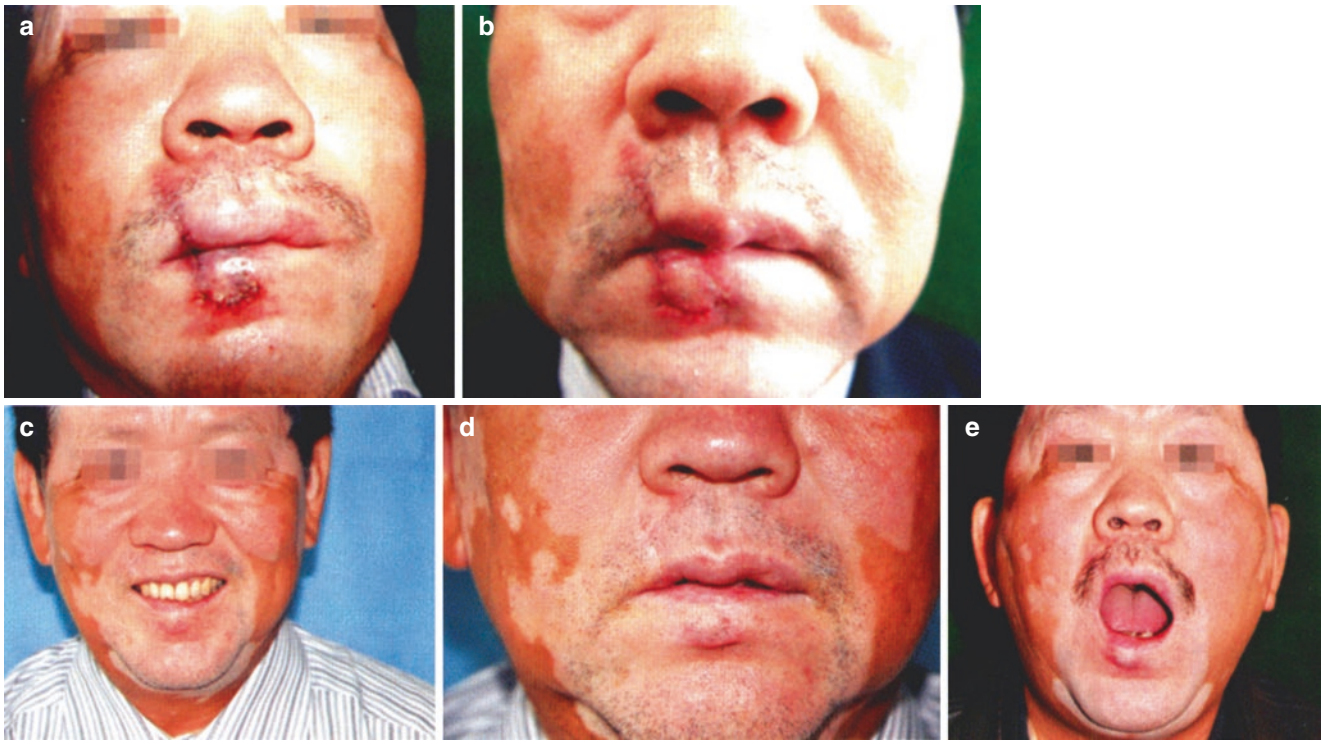

Fig. 5.10 Case III. (**a**) Before the pedicle was cut off. (**b**) After the pedicle was cut off. (**c**–**e**) At 2 months after operation

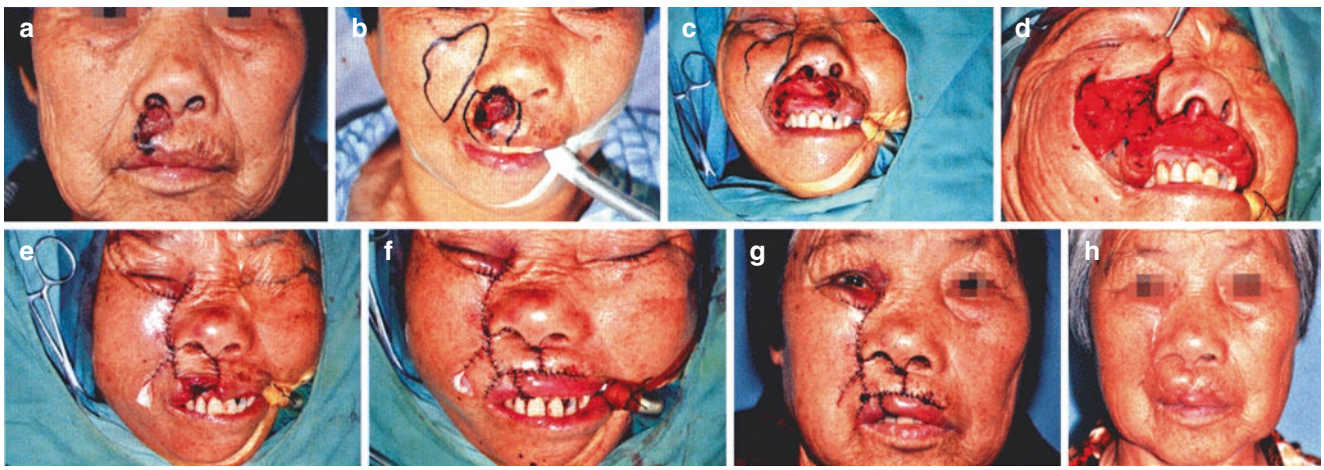

Fig. 5.11 Case IV. (**a**) Before operation. (**b**) Intraoperative incision design. (**c**) Defects after tumor resection. (**d**) Preparation of the nasolabial fold flap. (**e**) The nasolabial fold flap was used to repair the upper lip defect. (**f**) The vermilion sliding flap was used to repair the vermilion defect. (**g**) At 5 days after operation. (**h**) At 6 months after operation

3.5 Case V

The patient, male, 45 years old, was found with upper lip lump for a month. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys. The size of the upper lip lump was 1.0 × 1.0 cm, and no obvious swelling lymph nodes were palpated in bilateral cervical regions. Pathology: highly differentiated squamous cell carcinoma. Admission diagnosis: highly differentiated squamous cell carcinoma of the upper lip. The patient underwent lip cancer resection and lip cross flap transfer under the general anesthesia. Pathology: highly differentiated squamous cell carcinoma (Fig. 5.12).

3.6 Case VI

The patient, male, 42 years old, was found with a lump in the upper lip which had been ulcerated for 5 months. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung,

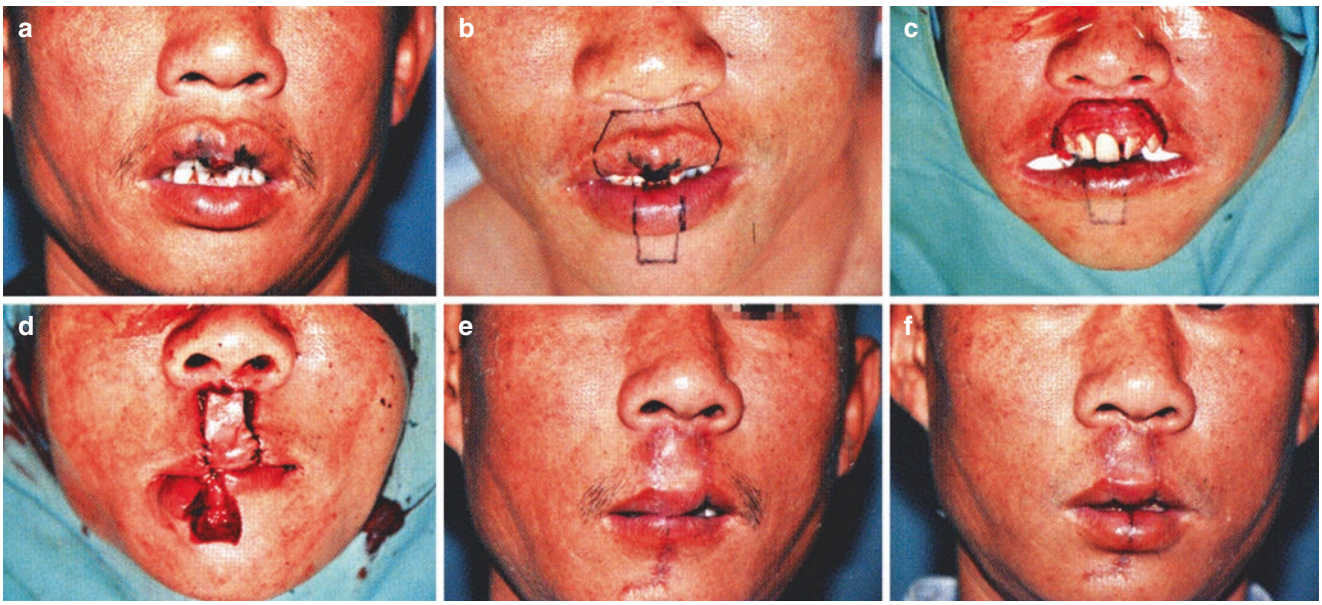

Fig. 5.12 Case V. (**a**) Before operation. (**b**) Preoperative incision design. (**c**) The upper lip defect after tumor resection. (**d**) The defect was repaired with cross lip flap. (**e**) Before the pedicle was cut off. (**f**). After the pedicle was cut off

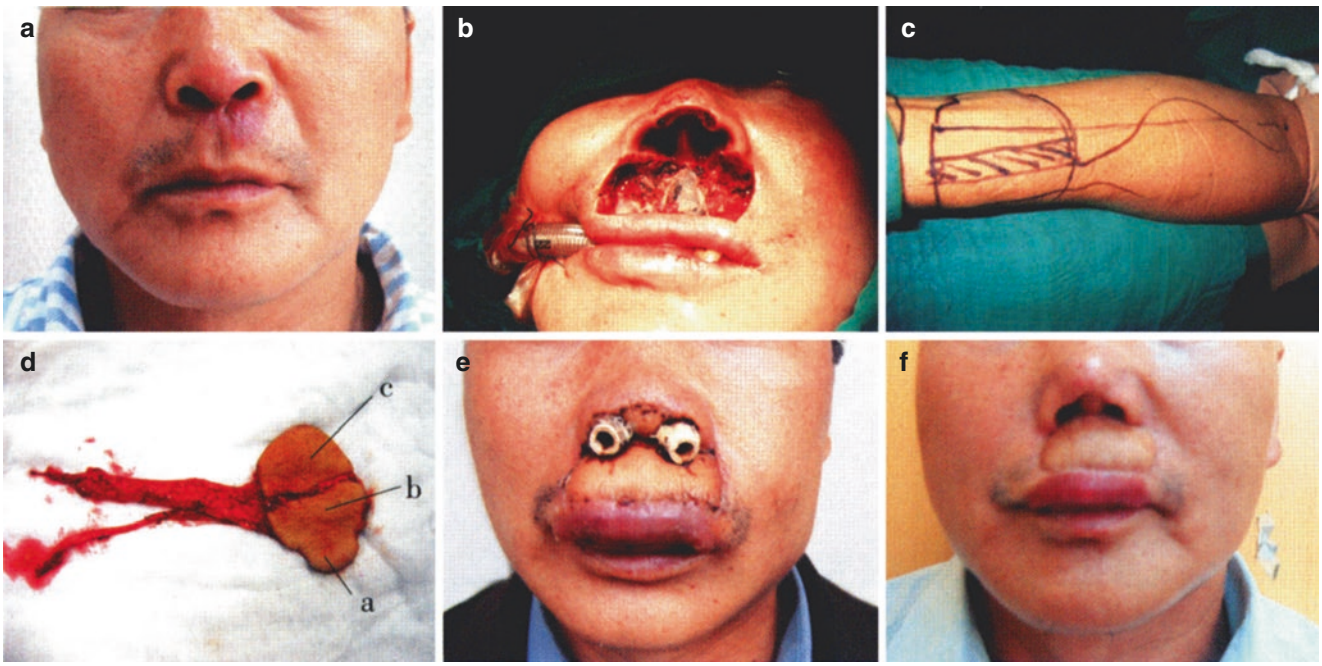

Fig. 5.13 Case VI. (**a**) The upper lip skin cancer invaded the nasal columella and the nasal tip. (**b**) The postoperative defects in the full thickness of the upper lip, the nasal columella, the nasal tip, bilateral soft triangles, and a part of upper gingiva; the vermilion was retained. (**c**) The radical forearm flap was designed according to the size and shape of the defect. (**d**) The forearm skin flap was harvested, and a portion of the epidermis was removed, of which, the a part was used to repair the defects in the nasal columella and bilateral soft triangles, the b part was used to repair the defect in skin surface of the upper lip, and the c part was used to repair the defect in the oral surface of the upper lip. (**e**) Primary repair of defects in the full thickness of the upper lip, the nasal columella, the nasal tip, and bilateral soft triangles. (**f**) At 1 year after operation

liver, spleen, and kidneys. The size of the upper lip lump was 3 × 3 cm; the boundary was not clear; the tumor invaded the nasal columella and the nasal tip and the soft triangle. No obvious swelling lymph nodes were palpated in bilateral cervical regions. Admission diagnosis: highly differentiated squamous cell carcinoma of the upper lip. The patient underwent extensive upper lip cancer resection + the forearm skin flap repair under the general anesthesia. Pathology: highly differentiated squamous cell carcinoma (Fig. 5.13).

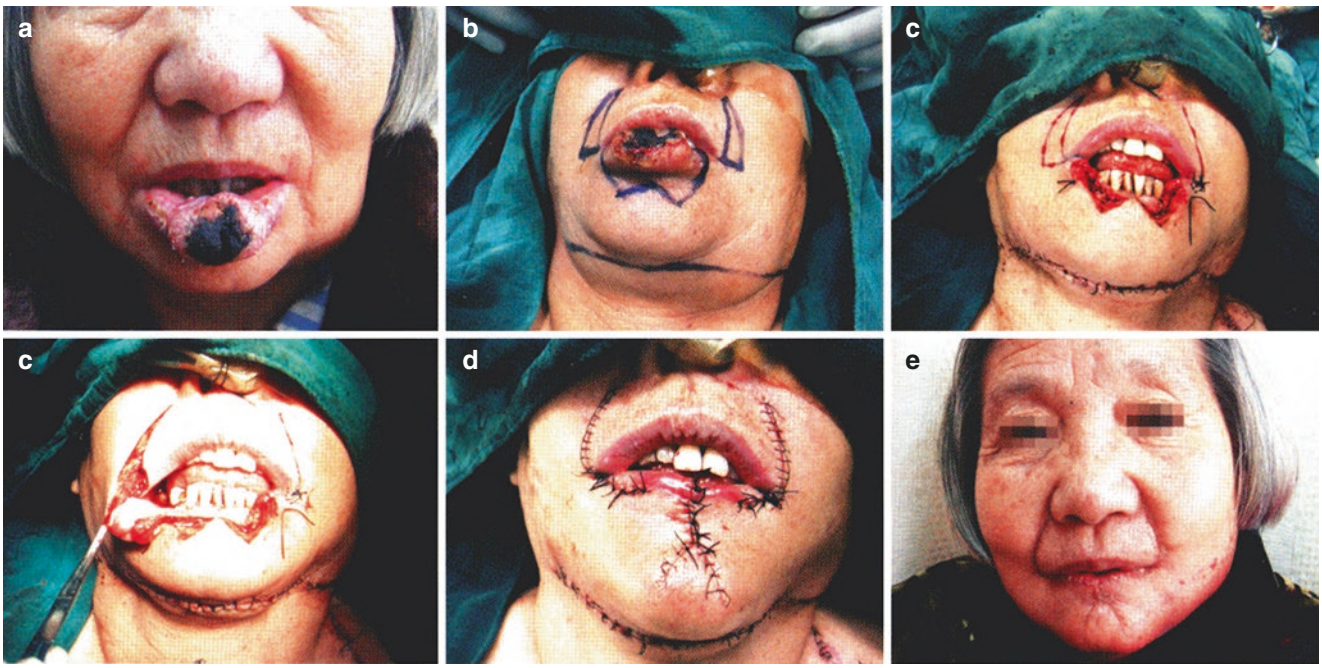

Fig. 5.14 Case VII. (**a**) Before operation. (**b**) Preoperative design, the most part of the lower lip was removed, only bilateral corners of the mouth were retained, and the lower lip resection was designed as W shaped for convenient suture and beauty; it was designed that the bilateral lip and cheek tissue flaps were glidingly advanced (Burow operation) to repair the lower lip defect. (**c**) Bilateral cervical lymph node dissections were performed, the lower lip lump was extensively resected, the skins and muscle tissues within bilateral nasolabial sulcus flaps were resected, and the mucosas were retained. (**d**) Bilateral lip and cheek tissue flaps were formed and glidingly advanced inward and were sutured in the midline; the buccal mucosal flap was everted to form the new vermilion. (**e**) After operation. (**f**) The patient was examined at 1 year after postoperative radiotherapy, the appearance was satisfied, the facial wound was hidden, the mouth opening was good, and the speaking and eating were not affected

3.7 Case VII

The patient, female, 70 years old, was found with a lower lip lump which had been ulcerated for 1 year. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys. The size of the lower lip lump was 3 × 2 cm, and the boundary was clear. The size of the left submandibular lump was 3 × 2 cm, whose texture was hard, and the lump could be moved around. Pathology: Highly to moderately differentiated squamous cell carcinoma. Admission diagnosis: lower lip cancer combined with metastasis in the left cervical region. The patient underwent extensive upper lip cancer resection + advancement of lip and cheek tissue flap. Pathology [5]: highly and moderately differentiated squamous cell carcinoma (Fig. 5.14).

All surgical photographs published in this chapter have been approved by the patients themselves.

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Defect Repair After Tongue Cancer Surgery

6

Zhou Xiao, Li Zan, and Yang Lichang

1 Overview

1.1 Incidence and Diagnosis

The tongue cancer is one of the more common oral malignant tumors, accounting for 32.3–50.6% of oral cancer. In China, the male to female prevalence ratio is 2:1; in foreign countries, the prevalence of tongue cancer is significantly greater in male than in female, and the male to female prevalence ratio is about 55:1. The disease mostly occurs in patients between 40 and 60 years, accounting for about 70%; the tongue cancer patients over 60 years of age are not uncommon; the tongue cancers in newborn babies and people under 20 years of age have been reported, but the tongue cancer patients under 40 years of age account for less than 3%.The patients with tongue cancers occurring in the lingual margin account for 60–70%, followed by the occurring places such as the ventral surface of the tongue, the tip of the tongue, and the dorsum of the tongue.

More than 98% of tongue body cancers are squamous cell carcinomas, the patients with high differentiated tongue cancer of stage I account for about 60%, and the patients with high differentiated tongue cancer of stage III account for only 2.3%.

1.2 Clinical Symptoms and Signs

The tongue cancers can be divided into three types such as ulcerative type, exogenous type, and infiltrating type. The first symptom is only tongue pain in some cases, and sometimes the pain is reflected to the temporal region or aural region. The exogenous type may be derived from the canceration of the papillary epithelioma. The surface of the infiltrating type may have no protrusions or ulcers. The ulcerative and infiltrating types of cancers often are accompanied by spontaneous pain and varying degrees of restricted tongue movement. The exogenous type generally has no obvious tongue movement disorder and less spontaneous pain.

The tongue cancers can cross the midline or invade the floor of the mouth at the advanced stage, can also infiltrate the lingual mandibular periosteum and bone, and involve backward to reach the root of the tongue or the anterior column of fauces and the lateral pharyngeal wall. At this time, the tongue movement can be severely limited and immobilized, and the salivary fluid is increased to overflow out; the patient feels difficulty in eating, swallowing, and speaking; the pain is severe and can be reflected to the hemi head.

1.3 Applied Anatomy

The lymphatic fluid of the front one-third of the tongue body is mainly drained into the submental and submandibular lymph nodes. In addition to the submandibular lymph nodes, the lymphatic fluid of the middle part of the lateral margin of the tongue body is drained mainly into the upper deep cervical lymph nodes under the digastric muscle, and it can also be drained directly into the branches of the common carotid artery and the middle group of the deep nodi lymphaticus juguloomohyoideus.

It was previously believed that the tongue cancer can be metastasized to the cervical lymph nodes through the lingual mandibular periosteum, and this theory has been amended in recent years. The study of Cheng Junjie further demonstrates that the lymphatic drainage in the lingual edge has no connective relation with the lymphatic vessels of the lingual mandibular periosteum, and, therefore, it is considered that the lymphatic vessels of the lingual mandibular periosteum have their own independent system and have no relation with the tongue mucosa.

The tongue cancers are more likely to have a higher incidence of lymph node metastasis, which ranges from 40% to 80% in the literatures. The metastasis sites are mostly the

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upper group of deep cervical lymph nodes, followed successively by the submandibular lymph nodes, the middle group of deep cervical lymph nodes, the submental lymph nodes, and the lower group of deep cervical lymph nodes. The metastasis rate and numbers gradually increase with T classification, and the patients with T4 tongue cancers and late recurrence can have metastasis in the posterior triangle lymph node group (i.e., the lymph nodes in horizontal chain and deputy chain). The tongue cancers which invade the midline and cross the midline or originate from the back of the tongue can lead to bilateral lymph node metastases.

The tongue cancers at the advanced state can lead to metastases in the lung or distant metastases in other sites.

1.4 The Treatment Plan

Before surgery, a scientific and rational treatment plan should be developed strictly in accordance with TNM staging.

1.4.1 Treatment of Primary Cancers

It can be considered that the patients with early and highly differentiated tongue cancers should be treated with radiation therapy, simple surgical resection, or cryotherapy. The advanced tongue cancers should be treated with comprehensive treatment. According to their conditions, the comprehensive treatment such as the radiation therapy plus surgery or the chemotherapy and surgery plus radiation therapy is performed.

The patients with T_1 tongue cancers can undergo wedge resection starting from the site, more than 1 cm away from the lesions, and the wound is directly sutured. The patients with T_2–T_4 can undergo resections of most part of the tongue or half tongue at the affected side and even the resection of total body of the tongue according to local conditions. If the tongue cancer invades the floor of the mouth, the floor of the mouth should be removed together.

In addition to that, the partial glossectomy can be directly performed in the mouth of the patients with T_1 andT_2 tongue cancers; it is required that all other primary tumor resections are performed through incising open the lower lip or the midline of the mandible; this is due to the fact that a good surgical field exposure is closely related to the thoroughness of the surgery.

Principles of mandible resection:

1. The mandible should be saved in the patient whose floor of mouth is not invaded.
2. The margin of the mandible can be resected to preserve the continuity of the mandible in the patient whose floor of mouth is invaded, but the mandibular lingual mucosa is not invaded.
3. The mandible should not be retained for the patient in whom a wider range of mandibular lingual mucosa is invaded. In general, the resection of mandibular body from mental foramen (or midline) to the mandibular angle should be performed.

   The tongue is a vital organ for chewing and speaking. If the defect is more than 1/2 of the tongue, the tongue reconstruction should be performed at the same period.

1.4.2 Treatment of Cervical Lymph Node Metastasis

Due to the high metastasis rate of tongue cancer, in addition to the patients with T_1 tongue cancers, it should be considered that the other patients undergo cervical lymph node dissection at the same period. Furthermore, the clinical patients with positive cervical lymph nodes should undergo therapeutic cervical lymph node dissection. Due to the wide range of lymph node metastasis in tongue cancer, in terms of the scope of operation, an appropriate cervical lymph node dissection should be performed according to the intraoperative pathology report.

2 Surgical Treatment of the Primary Foci of the Tongue Cancer

2.1 Local Resection

2.1.1 Indications

The small and well-differentiated cancers with clear boundaries and a diameter of no more than 1.5 cm, particularly in the tip of the tongue or in the margin of two-thirds of the tongue, cancers without obvious invasion in deep layers, precancerous lesions, or the well-differentiated cancers in the tongue back.

2.1.2 Surgical Methods

A thick silk thread is passed through the tip of the tongue, and the tongue is pulled out of the mouth. A wedge or fusiform incision is made at 1–2 cm outside the range of disease, and the tumor is completely removed. After the bleeding is stopped, the wound is closed and sutured directly with 4–0 thread or repaired using the tissue engineering patch.

2.2 Resection of Half of the Tongue Body

2.2.1 Indications

Primary lesion of tongue cancer in the front two-thirds of the tongue has invaded the muscles of the tongue, but the its range is no more than the midline and the circumvallate papilla. At the same time, regional lymph node metastasis has not occurred in the well differentiated tongue cancer. But Irving M. Ariel believed that the cancers confined to one side of the tongue should be treated with combined radical operation of jaw and neck in addition to the small and highly differentiated tongue cancers at an early stage.

2.2.2 Surgical Methods

1. Each thick silk thread is passed through out of the tongue, respectively, on both sides, and the tongue is pulled out. In order to block the blood supply to the tongue body, a thick silk thread is passed through the midline of the tongue body by a large and curved round needle at the place behind the tumor and near the root of the tongue, and the temporary ligation is performed at the margin of the tongue.
2. The full thickness of the tongue is sagittally incised at the midline of the tongue back, and the posterior boundary is transected at the site at 2 cm on the outside of the tumor. The lingual artery and active bleeding points are ligated. The affected part of the floor of the mouth should be removed together.

2.3 Resection of the Whole Tongue

2.3.1 Indications

The patients in whom the cancer in the front 2/3 of the tongue has invaded the muscles of the tongue, and the lesion range is more than the midline and the circumvallate papilla; the patients in whom the tongue cancer has violated a wide range and the tongue body has been fixed and the patients in whom the root of the tongue is invaded and bilateral lingual arteries cannot be retained should be treated with the resection of the whole tongue and the combined radical operation of the jaw and neck. If the tongue cancer has invaded the root of the tongue, when the epiglottis is involved and cannot be reserved, it is needed to perform the total laryngectomy simultaneously; otherwise, the postoperative aspiration will cause severe aspiration pneumonia.

2.3.2 Surgical Methods

Firstly the general anesthesia is performed after tracheotomy, and bilateral cervical lymph node dissection is completed. The neck dissection specimen is connected to the floor of the mouth. The lower lip is split off; the mandible is treated according to the range of disease; the whole tongue and related lesion area are removed; the en bloc resections of the floor of the mouth of the whole tongue and the neck specimen are performed.

3 Repair and Reconstruction of Tongue Defects

Skin flap selection for repair of the tongue defect: (1) the small tongue defects can be closed and sutured directly or repaired with tissue engineering patch; (2) the anterolateral thigh skin flap, forearm skin flap, lateral arm skin flap, and infrahyoid myocutaneous flap can be used for repair of defects after the resection of the half of the tongue; (3) the skin flaps with larger tissue volumes such as thigh anterolateral myocutaneous flap, pectoralis major myocutaneous flap, transverse rectus abdominis myocutaneous flap, deep inferior epigastric perforator flap, and trapezius myocutaneous flap can be used for repair of defects after the resection of the whole tongue.

3.1 The Repair Method with the Subhyoid Myocutaneous Flap

The surgery is to perform en bloc resection of primary tongue cancer, involved mandible and neck dissection specimens under the condition that the mandibular arch continuity is not damaged (Figs. 6.1 and 6.2), meanwhile the surgical defect is repaired with the subhyoid myocutaneous flap [1–3].

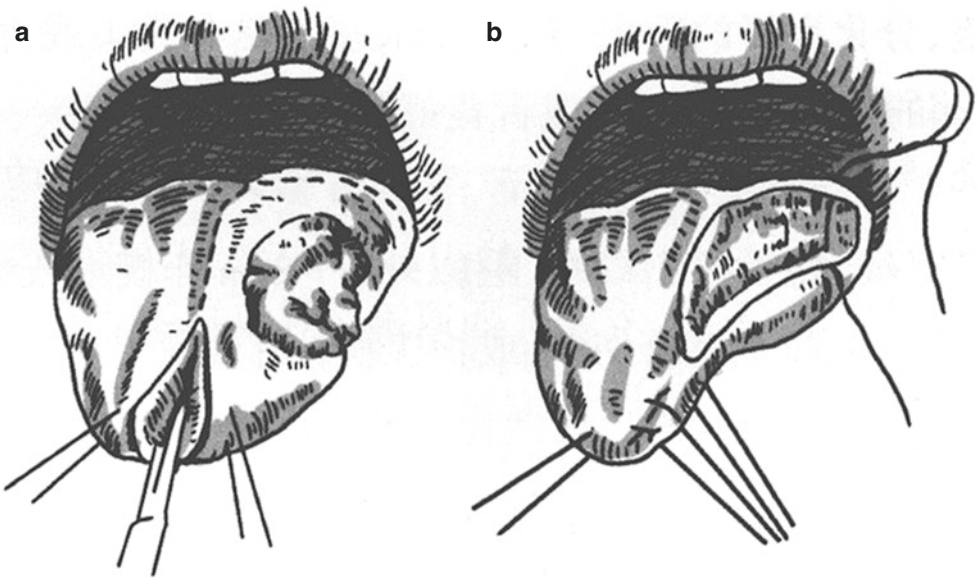

Fig. 6.1 Resection of half of the tongue body of the patient with tongue cancer. (**a**) Cut line of hemi tongue resection. (**b**) Wound suture of hemi tongue resection

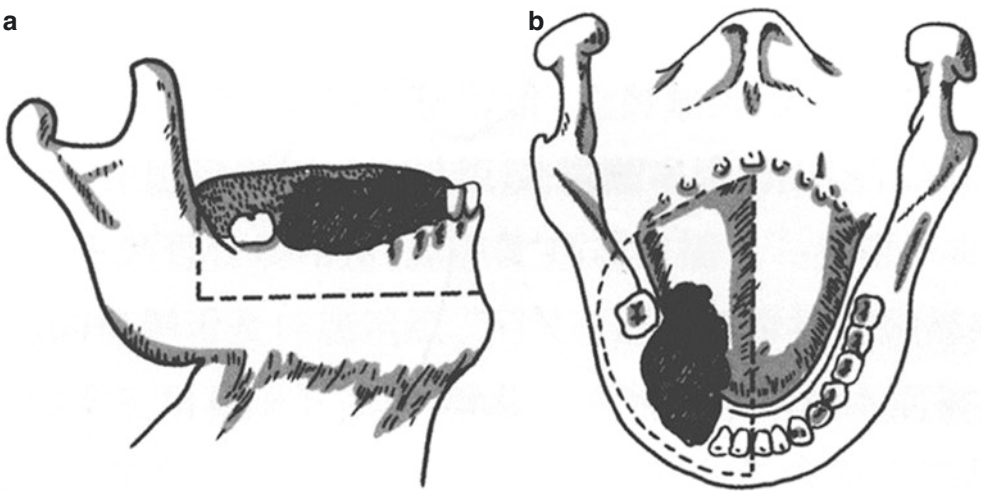

Fig. 6.2 Primary foci of the tongue cancer and the resection range of the mandible. (**a**) Side view. (**b**) Front view

3.1.1 Indications

1. The diameter of the tongue and/or the floor of the mouth is more than 2 cm, the margin of the tongue does not reach the midline or the cancers in the body of tongue, and the tip of the tongue has a range of infiltration which does not exceed the V-shaped sulcus.
2. The cancers in the tongue and/or the floor of the mouth which invade the gingiva and the upper one-third of the mandible or the cancers with suspected invasion.
3. The cancers in the tongue and/or the floor of the mouth with N_0 cervical metastasis foci and the ipsilateral functional cervical lymph node dissection and the repair with subhyoid myocutaneous flap can be performed.
   The patients with N_1-N_2a cervical metastasis foci should undergo ipsilateral radical cervical lymph node dissection and repair using subhyoid myocutaneous flap with venous anastomosis, and other skin flaps can also be used to repair the tongue defects. If the patients have ipsilateral-negative lymph nodes and contralateral cervical metastasis foci, they should undergo ipsilateral functional cervical lymph node dissection, contralateral radical cervical lymph node dissection, and the repair with subhyoid myocutaneous flap, and other skin flaps can also be used to repair the tongue defects.

3.1.2 Surgical Methods

The patients with $T_2N_0M_0$ tongue cancers undergo combined radical operation of tongue cancer (functional cervical lymph node dissection) plus repair with subhyoid myocutaneous flap, which is taken, for example.

1. Preoperative preparation
   (a) Clarify the diagnosis, which is confirmed by the preoperative biopsy.
   (b) The general physical examinations including examinations on the heart, liver, kidney, lung, bone, as well as nervous system and blood system are performed to exclude whether there are important organ diseases and the distal metastases of the tongue cancer and predict whether the patient can tolerate the surgery.
   (c) If the tumor has secondary infection, it is required to control the infection at first before performing an operation. The periodontal scaling should be performed at the same time, and the mouth is cleaned every day with 1.5% hydrogen peroxide solution or other mouthwash.
   (d) Prepare a sufficient volume of blood transfusion for intraoperative use.
   (e) The nasal feeding tube can be inserted before surgery for postoperative nutrition.
2. Anesthesia. The patient receives the intranasal intubation combined with compound intravenous general anesthesia.
3. Body position. The patient lies on their back, with a pillow under the shoulder and the head toward the healthy side, and the urethral catheter is placed in advance.
4. Disinfection and draping. Both eyes are smeared with chlortetracycline eye ointment, and small cotton balls are stuffed into bilateral external auditory canals. Complex iodine is used to disinfect conventionally the surgical areas such as the head, neck, chest, and shoulders for three times. The aseptic towel, medical bed sheet, and quilt with a hole are draped.
5. Incision. The upper and lower transverse incision lines of the subhyoid myocutaneous flap are made at first, and the length is 4.5 cm; then the inner and outer vertical incision lines are made; the length is 6 cm (Fig. 6.3).The lower incision line of the skin flap is extended to reach the medial side of the shoulder joint. A stepped line from the midline of the lower lip is made downward to intersect with the inner incision line of the skin flap, then the lower buccal gingival sulcus incision at the affected side is incised, and the

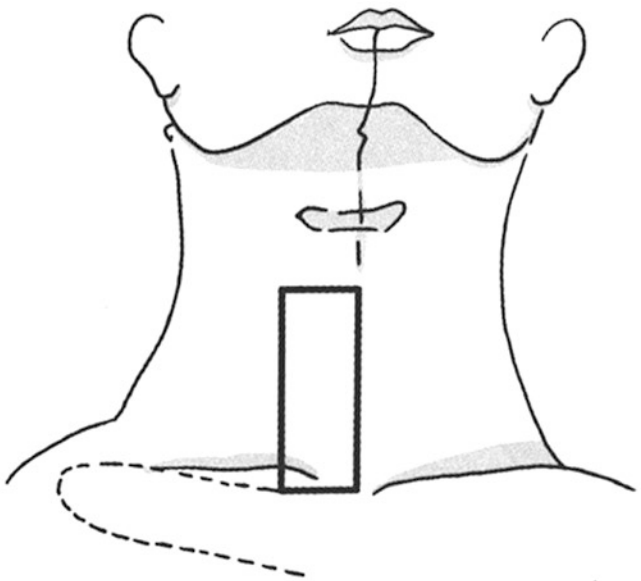

Fig. 6.3 Surgical incision

facial and cervical skin flap is turned over to the affected side to complete the primary tumor resection and the cervical lymph node dissection. In the subhyoid area, 6 × 4.5 cm of anterior cervical skin is prepared for use as the subhyoid myocutaneous flap. In general, the skin defect in the donor site of the skin flap can be closed and sutured directly. The skin below the clavicle is harvested to be used as the thoracic transverse fascia skin flap to repair the larger skin defect at the anterior cervical donor site.

6. Separation of facial and cervical skin flap. Incise open the skin along the midline of the lower lip downward to the upper incision line of subhyoid myocutaneous flap and the lateral incision line to the clavicle, and transversely incise the upper incision marker line of the thoracic transverse fascia skin flap in the level of the clavicle. Along the deep surface of the platysma muscle and the superficial face of the deep cervical fascia, turn over the skin flap from the lower inner side of the facial and cervical skin flap toward the upper outer side, the upper boundary reaches the lower margin of the mandible, and the outer boundary reaches the anterior margin of the trapezius muscle. Ligate off the transverse cervical artery and vein at the lower margin of the mandible. Attentions should be paid to protecting the marginal mandibular branch of the facial nerve. Incise open the periosteum along the lower margin of the mandible; ligate and cut off the submental artery and vein; cut off the attachment point of the musculi masseter in the mandibular angle. The skin flap in the face and neck is separated to the level of the gingival cheek groove and labiogingival groove.
7. Elimination of posterior cervical triangle. Pay attention to separately dissecting and protecting the external jugular superficial vein and its small branches for standby application. Incise open the anterior margin of the trapezius muscle; separate and reserve the accessory nerve; dissociate along the long axis of this nerve toward the anterior upper inner side, upward to the site where the accessory nerve gives off the sternocleidomastoid branch, and downward to the inner surface of the trapezius muscle. Dissect the adipose tissue within the supraclavicular fossa; cut off the nervi supraclaviculares (two to three branches); separate the shoulder end of the omohyoid muscle; cut it off after clamping; cut off the transverse cervical artery and vein; dually ligate the broken ends. Along the superficial surface of the prevertebral fascia, from the bottom up and from the rear to the front, dissect forward from the posterior triangle to the site below the rear edge of sternocleidomastoid. It is observed in the upper parts of the front and middle scalene muscles that the cervical plexus cutaneous nerves penetrate out of the deep fascia, from top to bottom in turn for the lesser occipital nerve, great auricular nerve, anterior cervical nerve, and supraclavicular nerve, which are cut off at 0.5 cm away from their penetrating out sites. The phrenic nerve runs from the outer upper side toward the inner lower side at the surface of anterior scalene muscle, the brachial plexus nerves penetrate out from the scalene fissure, both kinds of nerves are located at the deep surface of the prevertebral fascia, and attentions should be paid to protecting them from damage. When the proximal end of the transverse cervical artery is ligated, it should be noted that the cupula pleurae is not damaged.
8. Removal of internal jugular lymph node chain. Incise open at the anterior and posterior margins of the external jugular vein, separate this vein from the sternocleidomastoid muscle, and then reserve it. If there are communicating branches running to the anterior jugular vein above the level of the hyoid bone, they should be retained to be used as the reflux veins. If the external jugular vein has no branches communicating with the subhyoid myocutaneous flap, it is supposed to retain one to two small branches with a diameter of about 2 mm. When the subhyoid myocutaneous flap with venous anastomosis is formed, they can be used as the anastomosed reflux veins of the receptor site.

   Sharply incise the superficial layer of deep cervical fascia from the anterior margin of the sternocleidomastoid muscle, adopt the dissociation method of overturning the sternocleidomastoid muscle, dissociate at the middle of this muscle from the inner to the outer edge, and separate the muscle belly with the deep soft tissue. Then, lift the sternocleidomastoid muscle with a drag

hook, and dissociate the sternocleidomastoid muscle all the way at the deep side of the muscle belly, up near the end of the mastoid process, and down near the clavicle. The muscle at the sternal head of sternocleidomastoid muscle can be cut off, which is retained in the subhyoid myocutaneous flap. The sternocleidomastoid muscle is pulled outward to expose the cervical vascular sheath (middle layer of deep cervical fascia or called as the visceral fascia); the sheath membranes of cervical blood vessels are incised open starting from the inner margin of the internal jugular vein; the internal jugular vein, carotid artery, and vagus nerve are separated out; the internal jugular vein is completely exposed to be removed completely. Reach the prevertebral fascia at the deep side of the internal jugular vein, and thereby outwardly remove the soft tissue mass in the lateral area of the internal jugular vein, including soft tissues upward from the posterior belly of digastric muscle, downward to the clavicle, and outward to anterior margin of the trapezius muscle, the musculus levator scapulae, and the scalene muscle in the base surface and the deep surface of the sternocleidomastoid muscle in the front surface. It should be noted that it is required to protect the superior thyroid artery and vein when the sternocleidomastoid muscle is dissected. The thoracic lymph duct pours into the left jugular venous angle; the right lymphatic duct pours into the right venous angle. Before pouring into jugular venous angles, both lymphatic ducts collect lymphatic fluids, respectively, from the left and right subclavian trunks as well as the left and right jugular trunks, and thus these soft tissues should be clamped before being cut off and sutured. When the lymphatic fluid outflow is observed, a few stitches should be additionally performed to prevent the chylous leakage. The carotid triangle area is dissected after the subhyoid myocutaneous flap is formed.

9. Removal of submental and submandibular triangle areas. The submental and submandibular triangle areas are conventionally removed, and the specimens and primary tumor are resected and then are cleared away together. In addition, a part of the lower pole of the parotid gland is resected at the horizontal level of the mandibular angle, and its broken end is sutured to prevent postoperative parotid fistula.
10. Resection of primary foci. Cut open the mucosa to the molars at the gingival cheek groove, and then further turn over the facial and cervical skin flap. Strip off the periosteum at the inner surface of the mandible to the attachment site of mylohyoid muscle, and cut off the attachment site with an electric scalpel. A rectangular resection is performed in the mandible body, and the invaded tissues in the tongue and floor of the mouth are removed. Pass through a thread, respectively, on the left and right sides of the tongue tip to pull the tongue out of the mouth to the greatest extent; reach the site of circumvallate papillae along the midline from 2 cm at the outer edge of the tumor; resect the tissues in the affected floor of the mouth in the safe range to the V-shaped sulcus terminalis; transect half of the tongue; ligate the lingual artery; the removed half of the tongue and mouth floor tissue are connected to the mandibular bone block of rectangular resection. A pair of pliers is inserted into the buccal passageway in the inner surface of the affected mandible to grip the suture line which is placed in advance in the affected tongue tip; pull downward the separated and affected tongue; the mouth floor tissue and the mandibular bone block to the cervical area through the buccal cervical passageway. In this way, the affected tongue, mouth floor tissue, rectangular bone block, submandibular triangle, and submental triangle jointly constitute a whole piece of surgical specimen to be removed.
11. Formation of subhyoid myocutaneous flap. After removal of surgical specimen, the careful hemostasis is performed, and the hydrogen peroxide solution and the normal saline are used to wash the surgical cavity. The subhyoid myocutaneous flap is harvested for repair according to defect size. The subhyoid myocutaneous flap should be designed in the anterior cervical area at the defect side, and the area of the skin flap is 7.0 × 4.5 cm. After that, the skin and subcutaneous tissues are incised along the inner incision and lower incision of the skin flap. When the subhyoid myocutaneous flap is harvested, the separation should be started from the distal end. The pectoralis major fascia and the sternal head of sternocleidomastoid muscle may be included within the myocutaneous flap, the muscular fascial blood vessels at the surface layer of sternocleidomastoid muscle should be carried onto the skin flap, and the blood vessels of sternocleidomastoid branches are retained. The anterior jugular vein is ligated and cut off, and the lower end of the strap muscle is cut off. The broken ends of the muscle are sutured and fixed with the skin by a few stitches to prevent tearing off of the skin flap from the muscle. Separate along the outside of the true envelope of thyroid gland. When reaching the upper pole of the thyroid gland, don't excessively separate the upper pole of thyroid tissues with the anterior muscles of the skin flap to prevent damage to small supplying arteries. The anterior branch of the superior thyroid artery is retained behind the sternothyroid muscle and is ligated and cut off at the site near the midline. The blood

vessels and a portion of the thyroid tissue of the upper pole of the thyroid gland are retained in the vascular pedicle of skin flap. The residual stump of thyroid gland is sutured and ligated. The ending point of sternothyroid muscle on the thyroid cartilage is cut off, and it is noted that the external branch of the superior laryngeal nerve is not damaged. When the separation is performed continuously upward, the myolemma at the superficial surface of thyrohyoid muscle is retained onto the skin flap so as to increase the blood supply.

Upon completion of skin flap harvesting, the subhyoid myocutaneous flap is transferred into the defect area in the receptor site through the buccal cervical passageway at the inner side of the mandible, and the length of the skin flap is measured to evaluate whether it can meet the requirements of the receptor site. For the patients in whom the pedicle has no tension after the skin flap reaches the receptor site, the subhyoid myocutaneous flap with arteriovenous pedicle is formed, and this skin flap has two reflux veins such as external jugular superficial veins and superior thyroid vein. On the contrary, for the patients in whom the short skin flap with superior thyroid vein cannot reach the receptor site, or the patients in whom the large tension in the pedicle causes the circumfluence obstacle of the superior thyroid vein, it is needed to cut off the superior thyroid vein from the internal jugular vein, and the crevasse of the internal jugular vein is sutured with the needle and thread causing no damage to form the subhyoid myocutaneous flap with the superior thyroid vein and external jugular superficial vein (facial vein).

12. Repair of defects in the tongue and floor of the mouth. The proximal end of the prepared subhyoid myocutaneous flap is sutured to the root of the tongue and repair the floor of the mouth, the distal end is taken as the front portion of the tongue, and the buccal mucosa and lower lip are sutured. The anterior cervical defect can be directly sutured with gliding method, and it can also be repaired with the ipsilateral transverse thoracic fascial flap. The key point in harvesting the thoracic fascial flap is to include the pectoralis major fascia into the skin flap, and it is preferable to damage the pectoralis major muscle fibers rather than damage its muscular fascia.

3.1.3 Discussion and Analysis

According to our experience, the different reflux veins can be used in the subhyoid myocutaneous flap, and thus the skin flap harvesting can be divided into three types: (1) classical subhyoid myocutaneous flap, (2) the subhyoid myocutaneous flap with anomalous vein, and (3) the subhyoid myocutaneous flap in which the vein is cut off and then is anastomosed.

From March 1993 to September 1999, targeting against the reflux obstacle in some superior thyroid veins, we designed the surgical method using the subhyoid myocutaneous flap in which the vein was cut off and then was anastomosed, improved the design of the traditional surgical incision, and carried out one-stage repairs of the defects in 38 patients after oral tumor operation, including 6 patients using the subhyoid myocutaneous flap in which the vein was cut off and then was anastomosed and 32 patients using the subhyoid myocutaneous flap with arteriovenous pedicle. Among the 32 patients, the external jugular superficial vein and the superior thyroid vein were taken as the reflux veins in 5 patients, the common facial vein and the superior thyroid vein were taken as the reflux veins in 3 patients, the single superior thyroid vein was taken as the reflux vein in 24 patients, and satisfactory curative effects have already been achieved in clinics.

1. Improvement of surgical methods. The subhyoid myocutaneous flap pedicled with the external jugular superficial vein and the superior thyroid vein is taken as an example, with reference to traditional surgical procedures of the subhyoid myocutaneous flap, but there are the following exceptions:
   (a) The area of the skin flap is designed according to the size of the defect to be repaired. At first, the upper and lower transverse incision lines of the subhyoid myocutaneous flap are made, then the inner and outer vertical incision lines are made, and the lower incision line of the skin flap is extended to reach the medial side of the shoulder joint. A stepped line from the midline of the lower lip is made downward to intersect with the inner incision line of the skin flap, then the lower buccal gingival sulcus incision at the affected side is incised, and the facial and cervical skin flap is turned over to the affected side to complete the primary tumor resection and the cervical lymph node dissection.
   (b) Targeting against the reflux obstacle in superior thyroid veins of some subhyoid myocutaneous flaps, the ipsilateral external jugular superficial vein (facial vein) should be reserved intentionally during operation for standby application. The skin flap harvesting is completed at first, and the length of the skin flap is measured to evaluate whether it can meet the requirements of the receptor site. For the patients in whom the pedicle has no tension after the skin flap reaches the receptor site, the subhyoid myocutaneous flap with arteriovenous pedicle is formed, and then

the functional cervical lymph node dissection and primary oral cancer resection are performed. On the contrary, for the patients in whom the short skin flap with superior thyroid vein cannot reach the receptor site, or the patients in whom the large tension in the pedicle causes the circumfluence obstacle of the superior thyroid vein, it is needed to cut off the superior thyroid vein from the internal jugular vein, the crevasse of the internal jugular vein is sutured with the needle and thread causing no damage to form the subhyoid myocutaneous flap with the superior thyroid vein and external jugular superficial vein (facial vein), and then the functional cervical lymph node dissection and primary oral cancer resection are performed. In addition, for the oral cancer patients with cervical lymph node metastases who need to undergo internal jugular vein resection, the superior thyroid vein may be cut off from the internal jugular vein, and the internal jugular vein is removed, and then the subhyoid myocutaneous flap anastomosed with superior thyroid vein and external jugular superficial vein is formed. It is noted that the site where the terminal end of the external jugular superficial vein joins the internal jugular vein is kept unobstructed. Afterwards, the functional cervical lymph node dissection and primary oral cancer resection are performed.

2. Investigation of the cause for skin flap necrosis. It is reported in the literatures at home and abroad that the necrosis rate of the myocutaneous flap is 7–47%, and the analysis shows that it is mainly due to the venous flow obstruction caused by the short venous pedicle of the skin flap. Therefore, the following three points should be considered when the skin flap is designed:
   (a) When the myocutaneous flap is designed, generally it is feasible that the ipsilateral superior thyroid vein is reserved as the pedicle. However, in this group of patients, two reflux veins were reserved as the pedicle in eight patients, accounting for 21.1%, and all myocutaneous flaps survived after surgery. In such myocutaneous flaps taking the external jugular superficial vein or the common facial vein as the reflux vein, the superior thyroid vein is generally relatively short, and the reservation of the veins of uncommon type in the myocutaneous flap is conducive to the survival of the myocutaneous flap.
   (b) It is observed during operation that the starting point of the superior thyroid artery is located on the upper inner side of the site where the superior thyroid vein joins the internal jugular vein and its travel journey is generally Z-shaped. In addition to that, this artery has a high blood pressure; its vascular wall elasticity is greater than those of the accompanying veins. The length of the actually used venous pedicle of subhyoid myocutaneous flap is shorter than that of the arterial pedicle, and the change in the length of superior thyroid vein is greater. The reason is that the converging points of the superior thyroid veins have four different forms: (1) the superior thyroid vein is taken as an independent trunk to join the internal jugular vein, (2) the common trunk of the superior thyroid vein and the facial vein joins the internal jugular vein, (3) the superior thyroid vein and the throat vein converge into common facial vein, and (4) the superior thyroid vein joins the posterior facial vein at first and then joins the internal jugular vein through the common facial vein.

   Some superior thyroid veins with the form of independent trunk join the internal jugular veins at a lower location, the travel distance of the vein is short, and the harvested skin flap cannot be transferred into the receptor site. In this group, the superior thyroid vein of the subhyoid myocutaneous flap in which the vein was cut off and then was anastomosed had the form of independent trunk in six patients; the intraoperative observation showed that the length of the superior thyroid vein was 1.5–2.5 cm. According to the needs of the receptor site, the skin flap was 2–4 cm shorter, and the skin flap was extended by 2–5 cm through venous anastomosis. After operation, all six myocutaneous flap survived completely. The subhyoid myocutaneous flap in which the vein is cut off and then is anastomosed resolves the problems such as the venous flow obstruction of the skin flap due to the short superior thyroid veins in some subhyoid myocutaneous flaps and improves the survival rate of the skin flaps. The superior thyroid veins with other three forms join the internal jugular veins at a high location, and the travel distance of the vein is long. In general, the length of the skin flap can meet the need of the receptor site through ligating and cutting off the branches which are not related to the venous reflux of the skin flap and separating the venous trunk.
   (c) In this group, the single superior thyroid vein was taken as the reflux vein of subhyoid myocutaneous flap in 24 patients, all skin flaps were transferred into the receptor site under no tension during surgery, and the skin flaps were ruddy. Twenty-three skin flaps survived completely after surgery; one skin flap had about 5% skin necrosis in distal skin flap, and the skin flap survived after the necrotic skin was removed. It is analyzed that the reasons for the necrosis in the skin flap margin are the folding and extrusion of the margin due to the larger skin flap.

The subhyoid myocutaneous flap is contraindicated in patients after cervical radical radiotherapy and ipsilateral thyroidectomy and with ipsilateral cervical infection and ipsilateral superior deep cervical lymphatic node metastasis involving the superior thyroid artery and vein. The methods such as pectoralis major myocutaneous flap, trapezius myocutaneous flap, free forearm skin flap, and free vastus lateralis myocutaneous flap are used to repair the oral defects according to the concrete conditions.

3. Advantages of modified incision design:
   (a) The submandibular incision in the traditional incision design is reduced. The lower buccal gingival sulcus incision at the affected side is incised during surgery; the facial and cervical skin flap is turned over; the surgical field is well exposed. It is suitable for repair of defects in the tongue, buccal mucosa of the mouth floor, and tongue root.
   (b) The operation scars of submandibular incision are reduced after surgery, which is helpful for the improvement of the appearance.
   (c) The lower boundary of the skin flap can be extended to the site at 2 cm under the upper margin of the clavicle, which will help to extend the length of myocutaneous flap.

   For the subhyoid myocutaneous flap in which the vein is cut off and then is anastomosed, if necessary, the internal jugular vein can be removed for ipsilateral radical cervical lymph node dissection, which overcomes the shortcoming that the internal jugular vein can only be partly removed in the subhyoid myocutaneous flap with the arteriovenous pedicle and expands the surgical indications. Its clinical application value remains to be further studied.

   The subhyoid myocutaneous flap with a transverse cervical nerve is used, and the skin in the tongue flap has a sense after surgery. The effect and facilitation of the nerve reservation on the function of the tongue also remain to be further studied.

   Attentions should be paid to the nurse before waking in patients undergoing general anesthesia operation, and the intraoral secretions are sucked out timely. It is noted that the patients with preventative tracheotomy should be treated with tracheostomy care. The patients with reduced lung function should receive preventive tracheotomy.

   Before we carry out a comprehensive repair of the defects after tumor surgery with free skin flap, the subhyoid myocutaneous flap is one of the important repair methods for repairing the defects in the tongue and the defects after oral cancer surgery, but when the subhyoid myocutaneous flap is harvested, the supplying vessels vary greatly. When there are more cervical lymph node metastases with a larger size, the speed of cervical lymph node dissection is affected, and even the cervical lymph nodes are not easy to be dissected cleanly. The venous bypass should be performed in the advanced-stage patients with cervical lymph node metastasis and internal jugular vein invasion who need to undergo radical cervical lymph node dissection. In addition, there are tensions in the postoperative anterior cervical straight line wound, the wound after the donor site is closed and sutured, and generally there are significant cervical scars after surgery. After we totally carry out microsurgery, these skin flaps are gradually replaced by all kinds of free skin flaps. In the units which have not carried out microsurgery, the subhyoid myocutaneous flap is still regarded as a very practical and effective means of repair.

3.1.4 Typical Case

Case I The patient, male, 31 years old, was found with ulceration and pain on the right side of his tongue for 2 months, and the biopsy of the mass on the right side of his tongue performed within another hospital showed highly differentiated squamous cell carcinoma. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys. The mass on the right side of his tongue was 3.0 × 2.0 cm in size, with a hard texture and invasive growth, involving the floor of the mouth and no cervical lymph node enlargement. Admission diagnosis: squamous cell carcinoma on the right side of the tongue, T2N0M0. The patient underwent resection of the right half of the tongue and the mouth floor, mandibular rectangular resection, functional lymph node dissection on the right side of the neck, and the repair using the subhyoid myocutaneous flap with transverse cervical nerve under the general anesthesia. All the surgeries were successful, the postoperative cervical wound had effusion and infection, and it was cured by dressing change. Postoperative pathologic examination: highly differentiated squamous cell carcinoma on the right side of the tongue; the metastasis focus was observed in a cervical lymph node. The reconstructed tongue began to recover the sensation and had allachesthesia in cervical area at 1 week after surgery. After 3 months, the tongue sensation was well recovered and could respond to cold and hot stimulus; the two-point discrimination distance was 1 cm; the allachesthesia in cervical area disappeared; the tongue activity was good; the eating and speaking conditions recovered well; the facial morphology was good. Disadvantage: there were obvious scars in cervical donor site of the skin flap (Fig. 6.4).

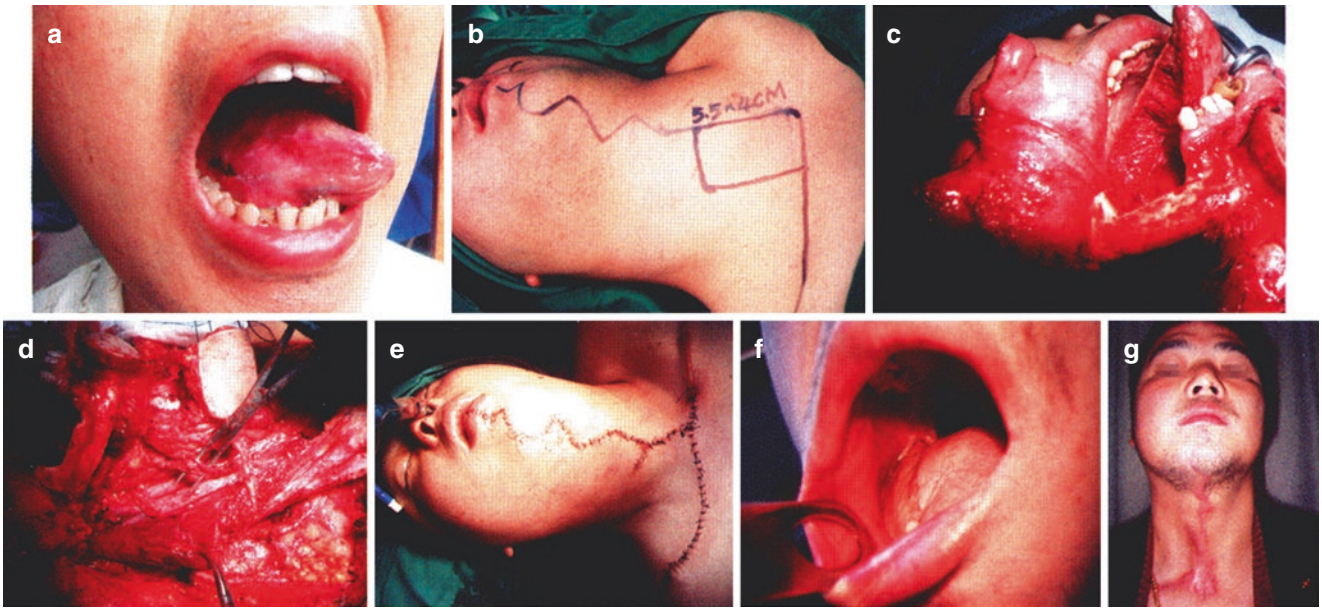

Fig. 6.4 Case I. (**a**) The cancer on the right side of the tongue involved the floor of the mouth, and the tongue movement seemed fine. (**b**) Surgical incision design, the size of the subhyoid myocutaneous flap was 5.5 × 4 cm. (**c**) The radical resection of primary cancer was completed, and the patient underwent resection of the right half of the tongue, mandibular margin resection, and right cervical lymph node dissection. (**d**) The cervical lymph node dissection was performed, while the subhyoid myocutaneous flap with transverse cervical nerve was harvested. (**e**) After the surgery was completed, the donor site of the subhyoid myocutaneous flap was closed and sutured directly. (**f**) The reexamination was carried out at 1 year after surgery. The skin flap healed well with a slight contraction, and the sensation of the skin flap was recovered well. The eating was still good, and the speech was clear. (**g**) There was tension in the anterior cervical donor site of the skin flap due to intraoperative suture, and the postoperative scars were obvious

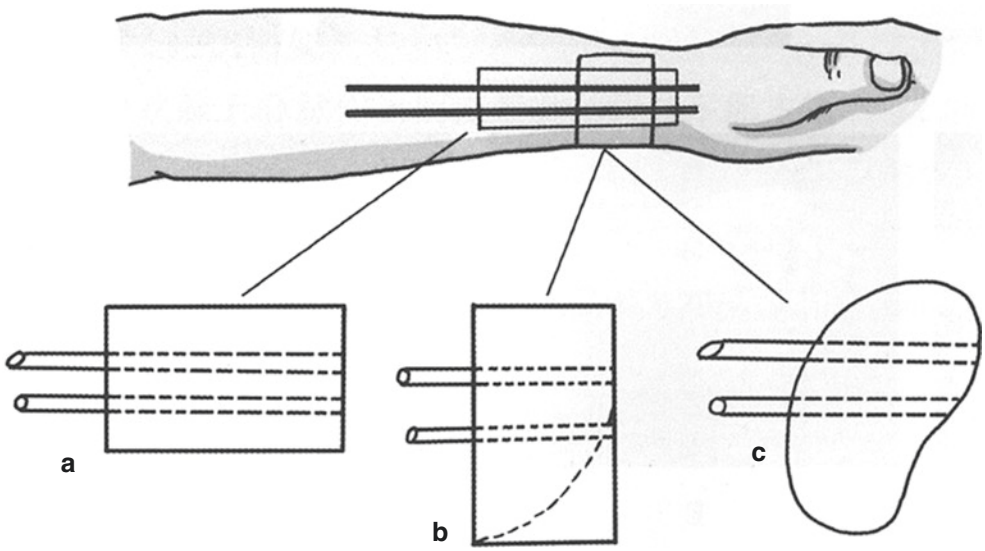

Fig. 6.5 Three types of tongue body defects (the shadow marked by the dotted line refers to the area which can be extensively resected). (**a**) Resection of half of the tongue. (**b**) Resection of the most part of the tongue. (**c**) Resection of the whole tongue

3.2 The Repair Method with the Forearm Skin Flap

The radial or ulnar forearm-free skin flap is used for tongue defect repair or reconstruction, which is considered to be a more commonly used method in free skin flap transplantation, because it can be used to repair a variety of tongue defects.

3.2.1 Indications

It is applicable to all types of large defects of the tongue body, such as defects in the half of the tongue, the most part of the tongue, and the transected tongue or the whole tongue, but the repair effect is best in the repair of the defects in the half of the tongue or the transected tongue.

3.2.2 Surgical Methods

1. Skin flap design. According to the scopes and sizes of the tongue tissue defects (Fig. 6.5), the shapes of the radial forearm skin flap can be designed as the following three forms:
   (a) Rectangular skin flap with the vascular pedicle parallel to the long axis of the skin flap: it is applicable to repair the defect after tongue transection (Fig. 6.6a).

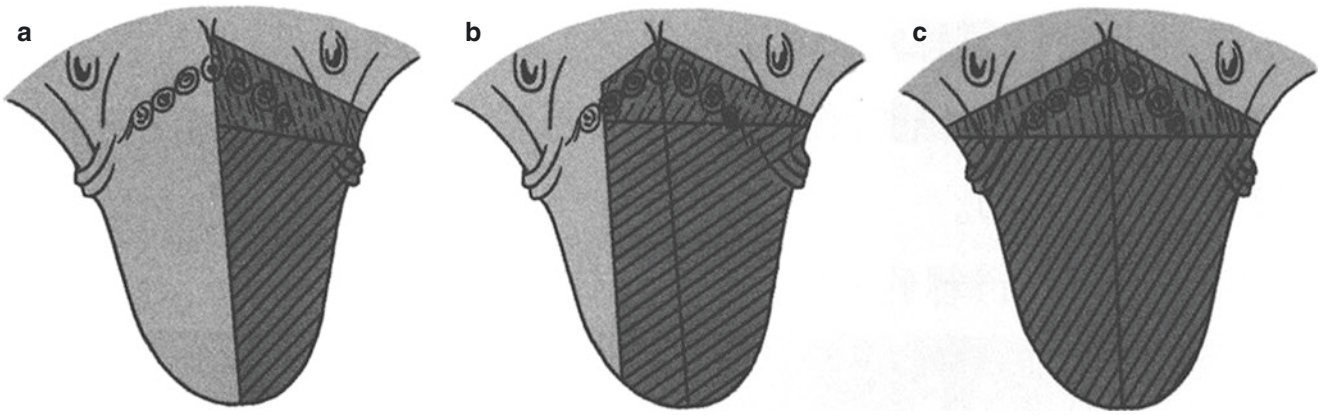

Fig. 6.6 Design of the radial forearm skin flap. (**a**) The vascular pedicle is parallel to the long axis of the skin flap. (**b**) The vascular pedicle is perpendicular to the long axis of the skin flap. (**c**) The vascular pedicle presents a certain angle to the long axis of the skin flap

(b) Rectangular skin flap with the vascular pedicle perpendicular to the long axis of the skin flap: it is applicable to repair the defect after the resection of half or most part of the tongue (Fig. 6.6b).

(c) Kidney-shaped skin flap with the vascular pedicle presenting a certain angle to the long axis of the skin flap: it is applicable to repair the ventral surface and tip of the tongue after total glossectomy (Fig. 6.6c). The proximal end of the kidney-shaped skin flap is used for repair of wounds in the ventral surface of the tongue and the anterior mouth floor; the distal end of the skin flap is used for repair of the tip of the tongue. The wound can be repaired with a single skin flap, and it can also be repaired through redesigning a tongue-shaped skin flap to cover on the former skin flap, namely, the repair is performed with two skin flaps tiled.

The vascular pedicle is designed to present a certain angle to the long axis of the skin flap, which contributes to the anastomosis of the vascular pedicle with the facial artery and vein without the occurrence of distortion, and it can be easily folded for shaping when the tongue reconstruction is performed.

The size of the skin flap should be determined based on the original size of the tongue of the patient. According to the measurement of cadavers, the average length of tongue body is 6.9 cm, the average length of the tongue root is 2.8 cm, and the maximum width of the tongue body is 5 cm.

That the width and length of the skin flap are, respectively, 4–5 cm and 6–9 cm is more appropriate, a slightly smaller skin flap has no significant impact, and an oversize skin flap can affect the patient's speaking and swallowing.

The length of the vascular pedicle of the skin flap may be determined according to the site of vascular anastomosis. If the site is located in the affected side, the length of the vascular pedicle is generally 7–9 cm; if the site is located on the healthy side, the length of the vascular pedicle can be extended by 2–3 cm; if the cephalic vein is anastomosed with the external jugular vein, and the radial cutaneous nerve is anastomosed with the greater auricular nerve, the length of the pedicle should be generally longer than that of the arterial pedicle.

The examination of blood vessels for anastomosis in the receptor site is even more important than that in the donor site, because the anatomical relationship in the donor site is mostly normal, while the blood vessels in the receptor site cannot be used due to hardened blood vessels and thickened vascular intima which are caused by factors such as radiation therapy, chemotherapy, surgery, or traumatic scars. This should be carefully examined before surgery, and the adequate prediction is made.

2. Surgical procedure. The resection of half of the tongue body is taken as an example, and the surgery is divided into two groups simultaneously. The harvesting of the radical forearm skin flap is performed in the donor site group, and the combined radical neck dissection with glossectomy and mandibulectomy at the side of tongue cancer is routinely performed in the receptor site.

Finally, the vascular pedicle of the forearm skin flap in the donor site is cut off. At first the cephalic vein is cut off to observe the situation in the blood return of the cephalic vein. The good blood return demonstrates that the cephalic vein can be used, while the poor blood return demonstrates that the cephalic vein cannot be used as the reflux vessel, and the radial artery can be cut off only after the accompanying vein of the radial artery is anastomosed. The prolonged incision in the forearm is sutured by layers, and the donor site of the skin flap needs to be repaired through transplantation of medium-thickness or full-thickness skin graft harvested in the abdomen and legs and is dressed properly. In receptor site group, after the vascular pedicle of the forearm skin flap is treated with heparin, the neurovascular pedicle is

passed through a tunnel in the mouth floor to reach the neck, and meanwhile the torsion or injury of the blood vessels should be avoided. At first, the margin of the skin flap is fixed and sutured with the margin of the normal tongue body by a few stitches, and then the vascular anastomosis is performed under the operating microscope. Generally the blood vessels at the affected side are used for anastomosis, we often use the superior thyroid artery for anastomosis, and the end-to-side anastomosis between the vein and the internal jugular vein is performed. If it is required to perform the radical cervical lymph node dissection at the affected side, the anastomosis can be performed at the contralateral side. After the confirmation of vascular anastomosis patency, the submandibular wound on the healthy side is sutured close, and the drainage tube is placed. The defect repair, folding, and shaping of the intraorally transplanted skin flap are performed to complete the reconstruction of the tongue. The forearm skin flap has a low ductility due to less subcutaneous tissues, and it is often needed to perform skin transplantation after harvesting of the skin flap, which increases the surgical trauma in the donor site. When it is not needed to harvest a larger skin flap, we try to divide the skin flap into two parts; after skin flap harvesting, two pieces of skin flaps are joined together to repair the wound, so that the donor site of skin flap can be closed and sutured directly, thus reducing the surgical wound. In addition, a major blood vessel is harvested for the forearm skin flap, which is bound to affect the blood supply of the hand, and this is one of the advantages of the forearm skin flap.

3.2.3 Typical Cases

Case II The patient, male, 44 years old, underwent local resection of the right half of the tongue and tissue patch repair due to stage I right tongue cancer ($T_1N_2M_0$) a year ago. He was found with right tongue ulceration a month ago, which was unhealed for a long time. Examination: the general conditions were good; no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys; an ulcerative mass at the rear of the right original surgical site was 2 × 2 cm in size; the floor of the mouth seemed fine; the tongue mobility was poor; one lymph node in area I under the left neck and mandible was observed and was 2 × 2 cm in size; the mobility was still good, with hard texture and no tenderness. Admission diagnosis: postoperative tongue cancer recurrence on the right side. Pathology: highly differentiated squamous cell carcinoma. The patient underwent resection of the right half of the tongue and the mouth floor, ripping the right mandibular body off in front of the mental foramen, internal titanium plate fixation, bilateral functional cervical lymph node dissection, and free transplantation of the right forearm skin flap under the general anesthesia. Postoperative pathologic examination: highly differentiated squamous cell carcinoma of the tongue; the cancer metastasis was observed in a lymph node in area I in the left cervical area. The reexamination was performed 3 months later: the appearance was good, the degree of mouth opening was 4 cm, the shape of the reconstructed tongue seemed fine, and the patient ate well, with clear speaking, good oral hygiene, and no food residue retention (Fig. 6.7).

3.3 The Repair Method with the Anterolateral Thigh Skin Flap

3.3.1 Indications

The supplying vessels are the descending branches of lateral femoral circumflex artery and vein, the tissue volume is rich, and the skin flap is applicable to repair defects in each part of the body such as head and neck [4, 5].

3.3.2 Advantages

The anterolateral thigh skin flap has the following advantages:

1. The donor site of anterolateral thigh skin flap is huge, and it can carry part of the anterolateral thigh muscle, which is conducive to intraoperative shaping and is particularly suitable for the whole tongue reconstruction.
2. The skin flap can carry the sensory nerves to form the free skin flap with sensory nerves, which play a significant role in the recovery of speech and eating after surgery.
3. The vascular pedicle of the skin flap – the descending branch of the femoral circumflex artery and its accompanying veins – is constant with thicker diameters and is suitable for anastomosis. And this blood vessel is non-trunk blood vessel; thus, after harvesting, the blood supply for the donor site is not affected.
4. In most cases, the donor site of the skin flap on the outer side of the thigh can be closed and sutured directly, without need of skin transplantation. Only the linear scar will be left in the donor site in the future.
5. The surgery can be divided into two groups at the same time, and the operation time is saved.

3.3.3 Typical Case

1. Case III. The patient, male, 41 years old, was found with the right lingual ulceration for 3 months. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung, liver, spleen, and

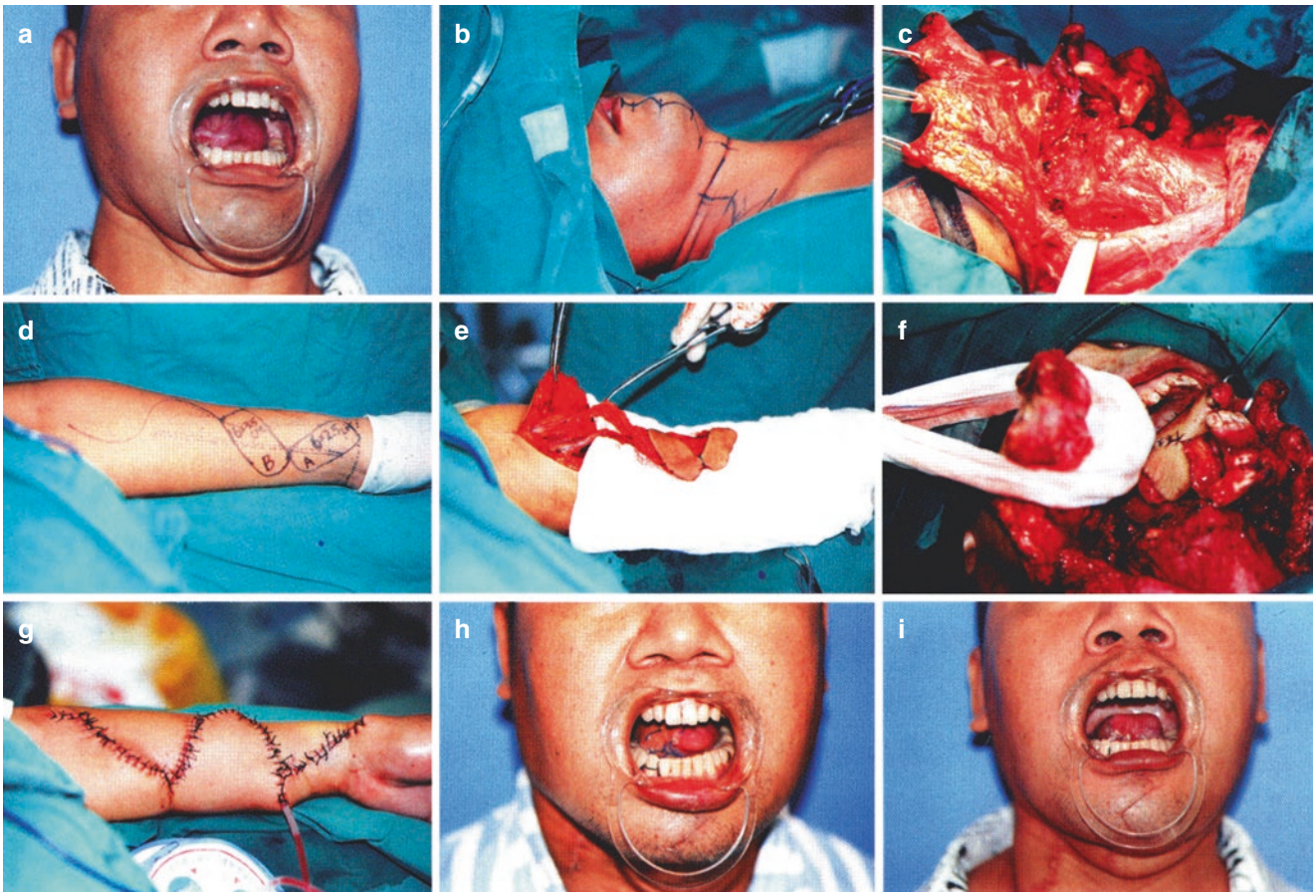

Fig. 6.7 Case II. (**a**) Local recurrence of tongue cancer on the right side after surgery. (**b**) Design of incision in head and neck. (**c**) The bilateral cervical lymph node dissection was performed, the lower lip was ripped off at the midline, the mandibular body was ripped off in front of the right mental foramen, and the resection of the right half of the tongue and the mouth floor was performed. (**d**) The left forearm skin flap was designed, the skin flap was divided into two parts, the right flap was 6 × 2.5 cm in size, and the left flap was 6 × 3.5 cm in size. (**e**) The forearm skin flap was harvested. (**f**) Two forearm skin flaps were joined together, and the right and left skin flaps were, respectively, used to repair the defects in the right mouth floor and the right half of the tongue, and then the mandible after reduction was fixed with two four-hole titanium plates. (**g**) The donor site of the forearm skin flap after subcutaneous dissociation was closed and sutured directly. (**h**) Intraoral situation at 7 days after surgery. (**i**) At 3 months after surgery, the skin flap and wound healed well, the degree of mouth opening was still good, and the patient spoke more clearly and ate well

kidneys. The mass near the circumvallate papillae at the right margin of the tongue was about 3 × 3 cm in size, with surface ulceration and normal mouth floor. The tongue mobility seemed fine, and no obvious mass was palpated in bilateral cervical regions. Admission diagnosis: stage II right tongue cancer ($T_2N_0M_0$). Pathology: highly differentiated squamous cell carcinoma. The patient underwent resection of the right half of the tongue and the mouth floor, ripping the right mandibular body off in front of the mental foramen, internal titanium plate fixation, functional right cervical lymph node dissection, and free transplantation of the right anterolateral thigh skin flap under the general anesthesia. Postoperative pathologic examination: highly differentiated squamous cell carcinoma of the tongue; no cervical lymph node metastasis. The reexamination was performed 3 months later: the appearance was good, the degree of mouth opening was 4 cm, the shape of the reconstructed tongue seemed fine, and the patient ate well, with clear speaking, good oral hygiene, and no food residue retention (Fig. 6.8).

2. Case IV. The patient, male, 13 years old, was found with the masses on the right side of the tongue and neck for 3 months. The pathological biopsy performed within another hospital showed that both masses on the right side of the tongue and neck were malignant myoepitheliomas. Examination: the general conditions were good;

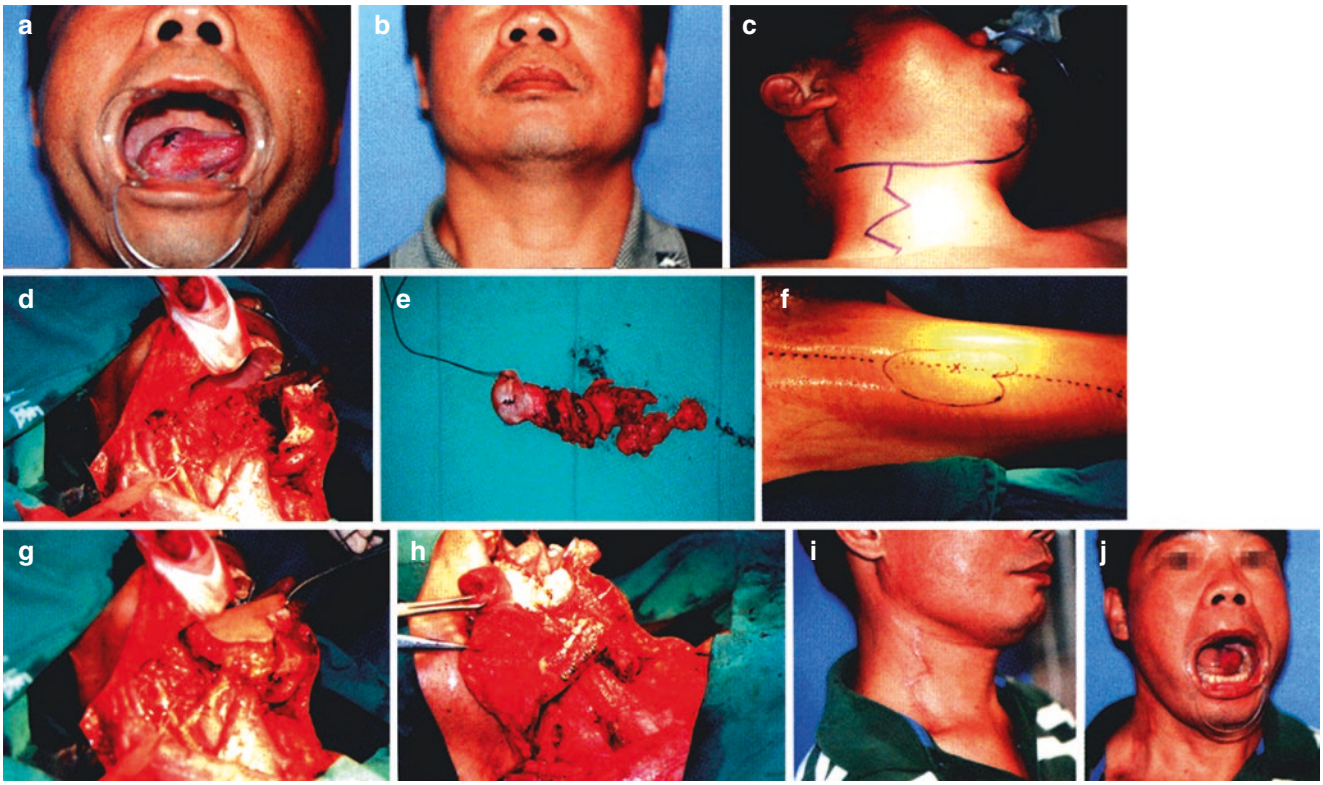

Fig. 6.8 Case III. (**a**) The mass in the right side of the tongue was 3 × 3 cm in size, and the tongue mobility seemed fine. (**b**) Before operation. (**c**) Design of the surgical incision in the head and neck. (**d**) The functional right cervical lymph node dissection was performed, the lower lip was ripped off at the midline, the mandibular body was ripped off in front of the right mental foramen, and the overall removal of the right half of the tongue and a part of the mouth floor was performed. (**e**) Surgical specimens. (**f**) Design of the right anterolateral thigh skin flap, the size was 9 × 6 cm. (**g**) The anterolateral thigh skin flap was harvested to repair the defects on the right side of the tongue and the mouth floor, the vascular pedicle was passed through the mouth floor to reach the right cervical area, the end-to-end anastomosis between the artery and the superior thyroid artery was performed, and the end-to-side anastomosis between the vein and internal jugular vein was performed. (**h**) The mandible reduction and the titanium plate fixation were carried out after the skin flap was sutured. (**i**) At 6 months after surgery, the neck wound healed well. (**j**) The skin flap healed well, the degree of mouth opening was normal, and the patient ate normally and spoke more clearly

no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys; the mass near the circumvallate papillae at the right margin of the tongue was about 3 × 3 cm in size; the surface showed changes after the biopsy; the mouth floor was normal; the tongue mobility seemed fine; there were postoperative scars on the right side of the neck; multiple masses were palpated in bilateral cervical regions; and the largest mass was about 2 × 2 cm in size. Admission diagnosis: the malignant myoepithelioma on the right side of the tongue with bilateral cervical metastases. The patient underwent resection of the right half of the tongue and the mouth floor, functional bilateral cervical lymph node dissection, and free transplantation of the right anterolateral thigh skin flap under the general anesthesia. The nasal intubation was retained for 24 h after surgery, and it was planned to perform chemotherapy. The reexamination was performed at 1 year after surgery: the appearance was good, and the mouth opening was normal. The shape of the reconstructed tongue seemed fine, and the patient ate well with clear speaking. No recurrence was observed (Fig. 6.9).

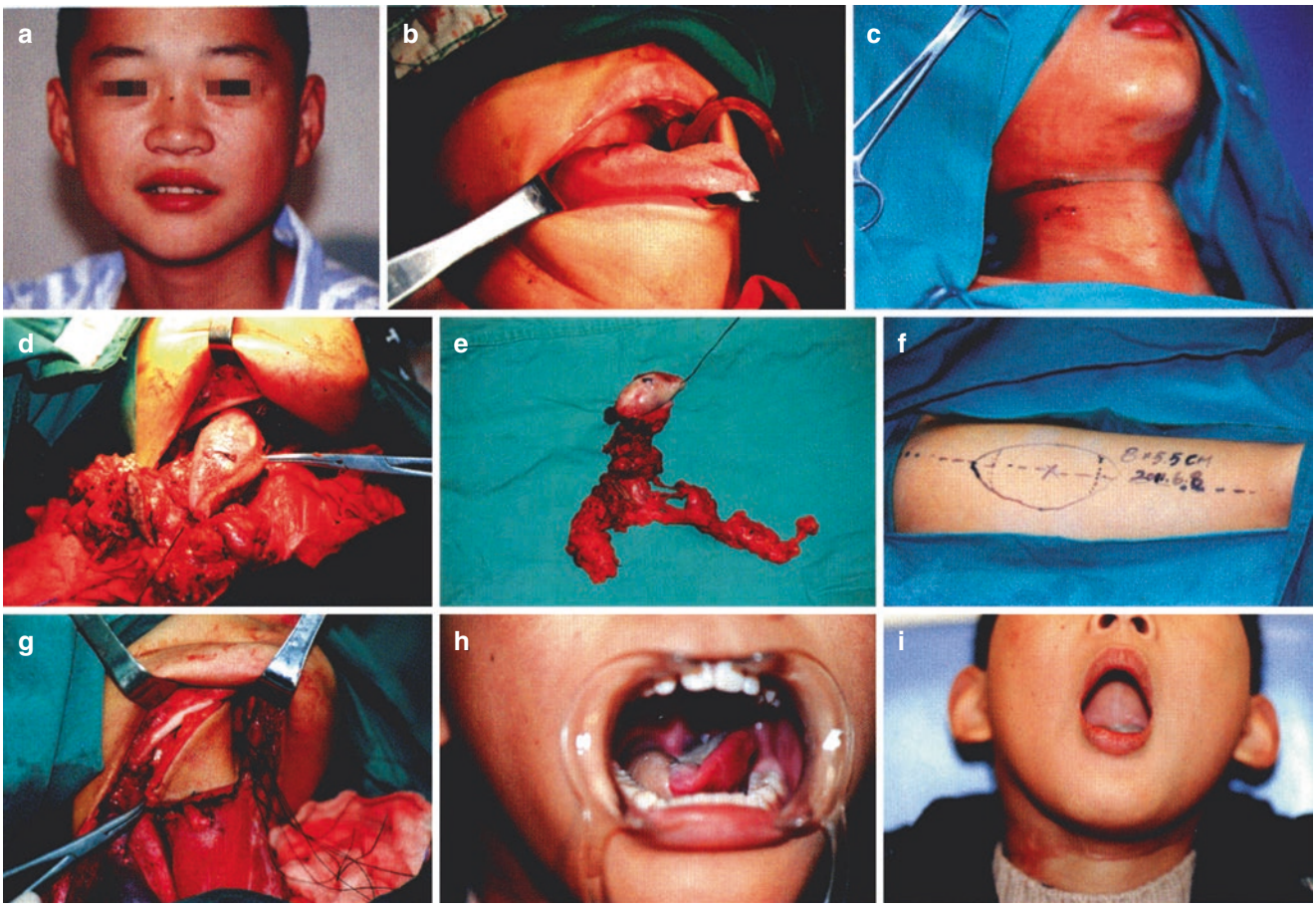

Fig. 6.9 Case IV. (**a**) Before operation. (**b**) The mass on the right side of the tongue was 3 × 3 cm in size, and the posterior border reached the circumvallate papillae. The mucosa in the mouth floor was normal. (**c**) The cervical surgical incision, the previous surgical scars were removed. (**d**) The bilateral cervical lymph node dissection was performed, the lower lip and the mandible were not ripped off, and the en bloc resection of the right half of the tongue and mouth floor, a part of the right tongue root, the periosteum on the inner side of the mandible, and bilateral neck dissection specimen was performed. (**e**) The whole specimen of the right half of the tongue, mouth floor, and bilateral cervical lymph node dissection. (**f**) The right anterolateral thigh perforator flap was designed with a size of 8.0 × 5.5 cm. (**g**) The anterolateral thigh skin flap was harvested and transferred to repair the defects on the right side of the tongue and floor of the mouth. At first, the tongue root and the mouth floor were sutured close in the neck, and then the skin flap was placed into the mouth; the medial side and the forepart of the skin flap were sutured close inside the mouth. (**h**) At 1 year after surgery, the skin flap healed well, the mobility of the residual tongue seemed fine, the mouth opening was normal, the patient ate well, and the speech was basically clear. (**i**) At 1 year after surgery, the appearance was good

3.4 The Repair Method with the Deep Inferior Epigastric Artery Perforator Flap

The perforator skin flap only taking the deep inferior epigastric artery as the pedicle is called as the deep inferior epigastric artery perforator (DIEP) flap. Since this skin flap retains the rectus abdominis muscle and its anterior sheath as well as the intercostal nerve controlling the rectus abdominis muscle, and only the rectus abdominis muscle perforator vessel is harvested as the supplying vessel, the skin flap has all advantages of rectus abdominis muscle flap and avoids the risks of weak abdominal wall and abdominal hernia.

3.4.1 Indications

This skin flap is rich in tissue volume and is applicable to repair of a wide range of defects in the tongue, mouth floor, and tongue root, and it can also be made into small flaps to repair the small defects [6, 7].

3.4.2 Typical Case

Case V The patient, female, 51 years old, was found with the repeated ulceration on the left side of the tongue for 5 years. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys. The ulcerative mass on the left side of the tongue was 5 × 4 cm in size, it had violated the left side of the floor of the mouth, its medial side had exceeded the midline of the tongue body, the tongue was fixed, one lymph node in area II of the left neck was observed and was 2 × 2 cm in size, and the mobility was still good, with medium texture and no tenderness. Admission diagnosis: tongue cancer $T_3N_1M_0$. Pathology: highly differentiated squamous cell carcinoma. The patient underwent whole tongue resection, left mouth floor resection (only the right mouth floor was retained), the resection of the margin of left mandibular body, the left cervical lymph node dissection, the free transplantation of the deep inferior epigastric artery perforator flap under the general anesthesia, and the radiotherapy was performed after surgery (DT 60 Gy). Postoperative pathologic examination: highly differentiated squamous cell carcinoma of the tongue; there were three metastasis foci in left cervical lymph nodes. The reexamination was performed 6 months later: the appearance was good, and the degree of mouth opening was 4 cm. The shape of the reconstructed tongue seemed fine, and the patient ate well, with clear speaking, good oral hygiene, and no food residue retention (Fig. 6.10).

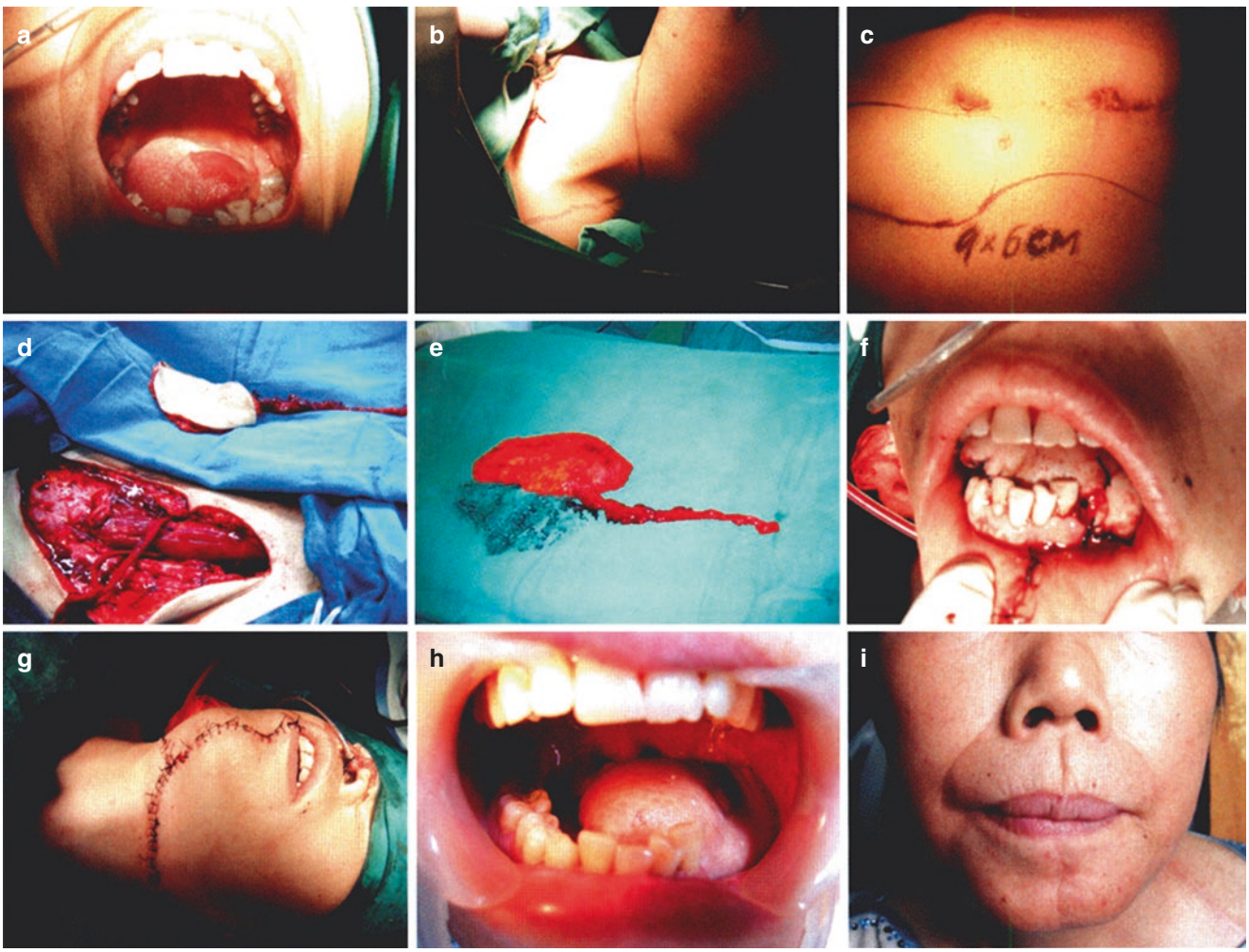

Fig. 6.10 Case V. (**a**) The cancer on the left side of the tongue exceeded the midline and violated the tongue root and left mouth floor, and the tongue was fixed. (**b**) Design of surgical incision in the head and neck, the whole tongue resection was performed, only a part of the tongue on the right side was retained, and the left margin of the mandible was resected. (**c**) The DIEP flap was designed near the navel at the right side, with a size of 9 × 6 cm. (**d**) The perforator skin flap pedicled with the deep inferior epigastric artery was harvested, and the rectus abdominis muscle and its anterior sheath as well as the intercostal nerve controlling the rectus abdominis muscle were retained. (**e**) The DIEP flap was harvested, and only the skin and subcutaneous tissues were harvested without carrying the rectus abdominis muscle and its anterior sheath. (**f**) The DIEP flap was used for whole tongue reconstruction. (**g**) When the operation was completed, the lower lip and neck were sutured close. (**h**) After the postoperative radiotherapy had been completed for four and half years, there was no tumor recurrence, the volume of reconstructed tongue was adequate, and the patient ate normally, with clear speaking, good oral hygiene, and no food residue retention. (**i**) After the postoperative radiotherapy had been completed for 4 and half years, the appearance was satisfied

3.5 The Repair Method with the Lateral Arm Skin Flap

3.5.1 Advantages

The lateral arm skin flap has the following advantages:

1. The lateral arm skin flap is thin with good skin elasticity and is suitable for repair of the defect after partial glossectomy retaining the mandible.
2. The donor site of the skin flap is hidden and can be closed and sutured directly, without the need of skin transplantation, and the supplying vessel of the skin flap is the posterior branch of the radial collateral artery, which is not a trunk blood vessel and has no effect on the blood supply to the upper limb after harvesting.
3. It can carry sensory nerves and be made into the free skin flap with sensory nerves, and a part of the sensation can be recovered through anastomosing the sensory nerves with the lingual nerves.

3.5.2 Disadvantages

The lateral arm skin flap has the following disadvantages:

1. The vascular pedicle of the skin flap is shorter, with a smaller diameter, and a better microsurgical skill is required.
2. The area of the donor site of the skin flap is limited and is not suitable for repair of large area defects. Generally the donor site of a skin flap with a width of 6 cm can be closed and sutured directly, and only the linear scar is left after surgery. If the donor site of the skin flap cannot be closed and sutured, it is needed to perform skin transplantation, and some very obvious scars will be left.

3.5.3 Typical Case

Case VI The patient, male, 43 years old, was found with lingual ulceration on the right side for three months. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys. The mass in the right side of the tongue was 3 × 2 cm in size, with hard texture and infiltrative growth, the mouth floor was normal, and the movement of the tongue was normal. Pathology: highly differentiated squamous cell carcinoma. Admission diagnosis: Right tongue cancer $T_2N_0M_0$. The patient underwent resection of the right half of the tongue; lymph node dissection in right cervical area I, II, and IV; and free transplantation of the lateral arm skin flap under the general anesthesia. Postoperative pathologic examination: highly differentiated squamous cell carcinoma of the tongue and no cervical lymph node metastasis foci. The reexamination was performed at 1 year after surgery: the faciocervical appearance was good, and the shape of the reconstructed tongue was good. The mobility of the tongue seemed fine, and the patient spoke clearly and ate normally (Fig. 6.11).

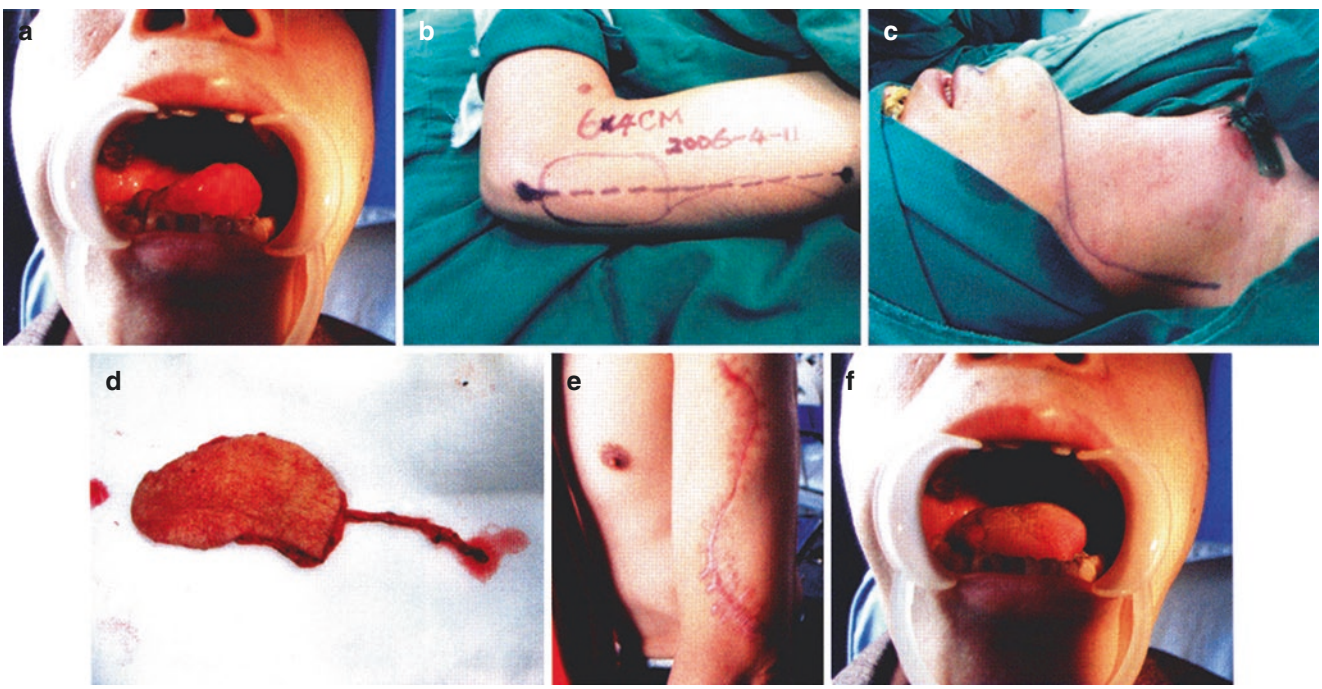

Fig. 6.11 Case VI. (**a**) The right tongue cancer presented an infiltrative growth. (**b**) Design of the surgical incision of the lateral arm skin flap. (**c**) Design of the surgical incision of primary foci. (**d**) The separated lateral arm skin flap. (**e**) The donor site situation of lateral arm skin flap. (**f**) The tongue situation at 1 year after surgery

3.6 The Repair Method with the Pectoralis Major Myocutaneous Flap

3.6.1 Indications

The pedicled transfer of this skin flap is feasible, and the vascular anastomosis can also be performed. The supplying vessels are the thoracoacromial artery and vein. The tissue volume is rich, and it is suitable for repair of defects in the whole tongue, floor of the mouth, and the root of tongue.

3.6.2 Typical Case

Case VII The patient, male, was 71 years old. The patient underwent radical resection of the tongue cancer on right side, the repair with platysma myocutaneous flap, and titanium plate internal fixation after ripping off the mandible due to stage II left tongue cancer ($T_2N_0M_0$) within another hospital 4 months ago. The patient always felt the left temporal pain after surgery and underwent MRI examination a month ago. The result showed the local recurrence of the left tongue cancer and the invasion of the left root of the tongue. Examination: the general conditions were good, and the heart and lung functions were mildly abnormal. The hard mass at the rear of the skin flap in the left original surgical site was 3 × 2 cm in size, with obvious tenderness. The mass was closely associated with the left mandible, and the tongue was fixed. The left cervical area showed a postoperative change, and the tension of skin was high. Admission diagnosis: postoperative recurrence of left tongue cancer. Pathology: highly differentiated squamous cell carcinoma. The patient underwent tracheotomy, resections of nearly a whole tongue and the left floor and root of the mouth, resection of left mandibular body, titanium plate fixation, and the repair with pectoralis major myocutaneous flap under the general anesthesia. Postoperative pathologic examination: highly differentiated squamous cell carcinoma of the tongue. The reexamination was performed 2 months later: the appearance was good, and the degree of mouth opening was 4 cm. The skin flap healed well. The choking and coughing appeared when the patient ate; therefore, the stomach tube had not been pulled out, and the tracheal tube had been taken out. The voice of the patient could be understood, and the oral hygiene was acceptable (Fig. 6.12).

3.7 The Repair Method with the Island Trapezius Myocutaneous Flap

3.7.1 Indications

It can be used for pedicled transfer, and the supplying vessels are the transverse cervical artery and vein or the occipital artery and the auricular artery and the upper trapezius muscle tissue. The tissue volume is rich, and it is suitable for repair of defects in the tongue, the floor of the mouth, and the root of the tongue.

3.7.2 Typical Case

Case VIII The patient, male, 60 years old, was found with tongue mass for 1 year. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys. The size of tongue tumor was 6.5 × 4.5 cm, with a hard texture, violation of the whole floor of the mouth, the tongue was fixed, the mass adhered closely to the inner side of the left mandibular symphysis, and no swelling lymph nodes were palpated in bilateral cervical regions. Admission diagnosis: tongue cancer $T_4N_0M_0$. Pathology: highly differentiated squamous cell carcinoma. The patient underwent resections of the whole tongue and whole mouth floor, mandibular symphysis, functional bilateral cervical lymph node dissection, the repair with double pedicled trapezius myocutaneous flap, and tracheotomy under the general anesthesia. Postoperative pathologic examination: highly differentiated squamous cell carcinoma of the tongue, no bilateral cervical lymph node metastasis. The postoperative radiotherapy was performed (DT62Gy). The tracheal tube was taken out 6 months later, the patient ate normally, and the speech was basically clear. The local tumor recurrence occurred at 2 years after surgery; the patient underwent extensive resection of oral cavity tumors and the repair with pectoralis major myocutaneous flap. The postoperative rehabilitation was successful, and the patient survived after 2 years of follow-up (Fig. 6.13).

3.8 The Repair with the Rectus Abdominis Musculo-Peritoneal Flap

Case IX The patients, male, 50 years old, was found with tongue mass for 6 months. Examination: the general conditions were good, and no obvious abnormalities were observed in the heart, lung, liver, spleen, and kidneys. The size of the right tongue mass was 2.5 × 2 cm, with hard texture, and no bilateral cervical lymph node enlargement. Admission diagnosis: tongue cancer $T_2N_0M_0$; pathology: highly differentiated squamous cell carcinoma. The patient underwent resection of the right half of the tongue, partial mandibular resection, right cervical lymph node dissection, and the repair with the rectus abdominis musculo-peritoneal flap under the general anesthesia. Postoperative pathologic examination: highly differentiated squamous cell carcinoma of the tongue; no right cervical lymph node metastasis. The postoperative recovery was good, and the patient ate normally (Fig. 6.14).

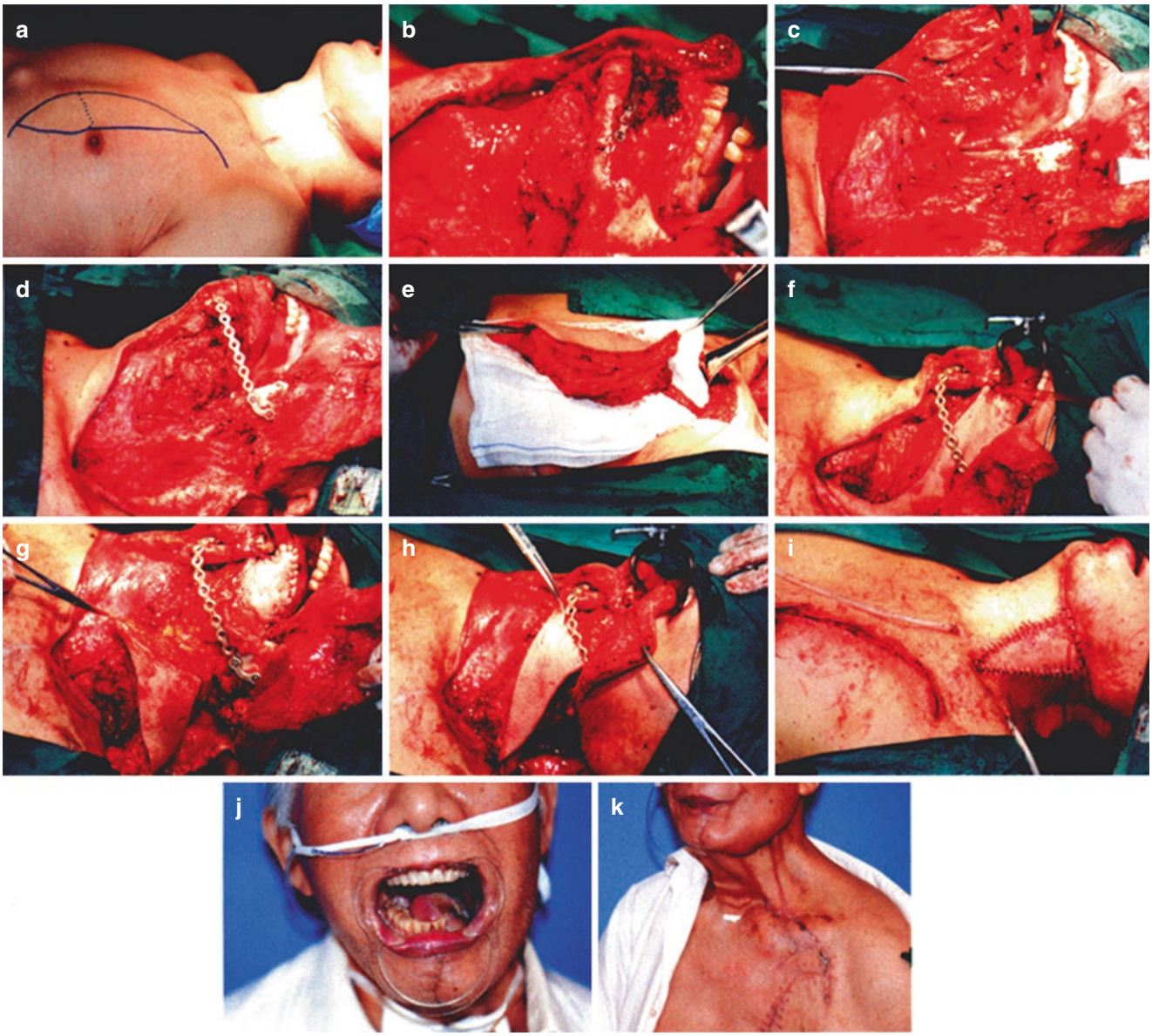

Fig. 6.12 Case VII. (**a**) Before surgery, the postoperative recurrence of the left tongue cancer. The suture after harvesting of platysma myocutaneous flap led to the high cervical skin tension, and the pectoralis major myocutaneous flap was designed. (**b**) The original surgical incision scars were incised open, and the midline of the lower lip was cut off to turn over the skin flap, and then the original titanium plate for fixation after the mandible was ripped off was observed. (**c**) The en bloc resection of the left mandibular body, left tongue, and tongue root, the muscle group in the mouth floor and the parapharyngeal tissue was performed, and the epiglottis was exposed. (**d**) The forming titanium plate was used to fix the left mandibular ramus and the right side and restore the function of the mandibular support. (**e**) The left pectoralis major myocutaneous flap was harvested, and the clavicular part of the pectoralis major muscle was retained. (**f**) The pectoralis major myocutaneous flap was passed through the left subclavian tunnel from the deep surface of the pectoralis major muscle, was transferred into the left side of the mouth, and then was sutured with the residual tongue and the margin of the left oropharyngeal defect. (**g**) Incise open the skin and subcutaneous tissue to reach the surface of the muscle of the pectoralis major myocutaneous flap, which was divided fully into two skin flaps. (**h**) The intraoral portion of the pectoralis major myocutaneous flap was used to repair the defects in the left tongue, tongue root, and left oropharynx, and the outside portion was used to repair the defect after the cervical area was incised. (**i**) The cervical area was sutured without tension, and the donor site of the skin flap in the chest wall was closed and sutured directly. (**j**) At 2 months after surgery, the degree of mouth opening was acceptable, the skin flap and wound healed well, and the choking and coughing appeared when the patient ate; therefore, the stomach tube was retained, and the language expression was still clear. (**k**) At 2 months after surgery, the wounds in the neck and chest healed well, the activities of the left arm were normal, and the tracheal tube was taken out

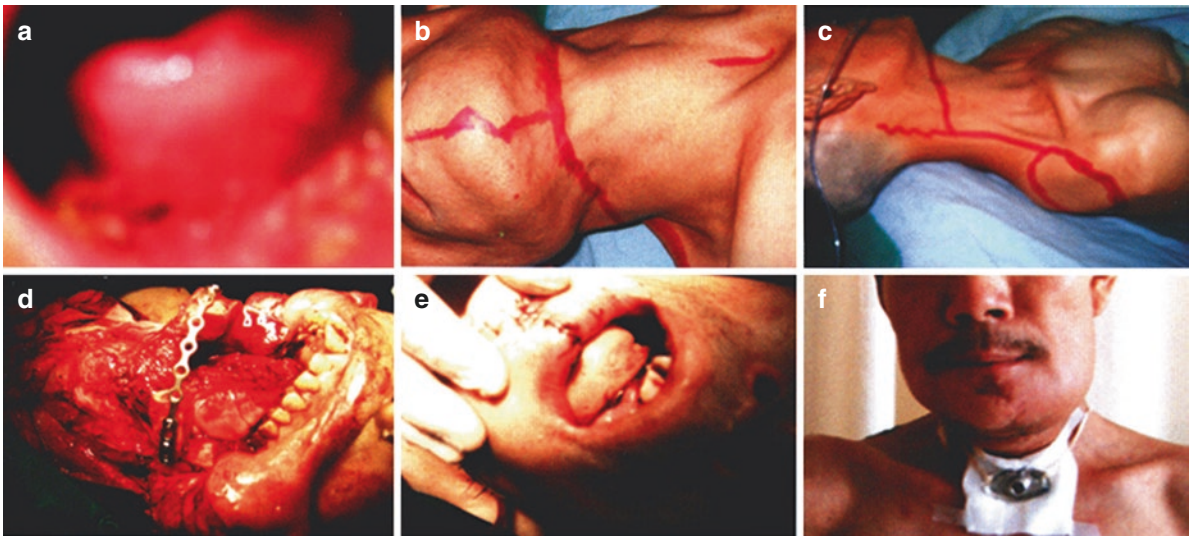

Fig. 6.13 Case VIII. (**a**) The tongue cancer involved the floor of the mouth and the mandibular symphysis. (**b**) Surgical incision design. (**c**) The incision of double pedicled trapezius myocutaneous flap was marked. (**d**) After the radical tumor surgery was completed, the continuity of the mandible was repaired with titanium plate. (**e**) The double pedicled trapezius myocutaneous flap was used to repair the defects in the tongue and the mouth floor. (**f**) At a month after surgery

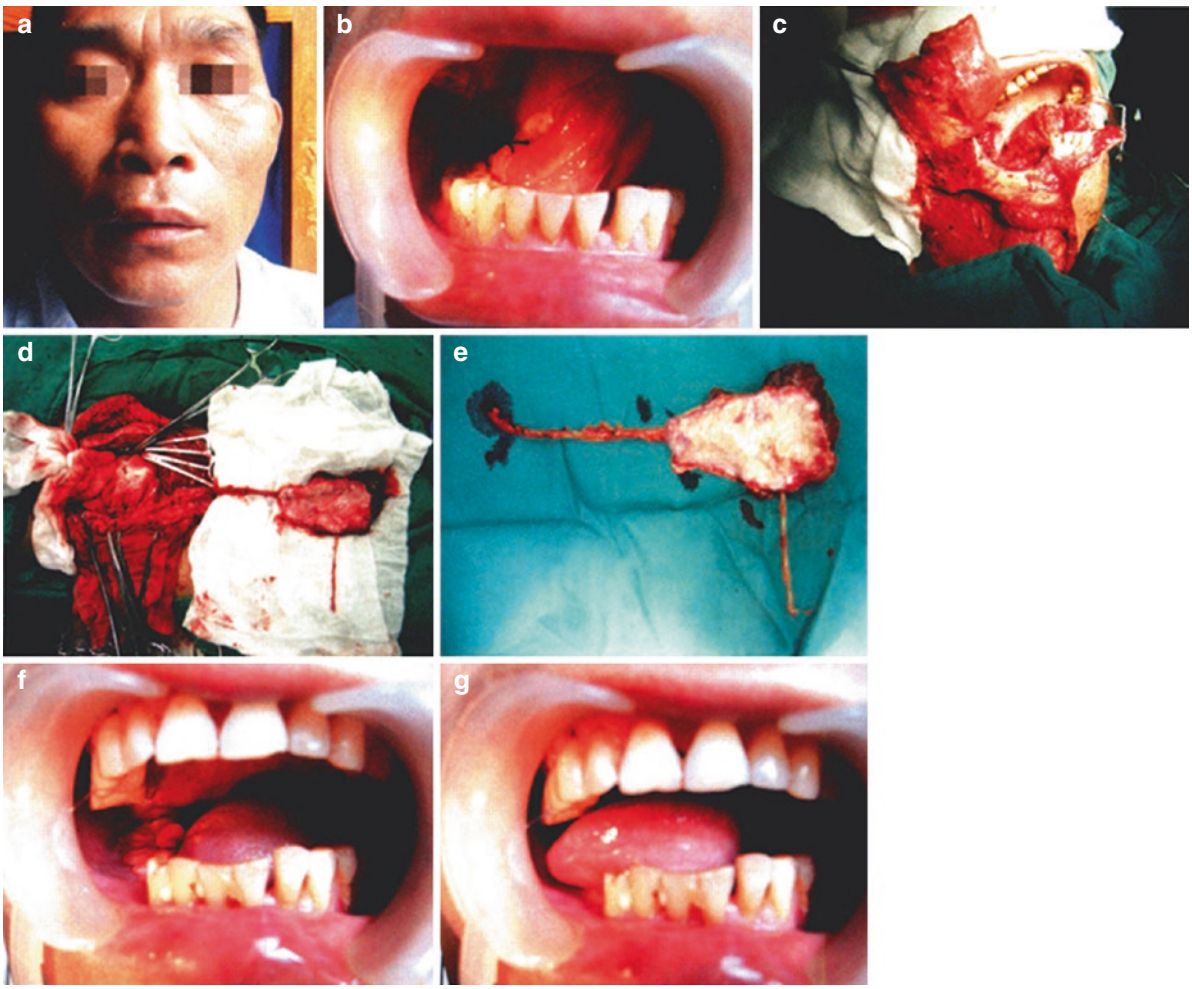

Fig. 6.14 Case IX. (**a**, **b**) Before operation. (**c**) After combined radical resection of tongue cancer. (**d**, **e**) Preparation of rectus abdominis musculoperitoneal flap. (**f**, **g**) At 6 months after operation

3.9 Other Repair Methods

Other repair methods can be selected according to the technical abilities of the surgeons:

1. Free transplantation of the transverse rectus abdominis myocutaneous flap. Its supplying vessels are the inferior epigastric artery and vein, the tissue volume is rich, and it is used for repair of defects in tongue, head, and neck.
2. Free transplantation of the latissimus dorsi myocutaneous flap. Its supplying vessels are the thoracodorsal artery and vein; the tissue volume is rich. It is used for repair of defects in the total tongue and floor of the mouth, and it can simultaneously carry the shoulder blade or ribs to repair the mandibular defects.

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Repair and Reconstruction of Penetrating Defects in Oral-Maxillofacial Area

7

Zan Li, Xiao Zhou, and Jianjun Yu

1 Overview

Oral buccal cancer, gingival cancer, tongue cancer, floor of mouth cancer, and palate cancer are common oral malignant tumors. Due to the anatomic location and biological characteristics, the advanced tumor after invasion of oral buccal area generally grows faster, and it will infiltrate deep to pass through the cheek muscle to reach the skin and spread around to the sites such as the jawbone and the pterygomandibular ligament; the postoperative recurrent oral cancers have a more extensive and hidden tumor growth range due to the disorder of anatomical structure and the loss of natural barrier. The treatment of such tumors is the comprehensive treatment based on surgery. The patients undergo radical surgery or extensive resection, and this can often lead to the formation of perforating defects in the buccal area, floor of the mouth, neck, or palatal area, of which the perforating defects in the buccal area are most commonly seen. The oral and maxillofacial area is one of the most important parts of the human body and assumes important functions such as maintaining appearance, eating, speaking, swallowing, and separating the nasal and oral cavities. If the defects in the oral and maxillofacial area are not repaired, they can cause severe appearance deformities and dysfunctions of speaking, chewing, swallowing, and breathing and bring catastrophic trauma to the patient's physiology and psychology, thus seriously affecting the quality of life of the patient, and therefore one-stage repair is of great significance [1, 2].

Because the oral and maxillofacial area is closely related to the maxilla, mandible, nose, tongue root, throat, and parotid gland, the perforating defects in the oral and maxillofacial area involve facial skin, muscles, and buccal mucosa and even involve complex defects in the corner of the mouth, upper and lower lips, upper and lower alveolar processes and jawbones, parotid gland, orbital contents, skull base, nose, and neck vessels, and the repairs are very difficult; therefore, the repairs of the perforating defects in the oral and maxillofacial area, especially the functional reconstruction, have always been an extremely challenging task faced by surgeons in oral and maxillofacial surgery, head and neck surgery, plastic surgery, and reparative and reconstructive surgery [3, 4].

1.1 The Applied Anatomy

The cheek is the side walls of the oral vestibule and can be divided into six layers from outside to inside, namely, the skin, subcutaneous tissue, buccopharyngeal fascia, cheek muscle, submucosa, and mucosa. The upper and lower domes of the oral cavity are respectively taken as the upper and lower boundaries of the oral cheek, the anterior boundary is the corner of the mouth, and the posterior boundary is the pterygomandibular ligament. The buccal fat pad is passed through by the buccal nerve, blood vessels, and the parotid duct, and the subcutaneous tissue is passed through by the facial nerve, the trigeminal nerve branches, the facial artery, and the anterior facial vein. The buccal mucosa is slightly rectangular shaped, and it is adjacent to the pharynx and soft palate, is fixed to the inner fascia of the cheek muscle through the tightly connected connective tissue, and moves accordingly along with the contraction of the cheek muscle. There are rich mucous glands and mixed glands in the buccal mucosa, and the glands are located between the inherent elastic layer of the mucosa and the buccal mucosa. The parotid duct turns to the inner side at the anterior margin of the jugomaxillary muscle, passes through the buccal fat pad and the cheek muscles, and has an opening in the mouth to form a parotid duct nipple which is located in the buccal mucosa rightly corresponding to the maxillary second molar crown.

The deep surface of the buccal mucosa is supported by the cheek muscle. The cheek muscle starts from the

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pterygomandibular ligament and the adjacent part of the mandible and maxilla, and the muscle fibers incorporate forwardly into the orbicularis muscle. Clinging to the buccal fascia between the cheek muscle and subcutaneous tissue and covering the superficial surface of the cheek muscle, the anterior part of the buccal fascia is continuously connected to the pharyngeal fascia. There is buccal fat pad covered by the thin fascia layer between the posterolateral surface of the cheek muscle and the masseter muscle, risible muscle, and zygomatic major muscle. The buccal fat pad extends inwardly to the pterygomaxillary fissure; attaches to the periosteum of the maxilla and posterior part of the cheek muscle; extends forwardly into the buccal space where it is passed through by the parotid duct, the buccal branch of the facial nerve, and the facial vein; extends back into the pterygopalatine recess; crosses the vessels and nerves within the pterygopalatine recess and is connected to the surrounding connective tissue; extends upward within the superficial temporal and deep temporal spaces to the area between the anterior margin of the temporalis muscle and the temporal surface of zygomatic bone; and extends toward the lower rear side to enter into the pterygomandibular space. Since the buccal fat pad is connected with the fat and connective tissues in each space, it becomes the passageway for the malignant tumors to invade the deep layers and then rapidly spread around, and some earlier-stage buccal cancers recur quickly and extensively invade the peripheral tissues, which is rightly based on the spread of these anatomical passageways.

There are about one to five buccal lymph nodes, which are located between the deep surface of the buccal fascia and the superficial surface of the cheek muscle and at about 1 cm under the parotid duct and mainly collect the lymphatic fluid from the area behind the maxilla. The facial lymph nodes are located at the anterior margin of the masseter muscle at about 1 cm above the inferior margin of the mandible and the front and rear surface of the facial artery and collect the lymphatic fluid from the area behind the mandible and the lymphatic fluid from the buccal area, and their output tubes mainly reach the submaxillary lymph nodes or the superior deep cervical lymph nodes. The blood supply of the buccal area comes mainly from the facial artery, infraorbital artery, and transverse facial artery, and there are a large number of anastomotic branches between each other. The movements in the buccal area are controlled by the upper and lower buccal branches of the facial nerve, and the senses are controlled by the maxillary and mandibular branches of the trigeminal nerve.

1.2 Pathology

The oral mucosa is covered by the stratified squamous epithelium and rich in mucous glands and mixed glands. The buccal cancer and gingival cancer are mainly the squamous cell carcinoma, accounting for about 90%, followed by adenogenous epithelium cell carcinoma, which is in the majority with the adenoid cystic carcinoma. The oral verrucous carcinomas are likely to occur in the buccal mucosa. Due to more glands, the palate cancers are more prone to appearance of adenogenous epithelium cell carcinoma which is in the majority with mucoepidermoid carcinoma, and followed by the squamous cell carcinoma.

The buccal cancers easily invade the submucosal layer to involve the muscular layer and present invasive growth, extend to different layers of tissues in the buccal area, even penetrate through the skin, and at the same time spread to closely adjacent lips, gingiva, mandibular bone, soft and hard palates, pharynx side, tongue root, throat, and pterygomandibular space.

1.3 Clinical Manifestations

The oral cancers often evolve on the basis of vitiligo or submucosal fibrosis, and the patients often have the habit of chewing betel nut. When the ulceration occurs, the patients easily tend to consider that it is an ordinary ulcer and thus neglect it. Only when the limited mouth opening or submaxillary lymph node enlargement appears would the patients come to see a doctor. The ulcerative tumor is often accompanied by infection, pain, and bleeding; the exophytic tumor may grow very large, thus affecting chewing, swallowing, or breathing; the development of verrucous carcinoma is hidden, and the patients often have no symptoms at the early stage of disease.

1.4 Treatment

The patients who have perforating defects occurring after surgery often have later-stage disease; in general, the comprehensive treatment mainly including surgical treatment is carried out. The preoperative chemotherapy is performed, and the postoperative radiotherapy is performed.

The surgery is the most important means of treatment of oral cancer. The surgical principles and key points are as follows:

1. The oral cancer is removed to a sufficient depth. The patients with oral buccal cancer or gingival cancer involving the muscle layer of the cheek should undergo routine resection of perforating defects in the oral buccal area. The patients with hard palate cancer invading the bone should undergo routine resection of perforating defects in the hard palate, and the patients with soft palate cancer often need to undergo full-thickness resection.

2. The oral cancer with enough boundaries is removed. The cancer should be removed with the normal tissues at 2–3 cm away from the outer side of the boundaries of cancer which can be judged. The patients with cancers located in the anterior part of the oral buccal area should undergo total resection of areas including the corner of the mouth and the upper and lower lips. The patients with cancers adjacent to the inferior buccal gingival sulcus should undergo total resection of the areas from the mandibular sigmoid notch to the margin of the mandibular body. The patients with limited mouth opening or invaded mandible should undergo total resection of areas including the ascending branch or body of the mandible. The patients with invaded upper gingiva should undergo partial or total resection of the maxilla. The patients with invaded pterygomandibular ligament should undergo total resection of areas including the anterior part of the mandibular ramus and the maxillary tuberosity area, and it is noted that the anterior part of the pharynx side and the affected tissue in pterion are removed. The tumor margins are submitted intraoperatively for fast frozen section examination.
3. Cervical lymph node dissection. In clinic, the patients with no enlarged lymph nodes undergo functional lymph node dissection in cervical areas I, II, and III. The patients with enlarged lymph nodes but no extracapsular extensions undergo functional whole cervical lymph node dissection. The patients with more enlarged lymph nodes and extracapsular extensions undergo radical cervical lymph node dissection, the contralateral cervical areas I, II, and III are explored, and the fast frozen section examination is performed. If there is lymph node metastasis, the contralateral cervical lymph node dissection is performed. When the combined radical operation of the jaw and neck is carried out, special attentions should be paid to the removal of lymph nodes in areas such as beside the facial artery, the deep surface of the mylohyoid muscle, the deep surface of the medial pterygoid, beside the superior thyroid artery, and the parapharyngeal area. The lymph nodes in these areas are hidden and prone to metastasis and are often the root cause of early postoperative recurrence.
4. The normal tissues are preserved to the greatest extent, and the uvula, the corner of the mouth, and the nerves without tumor invasion are preserved as far as possible. If the parotid duct has sufficient length, the openings will be made at the margin after repair; if the parotid duct has insufficient length after maximum preservation, the parotid duct will be ligated; if the parotid fistula occurs after surgery, the parotid gland area will be treated with radiotherapy (3Gy/5 times).
5. Timing for repair. The simple hard palate defect can be repaired by the method of one-stage repair and can also be repaired through covering and separating the oral and nasal cavities with prostheses after surgery. The soft palate defects and the perforating defects in oral buccal area are treated with one-stage repair by principle; if combined with jawbone defects, the fibular flap can be used in one-stage repair, or the perforating defect is repaired with the soft tissue flap at one stage, and the bone defect will be repaired at the second-stage flap.

2 Method for Repair and Reconstruction of Penetrating Defects in Oral-Maxillofacial Area

The perforating defects in oral and maxillofacial area often contain defects of a variety of tissues or organs; thus the difficulty in repair and reconstruction is very great. It must be taken into account that the two layers of tissues on both the inside and outside of the mouth should be covered by intact epithelia, and attentions should also be paid to the tissue thickness and skin texture after defect repair, in order to achieve the maximum recovery of function and appearance of the reconstructed cheek. Meanwhile, the oral perforating defects are repaired, and it is also required to reduce the donor site injury and the number of donor sites as far as possible and maximally protect the function and appearance of the donor site. At the same time, the location of the selected donor site should be more hidden, for example, the forehead skin flap which is more commonly used in the past is now rarely used due to its impact on appearance. In the past, the various pedicled skin flaps are commonly used as the tissues to provide skin flap, which has certain limitations. Due to the anatomical characteristics of different tissues having the same blood supply and the development of microsurgical techniques, the radical surgeries of many cancers plus one-stage repairs of perforating defects are performed successfully. After comprehensive treatment such as surgery, radiation therapy, and chemotherapy, the survival rate and the quality of life of the patients have been greatly improved. This is a very important progress in the history of treatment of oral and maxillofacial tumors. There are a variety of repair methods for perforating defects, and each has its own merits and demerits. The appropriate means of repair can be selected according to the local defect situation, the general condition of the patient, and the professional skill of the surgical surgeon, such as pedicled or free skin flap and single or double pedicled skin flap. Currently, there are following several repair methods commonly used in clinics.

2.1 Folding Repair with Single Skin Flap

2.1.1 The Skin Flaps for Selection and Their Characteristics

This is a repair method commonly used in clinics. Since the skin flap is folded, it requires a large volume of tissue, generally the free skin flap is selectively used, and the skin flap, myocutaneous flap, and osseous myocutaneous flap can also be recommended and applied. It has been reported in literatures that the pedicled pectoralis major or trapezius myocutaneous flap is used for folding repair, but the vascular pedicle is often not long enough. Under normal circumstances, the anterolateral thigh flap, transverse rectus abdominis myocutaneous flap, deep inferior epigastric perforator flap, forearm skin flap, and latissimus dorsi myocutaneous flap are most commonly used.

The anterolateral thigh skin flap is the most commonly used skin flap for the repair of perforating defects in the oral buccal area due to many advantages: (1) its location is hidden, (2) it doesn't have the need of changing position, (3) two groups of surgeries can be implemented simultaneously to significantly shorten the operation time, (4) the tissue volume for harvesting is large, and (5) the longer vascular pedicle is relatively constant. In the Head and Neck Surgery Department of Hunan Provincial Tumor Hospital, the anterolateral thigh skin flaps have been used in more than 1000 cases since 2005, far beyond other skin flaps, showing the strong vitality of this skin flap in repairing defects after tumor surgery. The skin flap has two to four major perforating branches; thereby, more than two perforating branches can be preserved; even if the very long skin flap is formed and folded or the full-thickness skin is incised, an adequate blood supply can also be ensured. In addition, the skin flap can also carry the vastus lateralis muscle for filling defects in the maxilla or skull base. For thick skin flap, the methods for thinning of skin flap can be used. Before repair with this skin flap, the perforating defects in oral buccal area or the palate defects are still bloated; therefore, the perforating defects involving the anterior part of oral buccal area, corner of the mouth, or palate had better be repaired selecting thinner skin flaps.

The transverse rectus abdominis myocutaneous flap is the myocutaneous flap pedicled with the inferior epigastric artery; it has many advantages that include (1) its location is hidden, (2) two groups of surgeries can be implemented simultaneously, (3) the tissue volume for harvesting is large, (4) the vascular pedicle is longer and relatively constant, and (5) the donor site of the skin flap can be closed and sutured directly without the need for skin transplantation; it is suitable for repair of huge perforating defects in oral buccal area or compound defect involving upper and lower jawbones, skull base, and orbital contents. The disadvantage is that it needs to harvest a part or one side of the rectus abdominis muscle, thus weakening the abdominal strength and increasing the likelihood of abdominal hernia; the skin flap is often too thick (especially in women). In order to ensure the strength of the abdominal wall, the tissue patches should often be used to strengthen and suture closely the posterior sheath of the rectus abdominis muscle and the peritoneum.

The inferior epigastric artery perforator flap is the skin flap pedicled with the perforating branch of the inferior epigastric artery; since the skin flap only needs to harvest the skin and subcutaneous fat dominated by the perforating branch, retain the rectus abdominis muscle, anterior sheath, and the nerve controlling the muscle; maximally retain the integrity of the abdominal wall, so that the skin flap has all the advantages of transverse rectus abdominis myocutaneous flap and overcomes its shortcomings and can replace part of the transverse rectus abdominis myocutaneous flap. However, this skin flap has very high demands on the operators, and its harvesting is more complex.

The forearm skin flap is mostly used for repairs of full-thickness perforating defects, defects in the anterior part of the oral buccal area, or the buccal perforating defects combined with nosewing due to the thin thickness, constant blood vessels, longer vascular pedicle, and simple harvesting. The skin flap can be divided into two skin flaps such as inner and outer skin flaps; one skin flap is used as the mucosa, the other skin flap is used as the skin, the epidermises between the two skin flaps are removed, and skin flaps are sutured with the wound margin to close the perforating defect. The forearm skin flap is thin, so it is a strip of epidermises rather than full-thickness skin is removed. Otherwise, the blood supply for the flap's front end could be affected. When the full-thickness upper and lower lips or palate are repaired, it is simply required to double up the skin flap itself to complete the repair of the mucous and cutaneous layers or repair of soft palate, because the folding area is used as the labial margin or the margin of soft palate, wherein it is not needed to remove the epidermis or skin. The disadvantage of repair of oral buccal perforating defects with the forearm skin flap is that a main artery is sacrificed, and thus the blood supply to the hand is affected; if there is a wider range of buccal defects, especially when the defects in the posterior part of the oral buccal area or the compound defects are repaired, the harvested volume of the forearm skin flap is often insufficient, and the local dent often occurs after repair and affects the appearance. In addition, the scars after skin transplantation in the donor site affect the appearance significantly, many patients with higher demands cannot accept them, and a skin harvesting wound is increased.

The latissimus dorsi myocutaneous flaps and scapular flaps can also be used as skin flaps for one-stage repair of perforating defects in the oral buccal area; the repair with

double island flap can be performed. The difference is that because the skin flap is thicker, in the folding area, the full-thickness skin can be removed or the skin and subcutaneous tissue can be incised open without affecting the blood supply; the muscles can be used to fill the dead space in sites such as the floor of the mouth, neck, or skull base. The disadvantages are the following: (1) the body position needs to be changed, (2) two groups of surgeries cannot be implemented simultaneously, (3) the operating time is extended, and (4) if the donor site of the skin flap cannot be closed, it requires skin transplantation.

The perforating defects in the floor of the mouth and cervical skin can be repaired selectively using the pectoralis major myocutaneous flap, because the amount of muscle is larger; it can be used to fill the dead space in the floor of the mouth and the upper neck; the skin at the junction of double islands of the skin flap can also be resected by means of full-thickness resection, or the skin and subcutaneous tissue is incised open to reach the muscle layer, so that two skin flaps are separated far away, and their activities are increased without sacrificing the tissue volumes of the skin flaps to facilitate suturing of the wound margins. The pectoralis major myocutaneous flap is the most classic and practical skin flap for repair of head and neck defects; the advantages include rich and reliable blood supply, easy and simple operation, large tissue volume to be harvested, no need of vascular anastomosis, and easily performed in the primary hospitals; it usually has no problem in repairing one side defect in the facial buccal area or oral buccal area, but if the skin flap is folded to repair the full-thickness defect in the oral buccal area, especially the defect near the upper position, the vascular pedicle length of the pectoralis major myocutaneous flap is often insufficient. The skin flap is also thicker, not suitable for repair of defects in the anterior part of the oral buccal area. The young women are not suitable for use of the pectoralis major myocutaneous flap.

When designing the size of the folded tissue flap, attentions should be paid so that the area of tissue consumed in the folding area is counted. In order to ensure that the distal skin flap is not affected after folding, the folding area is designed to be at the thickest site of the wound margin in the donor site as far as possible, and it should be made sure that the wound margin in folding area presents as blunt round shape instead of pointed horn shape, which requires that the epidermis or skin in the wound margin in folding area is harvested slightly wider, reaching at least up to 1.5–2 cm or more. The folding repair with osseous myocutaneous flap is carried out. When the skin flap is designed, attentions should be paid to the relationship between the direction of the bone segment placement and the position of the skin flap, particularly the design of the position of the intraoral skin flap. Only accurate design can ensure the correct position of the transplanted tissue, without distortion, while the bone segment and fixed titanium plate can be properly wrapped and protected.

The degree of safety is very high in one-stage repair of perforating defect with folded free tissue flap, whose success rate reaches up to more than 95%.

The soft palate defects can be repaired using the folded thinner skin flap in the forearm, dorsum of foot, and submentum. The wound at the nasal surface may be repaired by performing skin transplantation at the back of the skin flap, and the femoral fascia of the anterolateral thigh skin flap can be used to repair the nasal surface of the soft palate.

2.1.2 Typical Case

Case I The patient, male, 63 years old, at 8 months after undergoing radiotherapy after resection of the left tongue cancer, had a left submandibular mass for 3 months. The recurrent tongue mass invaded the whole tongue, lower mandible, left oropharynx and pyriform sinus, epiglottis root, and left false vocal cord; the left metastatic neck lymph nodes violated the left common carotid artery, internal jugular vein, and cervical skin; and there was right cervical lymph node metastasis. The balloon block test of the left internal carotid artery showed a negative result, suggesting that the resection of the left common carotid artery could be performed. Pathological diagnosis: highly differentiated squamous cell carcinoma. The patient underwent resections of the whole tongue, whole throat, and left mandible + resections of left faciocervical skin and soft tissue + resection of left common carotid artery + left cervical radical lymph node dissection + right cervical functional lymph node dissection + trachea fistula making + the repair with free transverse rectus abdominis myocutaneous flap under general anesthesia (Fig. 7.1).

Case II The patient, male, 47 years old, at 6 months after resection of the right oral buccal cancer in the other hospital, had right facial mass for 2 months. Physical examination: the mouth opening was limited, the postoperative scars were observed at the corner of the mouth, a nodular mass was visible on the right side of the face with red and swollen surface and obscure boundary, and the mass was fixed. MRI showed that the tumor invaded the full thickness of the right oral buccal area and right maxilla and mandible. Pathological diagnosis: highly and moderately differentiated squamous cell carcinoma. The patient underwent a wide range of resection of the right buccal area and right prostatectomy, resection of the right maxilla and mandible, and the repair with free thigh anterolateral myocutaneous flap under general anesthesia (Fig. 7.2).

Case III The patient, male, 51 years old, had a mass in the left lower gingiva for 6 months and had left facial redness and swelling for 1 week. Physical examination: the size of the left

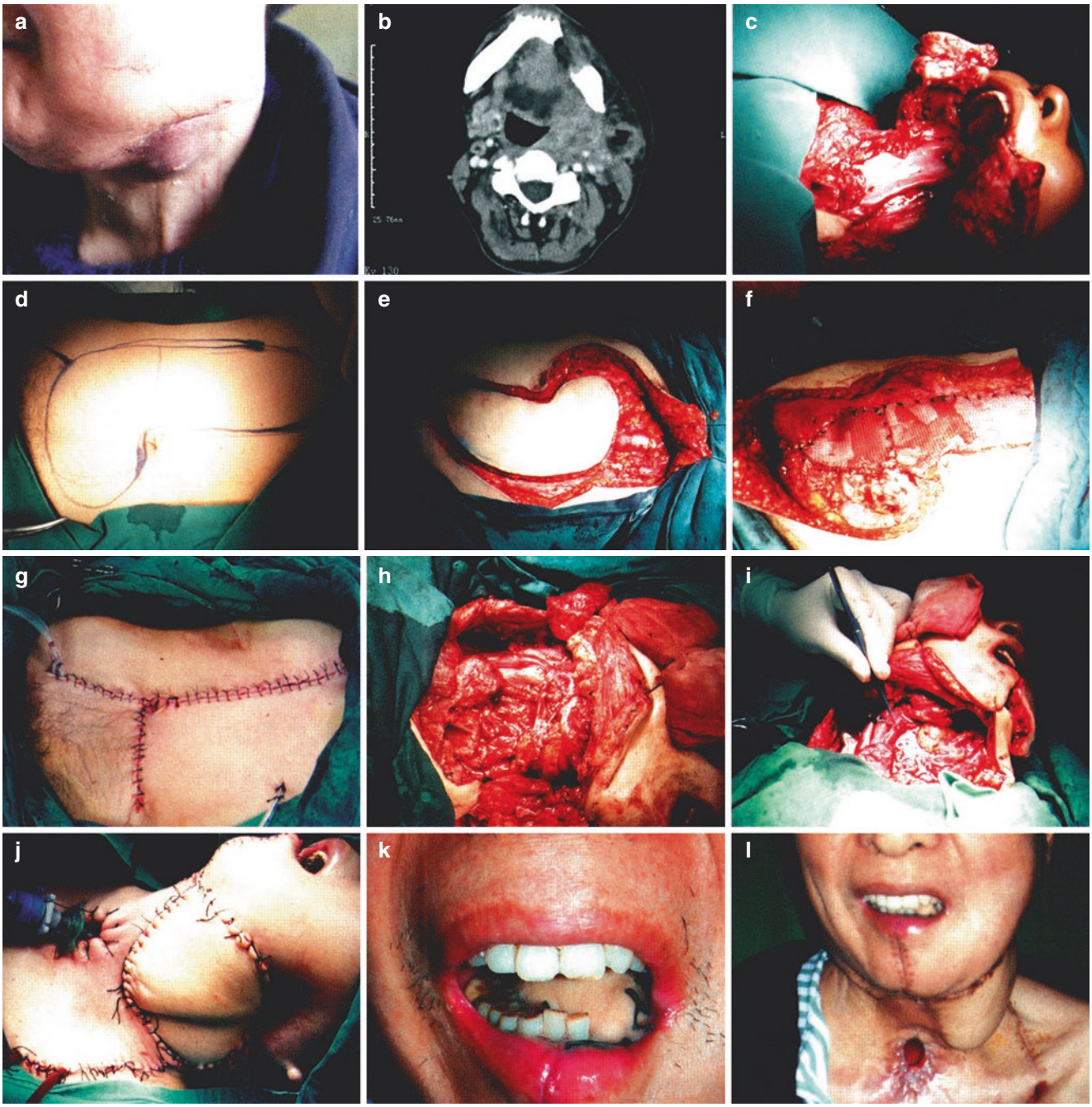

Fig. 7.1 Case I. (**a**) Preoperative performance of recurrent tongue cancer. (**b**) The tumor invaded the whole tongue, left mandible, left oropharynx side and pyriform sinus, epiglottis root, and left false vocal cord; the left cervical lymph node metastasis invaded the left common carotid artery and the internal jugular vein and cervical skin; there was right cervical lymph node metastasis. (**c**) The patient underwent resections of the whole tongue, whole throat, left mandible, left faciocervical skin and soft tissue, and left common carotid artery, dissections of the left cervical radical lymph node and right cervical functional lymph node, and trachea fistula making. (**d**) Design of transverse rectus abdominis myocutaneous flap (the flap was 25 cm × 10 cm in size). (**e**) Skin flap preparation; the transverse rectus abdominis myocutaneous flap pedicled with the inferior epigastric artery was harvested. (**f**) Reinforcement of the abdominal wall with tissue patch. (**g**) The donor site of the skin flap was closed and sutured directly. (**h**) The skin flap was used for defect repair during surgery; the skin and subcutaneous tissue of the skin flap were incised to be divided into two parts, one part was used to repair the hypopharynx and oral defects and another part was used to repair the cervical and facial defects. (**i**) Vascular anastomosis: the vascular anastomoses were performed in the right superior thyroid artery and internal jugular vein. (**j**) The situation when the operation was completed. (**k**), (**l**) At 2 months after surgery, the wound healed well, the skin flap healed well, the tracheostomy stoma was smooth, and the patient could take semiliquid diet

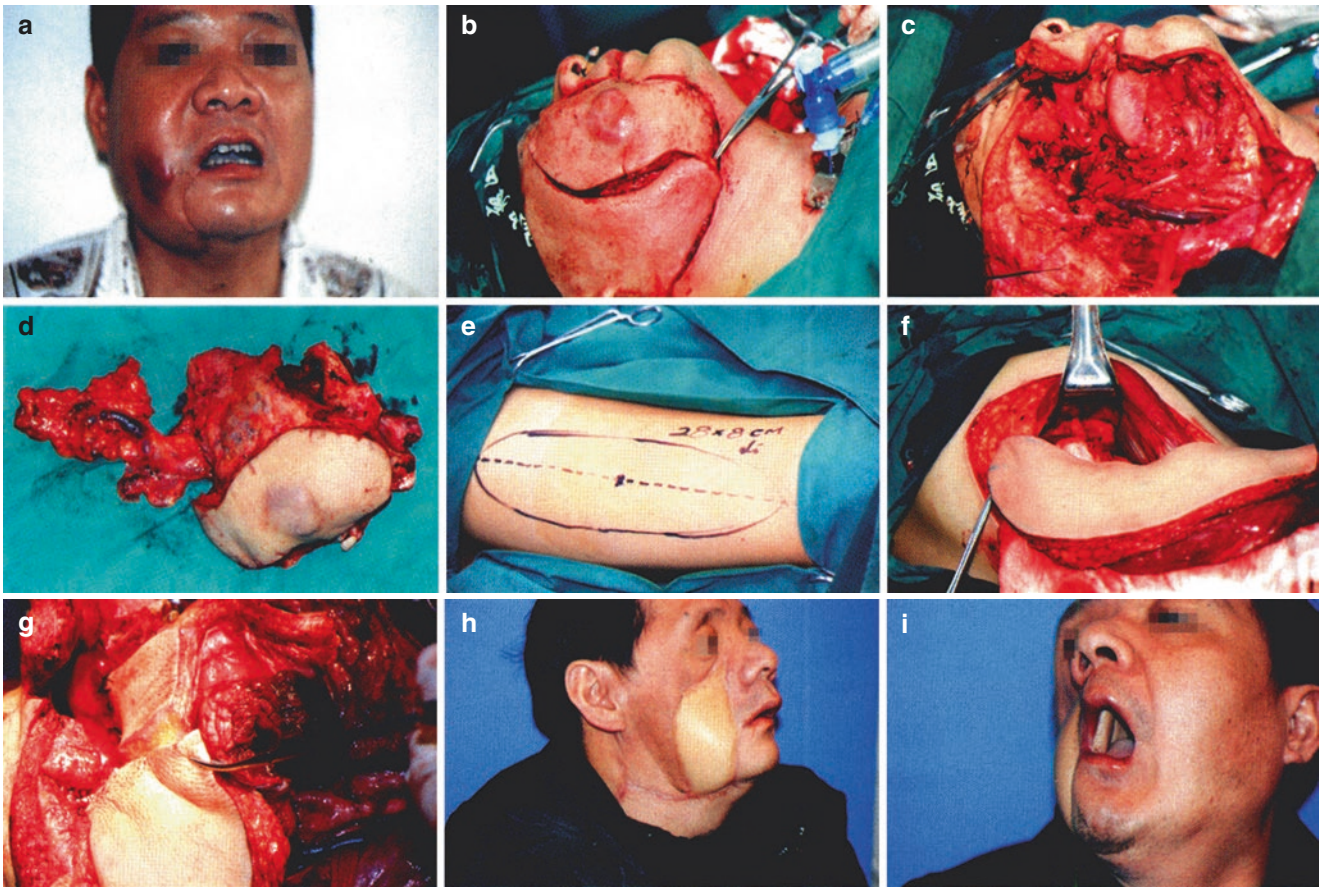

Fig. 7.2 Case II. (**a**). Before surgery. (**b**) The patient underwent a wide range of resection of the right buccal area and right maxilla and mandible. (**c**) The huge perforating defect in the right buccal area after surgery and the defects in the right maxilla and mandible, and the defect reached up to the lateral skull base. (**d**) The specimen was removed. (**e**) The right anterolateral thigh skin flap was designed as 28 cm × 8 cm in size. (**f**) The anterolateral thigh cutaneous flap was harvested and transplanted. (**g**) After the anterolateral thigh skin flap was partially incised and folded, one part was used to repair the defects in the oral buccal area, right maxilla, and lateral skull base, and another part was used to repair the defects in the facial buccal area. (**h**), (**i**) At 6 months after surgery, the wound healed well; the skin flaps healed well; the degree of mouth opening was acceptable; the patient spoke clearly and could take the semiliquid diet

facial redness and swelling was 3 cm × 2 cm, and the subcutaneous hard mass was palpable and fixed. The degree of mouth opening was acceptable. A cauliflower-shaped mass was located at the left lower buccal gingival side, and it had invaded the left oral buccal area. Pathological diagnosis: highly differentiated squamous cell carcinoma. The patient underwent radical resection of left gingival cancer, full-thickness resection of the left buccal area, and the repair with the deep inferior epigastric perforator skin flap under general anesthesia (Fig. 7.3).

2.2 The Repair with a Free Skin Flap and a Pedicled Skin Flap

2.2.1 The Skin Flaps for Selection

The perforating defects in the upper part of the face and the lip-cheek region can be repaired with the forehead skin flap (pedicled axial pattern skin flap) plus free forearm or scapular skin flap, of which the former is mostly used as the lining and the latter is mostly used as the outer covering. The perforating defects in the lower part of the face and the upper part of the neck can be repaired with pedicled pectoralis major myocutaneous flap plus the free forearm skin flap, and sometimes they can also be repaired with cervical skin flap (or superior trapezius myocutaneous flap) plus free scapular skin flap. The patients with perforating defects and mandibular defects can be repaired with fibula-peroneal artery perforator flap, the fibula flap is used to repair the mandibular defect, the peroneal artery perforator flap is used to repair the defects in the oral buccal and gingival area, and the facial buccal defect is repaired using the ortho-position skin flap or another free skin flap.

2.2.2 Typical Case

Case IV The patient, male, 49 years old, had a mass in the right lower gingiva for 3 months. Physical examination: the right side of the face was uplifted, and a subcutaneous hard

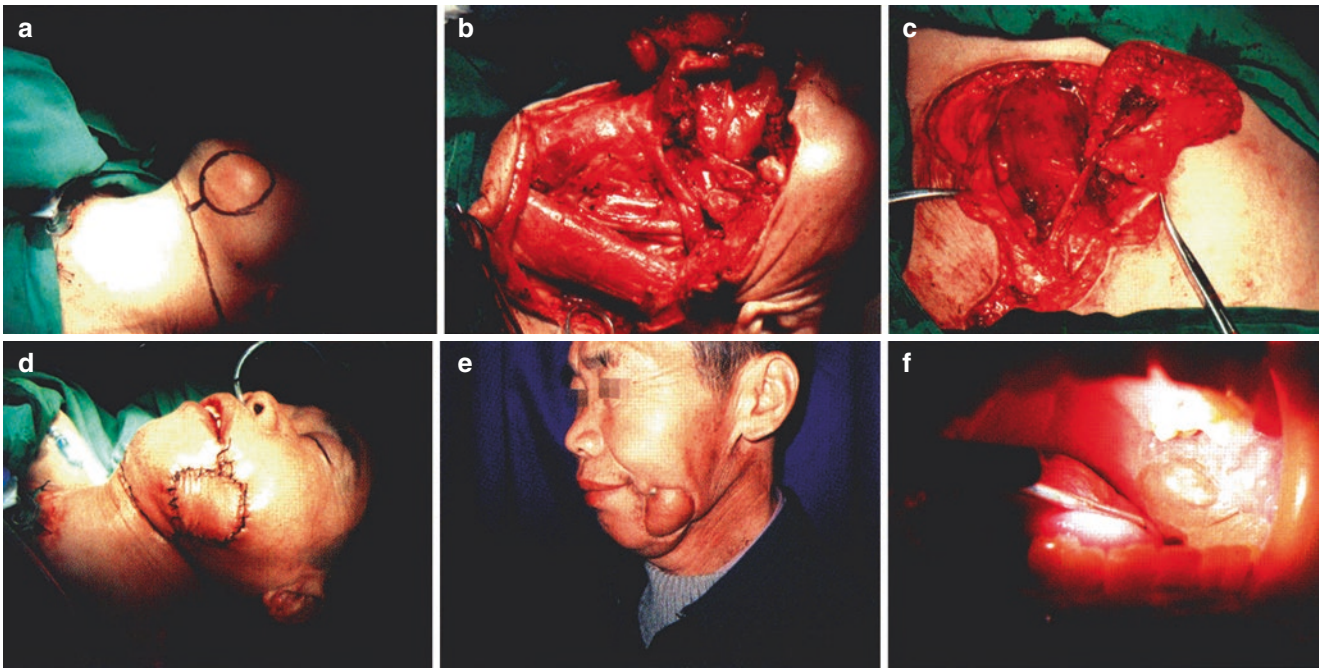

Fig. 7.3 Case III. (**a**) The mass in the left lower gingiva invaded the left mandible and the oral buccal area, and the facial skin was invaded. (**b**) The patient underwent full-thickness resection of the left buccal area, partial resection of the left body of mandible, and dissection of the left cervical functional lymph node. (**c**) The perforator skin flap pedicled with the deep inferior epigastric artery was harvested. (**d**) The middle part of the skin flap was partially removed, the skin flap was folded, a part was used to repair the oral buccal defect, and another part was used to repair the facial buccal defect. (**e**), (**f**) At 3 years after surgery, the skin flaps healed well, the mouth opening seemed fine, there was no recurrence, and the intraoral skin flap was mucosalized

mass was palpable with poor activity. The degree of mouth opening was acceptable. There was a cauliflower-shaped mass in the buccal side of the right lower gingiva and the vestibular groove. The loosening of fourth and fifth lower right teeth reached grade 3. CT showed that the right lower gingival mass invaded the mandible and cheek muscle, and the subcutaneous fat space disappeared. Pathology: highly and moderately differentiated squamous cell carcinoma. The patient underwent radical resection of right gingival cancer, full-thickness resection of the right buccal area, and repair with the free fibular skin flap and the submental orthoposition skin flap under general anesthesia (Fig. 7.4).

2.3 The Repair with Transplantation of Double Free Tissue Flaps

2.3.1 The Skin Flaps for Selection

The transplantation of double free tissue flaps is commonly used in the repair of the oral perforating defect combined with complex defects of other tissues, for example, combined with the defects in the upper and lower jawbones and the defect in the nose. It is often very difficult to repair this kind of complex defect satisfactorily with a folded skin flap, which is often repaired with the transplantation of double free tissue flaps. To some extent, the transplantation of double free tissue flaps means that four blood vessels must be anastomosed at least, that is, two arteries and two veins. There is no doubt that in order to ensure the success of the surgery, there is a higher requirement on the technique of vascular anastomosis. In clinics, the fibular skin flap plus the anterolateral thigh skin flap or the latissimus dorsi myocutaneous flap plus the forearm skin flap is mostly selected. This method is particularly suitable for the defect after combined radical resection of cranio-jaw. It can not only fill the dead space and protect the brain tissue but can also form the new palate and repair the facial defects. This approach requires two arteries and two veins for anastomosis. If only one artery and one vein are available for the patients with insufficient supplying vessels in the receptor site, the forearm skin flap can be selected as the bridge skin flap in the middle part, the arteries and veins at one end of the forearm skin flap are anastomosed with those of another forearm skin flap or other myocutaneous flaps, and such skin flaps can also be called as the tandem skin flaps (Fig. 7.5). Among numerous skin flaps, it is most appropriate to take the forearm skin flap as the bridge skin flap (or middle skin flap) because it is an arterial pattern skin flap, and the diameters of both ends of the blood vessel are similar. In addition, the supplying vessel of the anterolateral thigh skin flap such as the descending branch of the femoral circumflex artery and the supplying vessel of fibula flap such as the distal end of the peroneal artery can also be used as the

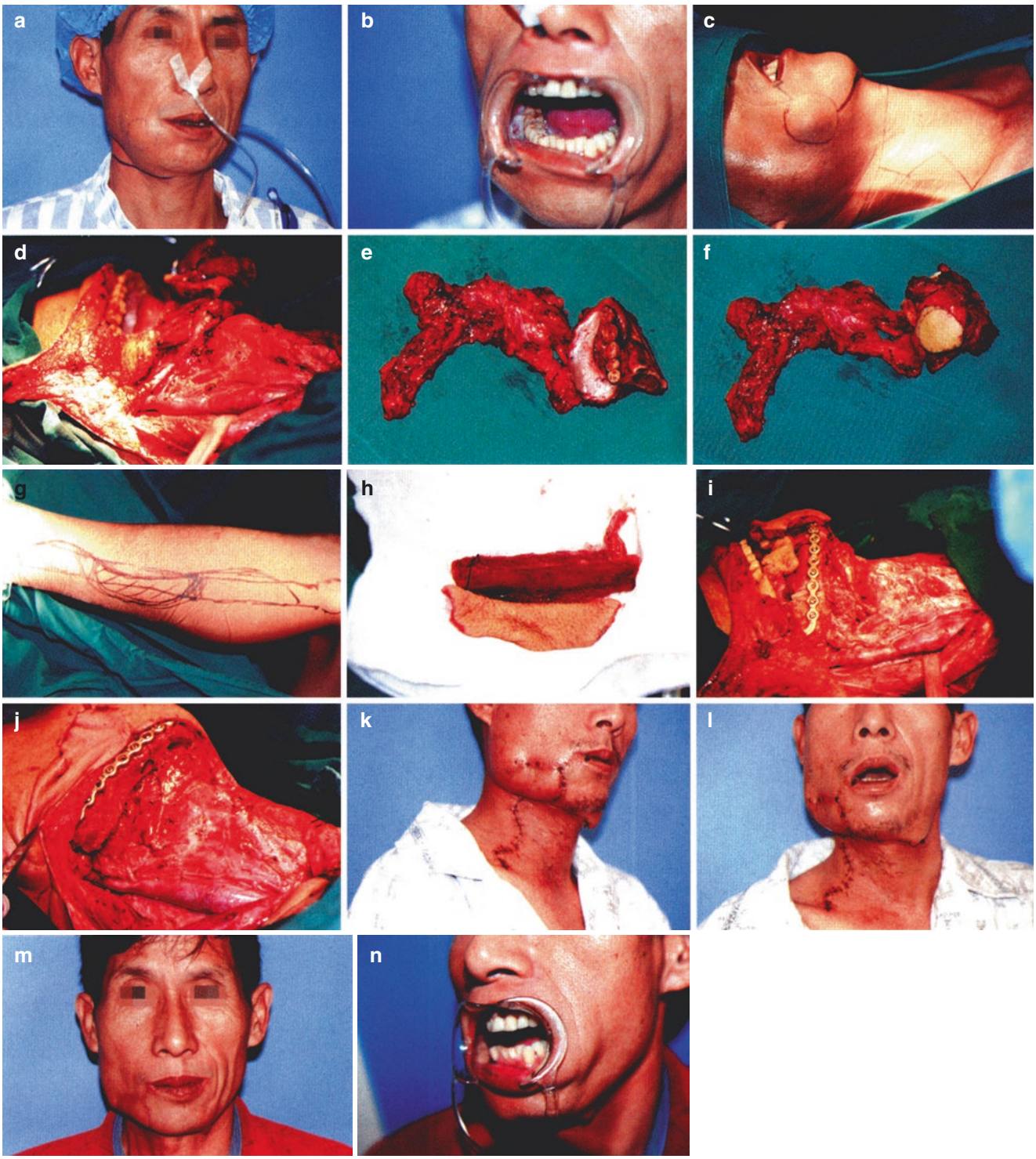

Fig. 7.4 Case IV. (**a**), (**b**) Preoperative appearance. (**c**) Incision design; it was noted to preserve the integrity of the corner of the mouth, incise the lower lip instead of the corner of the mouth, and design the submental platysma myocutaneous flap with the pedicle in the posterior part. (**d**) Radical resection of the right gingival cancer; the right facial buccal area of about 4 cm × 4 cm was removed, and the right oral buccal area and the mandibular body were removed, and then the perforating defect in the right buccal area was formed after surgery. (**e**), (**f**) Radical resection specimen. (**g**), (**h**) The fibula-peroneal artery perforator flap in the left calf was harvested. (**i**), (**j**) The fibula flap after shaping was used to repair the mandibular defect, and titanium plate fixation was performed, the peroneal artery perforator flaps was used to repair the oral buccal and gingival defects, and the submental platysma myocutaneous flap was transferred to repair the facial buccal defect. (**k**), (**l**) The stitches were taken out at 8 days after surgery, the wound healed well, the skin flaps healed well, the degree of mouth opening was acceptable, there was still swelling in the faciocervical area, and the speaking was clear. (**m**), (**n**) At 3 months after surgery, the degree of mouth opening was 4 cm; the intraoral skin flap healed well; a small amount of hair growth was observed; the appearance was satisfactory; the speaking and eating seemed fine

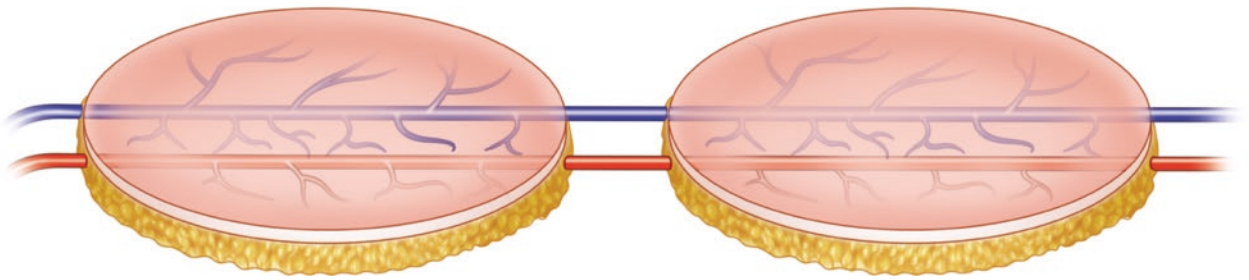

Fig. 7.5 Schematic diagram of tandem skin flaps

bridge blood vessels. The diameters of the ends of the blood vessels of most skin flap are very thin, and they are difficult to be taken as the blood vessels for vascular anastomosis.

2.3.2 Typical Case

Case V The patient, female, 67 years old, had a mass on the right side of the nose and face combined with ulceration for 3 years. Physical examination: the ulcers are visible on the right side of the nose, nasal floor, nasal columella, facial buccal area, upper lip, and vermilion; the ulcer surfaces were covered by dry scabs, the margin uplifts were irregular, and the boundaries were not clear. Pathological diagnosis: highly differentiated squamous cell carcinoma. The patient underwent extensive resection of the right side of the nose, facial buccal area, upper lip cancer, free forearm skin flap, and repair with free auricle compound tissue flap under the general anesthesia (Fig. 7.6).

2.4 The Repair with Transplantation of Pedicled Double Axial Pattern Skin Flap

This method is more practically used in hospital clinics which have not developed microsurgery; the selection of skin flap can be designed according to specific statuses of perforating defects in the patients. For perforating defects in the facial buccal area or floor of the mouth and neck, when the oral mucosa is repaired, the platysma myocutaneous flap, subhyoid myocutaneous flap, forehead flap, and submental flap can be selectively used as the lining. The deltopectoral skin flap, pectoralis major myocutaneous flap, and trapezius myocutaneous flap can be selectively used to cover the outer layer of the faciocervical skin. In some cases, the cervical sliding skin flap can be designed to repair the small- and medium-sized skin defects in faciocervical area.

2.5 The Repair with Transplantation of Single Pedicled Double Skin Flaps or Multiple Skin Flaps

With the development of anatomy and the more and more extensive clinical application of perforator skin flaps, the method of transplantation of single pedicled double skin flaps or multiple skin flaps gets more and more clinical application. According to the repair needs of the defects, multiple branches or multiple perforators of a main blood vessel can be used to design the single pedicled double skin flaps or multiple skin flaps. Typically, the subscapular artery is taken as the total vascular pedicle, and a scapular flap, a latissimus dorsi myocutaneous flap, and even a scapular bone flap can also be prepared simultaneously, whose blood supplies come respectively from the branches of subscapular artery such as the thoracodorsal artery and the circumflex scapular vessel. The anterolateral thigh skin flap can also be designed as single pedicled double skin flaps according to different perforators. The advantages of this kind of skin flap include the following: (1) it is only needed to anastomose a set of blood vessels, (2) the flexibility between the two skin flaps is great, and (3) it is suitable for repair of a variety of perforating defects in the facial and cervical area; the defects in two layers of tissues and the tissue between them were simultaneously repaired (Fig. 7.7). In addition, because the two skin flaps can be individually designed, when the larger skin flap is harvested, the donor site can still be directly closed and sutured, maximally protecting the appearance and function of the donor site. To adapt to the unique structure of the facial cheek with the outer skin and inner mucosa, in 2006, we began to use the peritoneal flap-perforator skin flap pedicled with inferior epigastric artery and vein to repair the perforating defects in the facial cheek and achieved good curative effect.

2.5.1 Surgical Method

According to the size of the defect, the skin flap is designed beside the navel. The outer margin of the skin flap is incised open to reach the superficial surface of the aponeurosis of obliquus externus abdominis muscle, the skin flap is separated toward the navel, and then one to two large perforators are observed at the superficial surface of the anterior sheath of the rectus abdominis muscle to enter into the skin flap. The additional incision designed along the body surface projection of the inferior epigastric artery at the lower part of the skin flap is incised open, the anterior sheath is incised open beside the perforator to directly reach underneath, and then the anterior sheath is separated outward, so that the

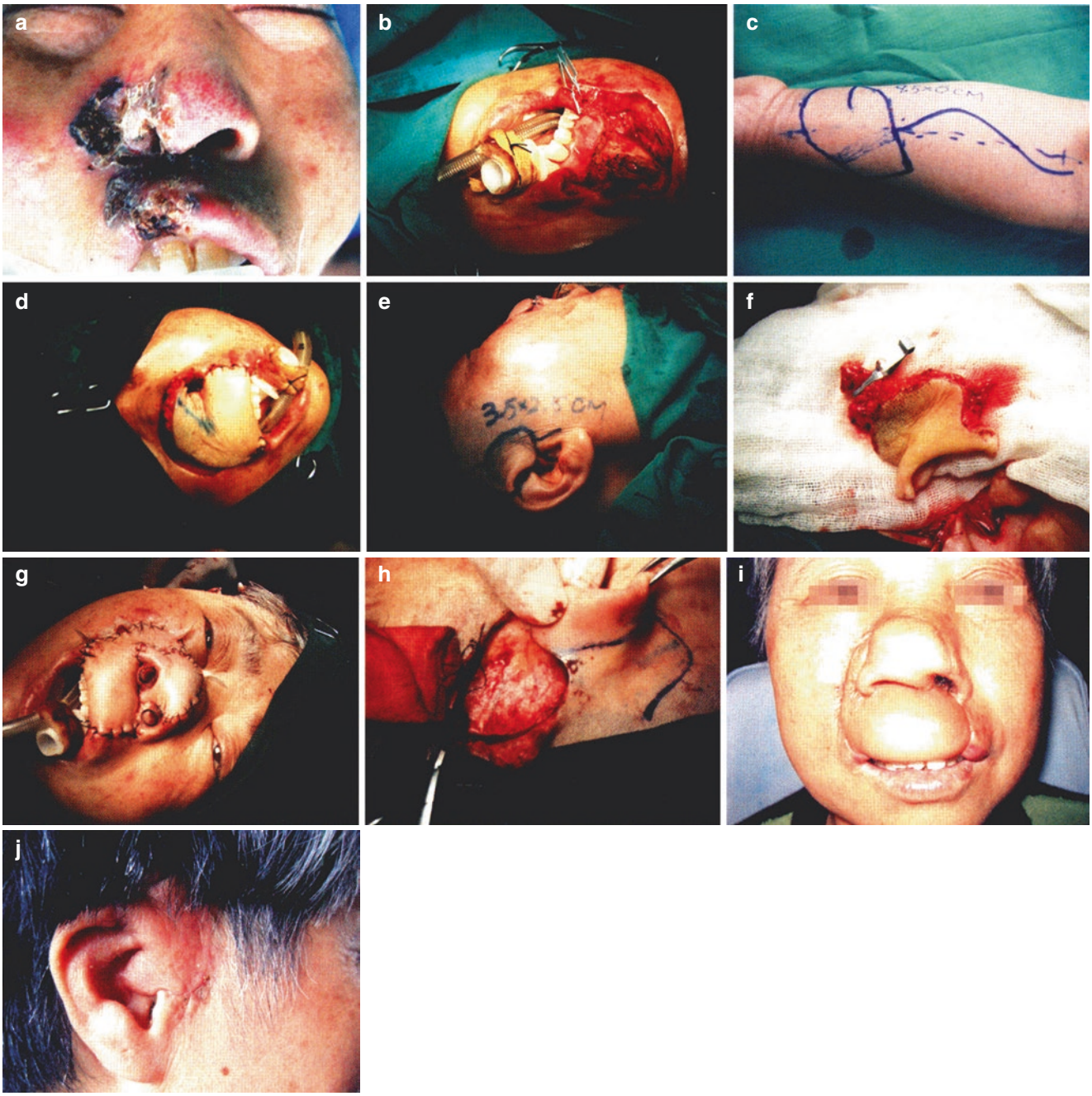

Fig. 7.6 Case V. (**a**) The surface appearances of skin cancer involving the right upper lip, facial buccal area, nosewing, nasal tip, nasal columella, and nasal floor; the right nostril was significantly reduced. (**b**) The facial skin cancer was extensively removed, which led to the perforating defects in the upper lip and right buccal area and the defects in the right nosewing part of nasal septum, nasal columella, nasal tip, and bilateral soft triangles; the right nasal bone and part of maxilla at the outer side of the piriform aperture were partially removed, and the maxillary sinus was not opened. (**c**) The forearm skin flap was designed according to the defects in the upper lip and buccal area; three parts such as the defect in the intraoral part of the upper lip, the defect in nasal floor, and the defect in the right buccal area were repaired respectively. (**d**) The forearm skin flap was folded to repair the defects in the upper lip, nasal floor, and buccal area; the vascular pedicle was passed through the subcutaneous tunnel to reach the neck and was anastomosed with the facial artery and vein. (**e**) The auricle compound tissue flap was designed according to the nasal defect. (**f**) The auricle compound tissue flap pedicled with superficial temporal artery and vein was harvested. (**g**) The auricle compound tissue flap was used to repair defects in the nosewing, nasal columella, nasal tip, and soft triangle of upper lip; the supplying vessels of the skin flap such as the superficial temporal artery and vein were anastomosed with the supplying vessels of the forearm skin flap such as the distal ends of radial artery and vein, and the nostrils were supported with plastic tubes for shaping. (**h**) The postauricular flap was used to repair the defect after harvesting of the auricle compound tissue flap; the donor site of postauricular flap was directly closed and sutured. (**i**), (**j**) The reexamination was carried out at 8 months after surgery; the skin flap healed well; the appearances of the nose, upper lip, and facial cheek were basically satisfied; the degree of mouth opening was acceptable; the eating was normal; the speech was clear; the nasal ventilation seemed fine; the appearance of donor site of skin flap in the right ear auricle was satisfactory

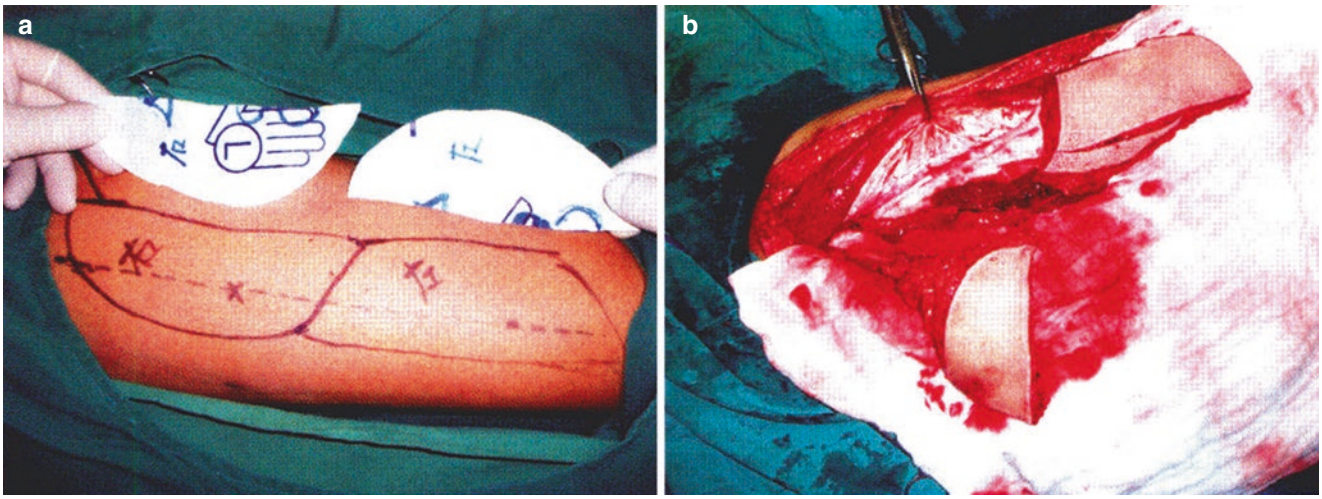

Fig. 7.7 Examples of single pedicled double skin flaps. (**a**) Two perforators of the descending branch of femoral circumflex artery are used to form the single pedicled double skin flaps. (**b**) Two skin flaps possess their own perforator to provide blood supply and can be freely put together to repair the large defect or folded to repair the perforating defect

lateral margin of the rectus abdominis muscle, the epigastric inferior vessels, and the posterior sheath are exposed. After that, a part of rectus abdominis muscle is incised open along the perforator, the branch of total trunk is dissected out, and then the branches of inferior epigastric artery and vein which enter into the posterior sheath and peritoneum are identified and dissected out. The posterior sheath and peritoneum are incised open according to the design, and the posterior rectus sheath-peritoneal flap of the required size is harvested and attached to the vascular pedicle. At the same time, the paraumbilical flap is passed out from the clearance of the rectus abdominis muscle and under the intercostal nerve, and the formed composite flap is in the form of single pedicled double skin flaps.

After the vascular pedicle is ligated and cut off, the peritoneum, rectus abdominis muscle, anterior sheath, and abdominal skin are sutured by layers, and the bellyband is used for compression bandaging. Attention should be paid to the protection of the 10th,11th, and 12th intercostal nerves which enter obliquely from the outer upper side into the rectus abdominis muscle, avoiding that the intercostal nerves are cut off and thus causing corresponding dysfunctions. After the primary tumor surgery is completed, the composite flap is placed into the defect; the paraumbilical flap is placed toward the skin side to repair the defect in the facial buccal area; the posterior rectus sheath-peritoneal flap is placed at the mouth side to repair the mucosa defect in the oral buccal area; two skin flaps are superimposed to repair perforating defects in buccal area; the rubber drainage strip is placed between two skin flaps to avoid effusion; and the inferior epigastric artery and vein are anastomosed respectively with the cervical blood vessels.

2.5.2 The Advantages and Disadvantages

1. Advantages. Compared with other tissue flaps, there are several advantages in repair of the composite perforating defects in the buccal area: double skin flaps can be formed using the same vascular pedicle, and the reconstructed buccal area can recover the unique structure of the buccal area with the outer skin and inner mucosa; the rectus abdominis muscle and the anterior sheath are still retained in the donor site, and the main structures of the abdominal wall are retained; thus the chances of the abdominal wall bulging and the abdominal wall hernia are reduced; a kind of new method is provided for the repair of vermilion defect among the complex lip and cheek defect.

In the previous literatures, the repair methods for the vermilion defect among the complex lip and cheek defect are rare, and mostly the skin flap is folded to form the shape of the oral fissure; however, the commonly used tongue flap and the adjacent mucosal flap are difficult to be applied for such defects. The skin surface of the peritoneal skin flap pedicled with the inferior epigastric artery and vein is fine and smooth with lighter color, and it is more suitable for repair of facial soft tissue defects. Meanwhile, the vascular pedicle of this skin flap is longer, up to 10–13 cm, and the vascular diameter is also large, which is beneficial for anastomosis. In addition, due to the fact that it is not needed to fold the skin flap for use, and the harvested skin flap is relatively small, the donor site can be sutured and closed directly without the need for skin transplantation, and no new surgical wound is increased.

2. Disadvantages. In the clinical observation, we also note that the skin flap has some of the following disadvantages:

(a) Due to defects in the posterior sheath and peritoneum, the possibility of occurrence of abdominal wall rupture in the perioperative period is increased. Therefore, when the harvested posterior rectus sheath-peritoneal flap is wider than 5 cm, the donor site of the peritoneum should better be repaired with an artificial patch to reduce the peritoneum tension, while the local bellyband is retained for more than 3 weeks.
(b) The surface color of the posterior rectus sheath-peritoneal flap becomes faint to be yellowish white 3 weeks later, while significant shrinkage occurs, which may be related to a lack of submucosal structure underneath. In order to avoid the appearance of the phenomenon of limited mouth opening, the patients are advised to carry out the mouth opening exercises in the early period of postoperation.

2.5.3 Typical Case

Case VI The patient, male, 38 years old, at 9 months after resection of the right oral buccal cancer in the other hospital (local resection and skin transplantation), had a right oral buccal mass for 3 months. Physical examination: the postoperative scars were observed in the right faciocervical area, the degree of mouth opening was 2 cm. The nodular mass in the right oral buccal area was about 3 cm × 2 cm in size, and it had invaded the faciocervical skin and the corner of the mouth. Admission diagnosis: postoperative recurrence of right oral buccal cancer. Pathological diagnosis: highly differentiated squamous cell carcinoma. The patient underwent extensive resection of the right buccal area, resection of maxillary tuberosity, resection of the right margin of the mandible, and free transplantation of peritoneal perforator skin flap pedicled with the inferior epigastric artery for repair of penetrating defects in the right buccal area under general anesthesia [5] (Fig. 7.8).

Case VII The patient, male, 70 years old, had black masses in the right face, the upper and lower lips, and the oral buccal area for 1 year, which grew at an accelerated rate for a month. Physical examination: multiple black masses were visible in the right facial area, upper lip, and vermilion, and they had invaded the upper front gingiva. Pathological diagnosis: malignant melanoma. The patient underwent extensive resection of masses in the right buccal area and the upper and lower lips + free transplantation of peritoneal perforator skin flap pedicled with the inferior epigastric artery for repair of the complex defects in the right buccal area and the upper and lower lips under general anesthesia (Fig. 7.9).

Case VIII The patient, female, 38 years old, at 6 years after resection of hard palate cancer, had hard palate masses for 6 months. Physical examination: the mouth opening was normal, small perforating defects were observed in the hard palate after surgery, the uplifted masses in the anterior and right sides of the original defect were observed, and the surfaces were less smooth. Admission diagnosis: recurrence of hard palate cancer. Pathology: mucoepidermoid carcinoma. The patient underwent extensive resection of hard palate cancer + free transplantation of peritoneal perforator skin flap pedicled with the inferior epigastric artery for repair of perforating defect in the palate under general anesthesia (Fig. 7.10).

2.6 Composite Full-Thickness Abdominal Wall Tissue Flap

2.6.1 Indications

The perforating defects in the oral buccal area can be repaired with the composite full-thickness abdominal wall tissue flap pedicled with the inferior epigastric artery, the peritoneal surface of the composite tissue flap is used to repair the oral buccal mucosa defect, and the skin surface of the skin flap is used to repair the facial skin defect. However, this method is only applicable to patients with thin abdominal wall, and this surgical method sacrifices the rectus abdominis muscle and the anterior and posterior sheaths of the rectus abdominis muscle, causing a weak abdominal wall, prone to abdominal hernia, which is generally required to be reinforced and repaired with the tissue patch [6].

2.6.2 Typical Case

Case IX The patient, male, 40 years old, had right buccal mass for 5 months. Physical examination: the degree of the mouth opening was 3 cm, and the cauliflower-shaped masses were observed in the right oral buccal and retromolar area. CT showed that the masses invaded the cheek muscle and skin. Pathology: highly differentiated squamous cell carcinoma. The patient underwent combined radical resection of right oral buccal cancer, resection of the processus alveolaris maxillae on the right side, resection of right mandibular margin, and free transplantation of the composite full-thickness abdominal wall tissue flap pedicled with the inferior epigastric artery to repair the perforating defects in the right buccal area under general anesthesia (Fig. 7.11).

2.7 Single Skin Flap Plus Skin Transplantation

2.7.1 Indications

When the perforating defects in the palate are repaired, the skin flap is folded or double skin flaps are tiled together, which often show a bloated appearance, the single skin flap can be used, the skin can be transplanted onto the tissue surface of the skin flap to repair the nasal surface and the

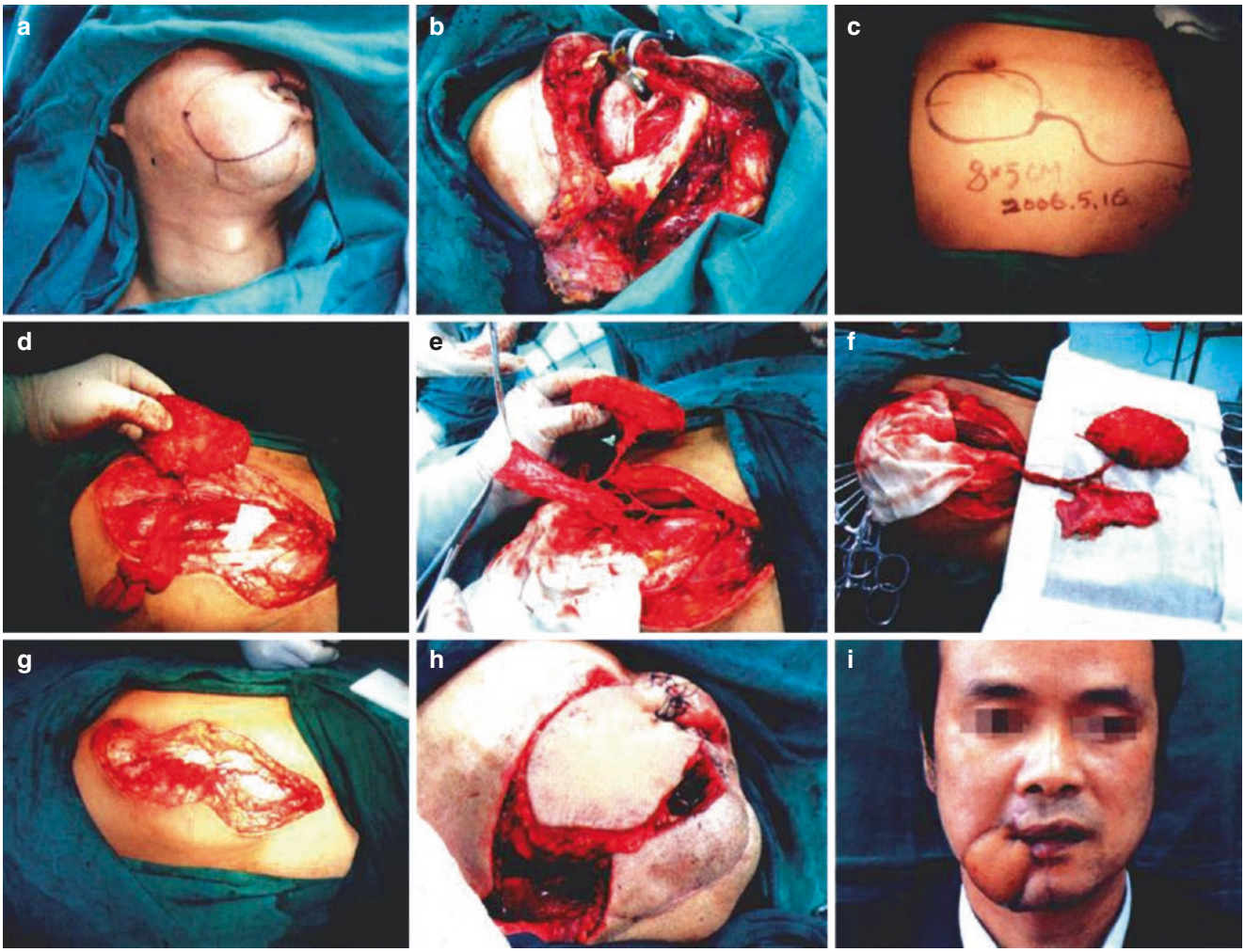

Fig. 7.8 Case VI. (**a**) The right oral buccal cancer recurred after surgery and invaded the faciocervical skin and the corner of the mouth. (**b**) The patient underwent extensive resection of the right buccal cancer, resection of maxillary tuberosity, and resection of the margin of the mandibular body, and the perforating defect occurred in the right buccal area after surgery. (**c**) The peritoneal perforator skin flap pedicled with the inferior epigastric artery was designed beside the navel. (**d**) The deep inferior epigastric perforator flap was formed; the rectus abdominis muscle, anterior sheath, and the control nerves were retained, and only the paraumbilical perforator was taken for providing blood supply. (**e**) The peritoneal flap with blood vessels was formed. (**f**) Prepared peritoneal perforator skin flap pedicled with the inferior epigastric artery (single pedicled double skin flaps). (**g**) The peritoneum in donor site and the posterior sheath of rectus abdominis muscle were closed and sutured directly, the anterior sheath of rectus abdominis muscle was fixed and sutured, and the skin was closed and sutured directly. (**h**) The skin flap was used to repair the facial buccal skin defects, and the peritoneal flap was used to repair the oral buccal defect. (**i**) At 6 months after surgery, the wound healing was acceptable, the skip flap healed well, the degree of mouth opening was 3 cm, and the patient ate well and spoke more clearly

femoral fascia at the deep surface of the anterolateral thigh skin flap or the fascia surfaces of the forearm skin flap, and the dorsalis pedis skin flap can also be used as the nasal lining. When this method is used for repair, attentions must be paid so that the site where the vascular pedicle penetrates into the skin flap is close to the margin of the skin flap, so that it is easy to embed the vascular pedicle well in the soft tissues of the pharynx side. If the position of the perforator vessel of the skin flap is exposed at the nasal side, this can easily lead to skin flap necrosis induced by vascular spasm. Someone also has proposed the surgical method that only the transplantation of single skin flap is performed, the other side of the wound is packaged for self-healing; generally this method should not be used due to the increase in the chances of the surgical failure caused by postoperative infection and necrosis and the postoperative scar contracture.

2.7.2 Typical Case

Case X The patient, male, 41 years old, had soft palate ulceration for 7 months. Physical examination: the degree of mouth opening was acceptable. An ulcerative mass of about

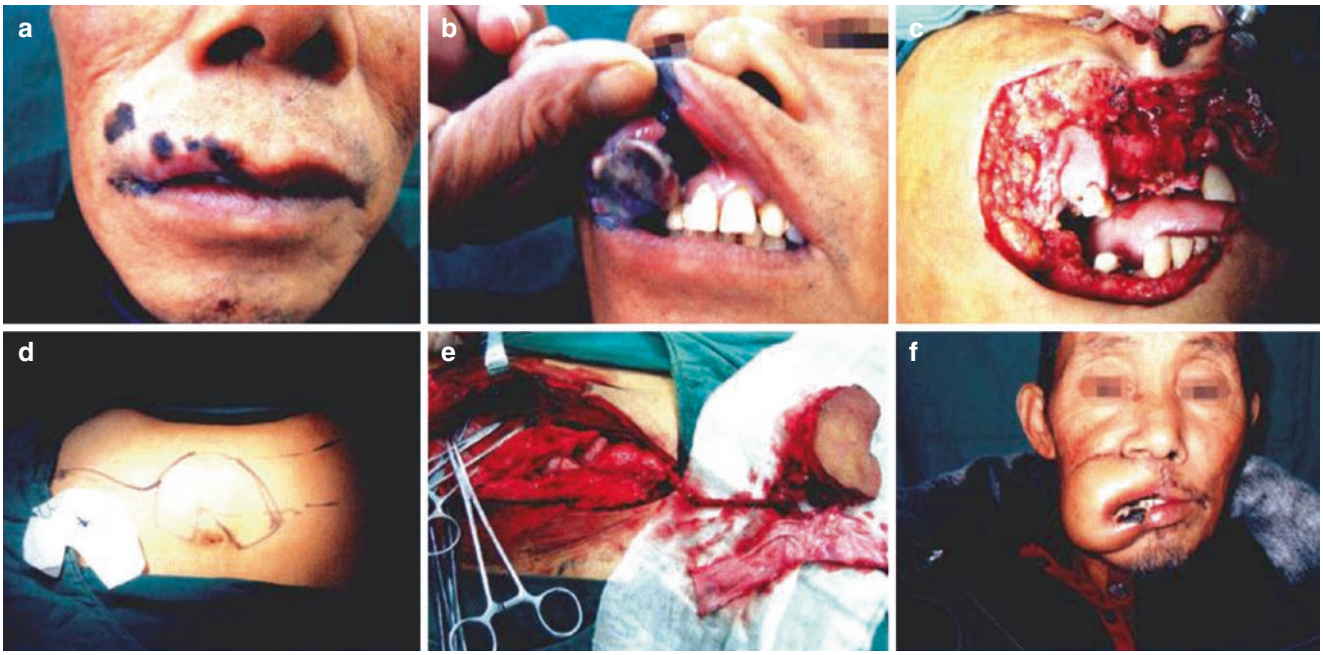

Fig. 7.9 Case VII. (**a**), (**b**) The primary foci were located on the right oral buccal area, outer one half of the upper lip, the corner of the mouth, and the right face. (**c**) The patient underwent extensive resection of the right buccal melanoma, partial resection of the right upper gingiva, and dissection of the right cervical lymph node, and there were full-thickness defects in part of the right upper and lower lips and perforating defects in the buccal area. (**d**) The paraumbilical peritoneal perforator skin flap was designed according to the scope and size of the defects in the primary foci. (**e**) The peritoneal perforator skin flap pedicled with the inferior epigastric artery was harvested. Meanwhile, the rectus abdominis muscle, anterior sheath, and the intercostal nerve controlling the rectus abdominis muscle were retained. The peritoneal skin flap was used to repair the defects in the oral buccal area and the intraoral sides of the upper and lower lips, and the perforator skin flap was used to repair defects in facial buccal area and the outer sides of the upper and lower lips. (**f**) At 2 weeks after surgery, the skin flaps healed well and still had swelling

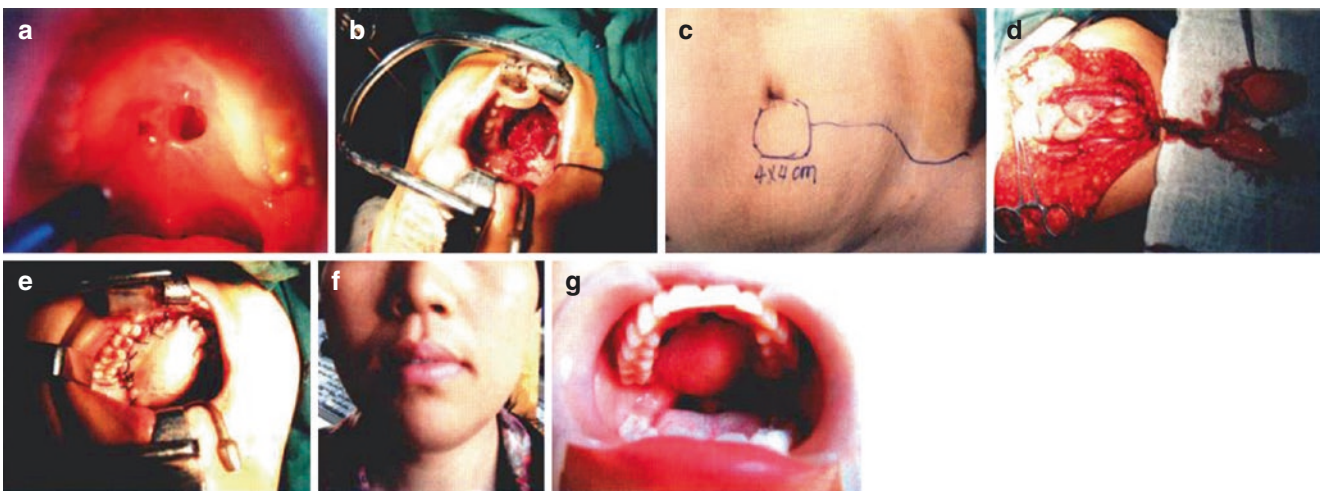

Fig. 7.10 Case VII. (**a**) Postoperative changes in the palate and the masses were observed beside the perforating defects. (**b**) The full-thickness resection of the hard palate was performed, and the nasal floor was exposed. (**c**) The peritoneal perforator skin flap pedicled with the inferior epigastric artery was designed. (**d**) The peritoneal perforator skin flap pedicled with the inferior epigastric artery was harvested; the rectus abdominis muscle, anterior sheath, and the intercostal nerves controlling the rectus abdominis muscle were retained; the posterior sheath of the rectus abdominis muscle and the peritoneum was closed and sutured directly; and the abdominal wall defect was closed and sutured directly. (**e**) The peritoneal skin flap was used to repair the defect in the nasal surface of the palate, the perforator skin flap was used to repair the defect in the oral surface of the palate, and the vascular pedicle was passed through the tunnel to reach the neck and anastomosed with the facial artery and vein. (**f**), (**g**) At 3 months after surgery, the skin flaps healed well, the patient spoke clearly and ate normally with no nasal regurgitation, the nasal base healed well, and the bilateral nasal ventilation function was good

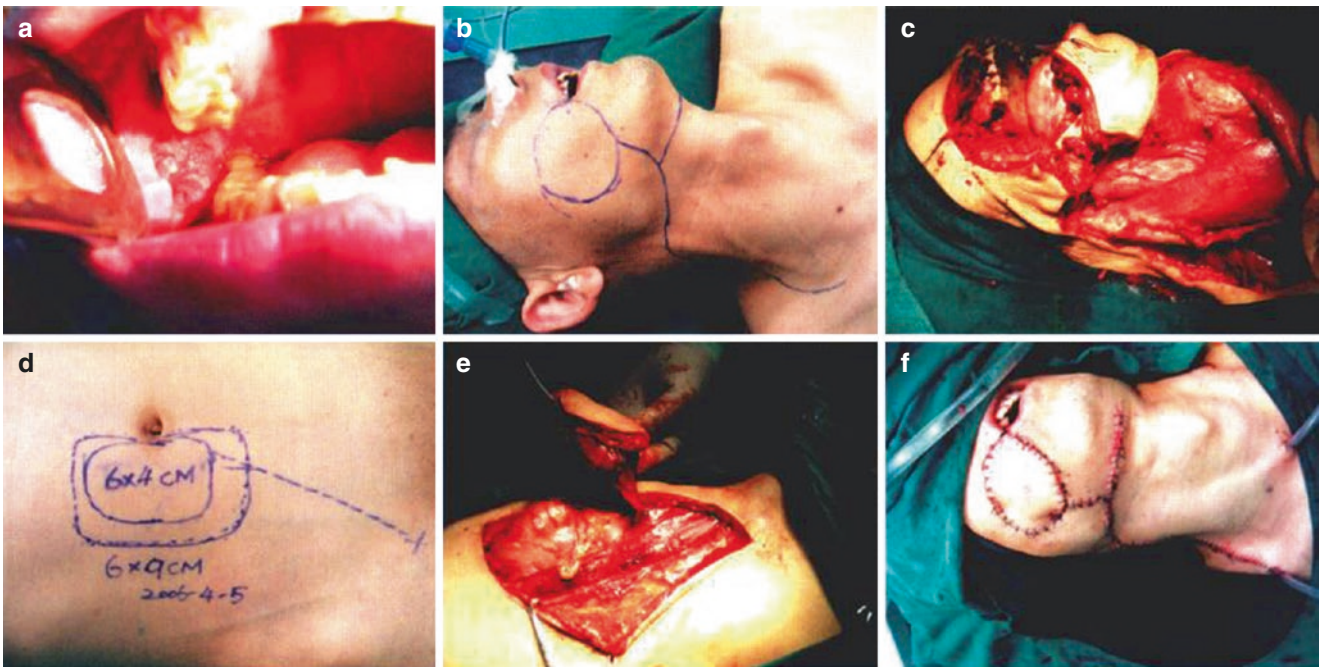

Fig. 7.11 Case IX. (**a**) The right masses in the oral buccal and retromolar area had invaded the upper and lower gingiva and facial skin. (**b**) Surgical incision design. (**c**) The patient underwent combined radical resection of the right oral buccal cancer, dissection of the bilateral cervical lymph node, resection of the processus alveolaris maxillae on the right side, resection of the right mandibular margin, and repair of full-thickness perforating defects in right buccal area. (**d**) The composite full-thickness abdominal wall tissue flap pedicled with the inferior epigastric artery was designed, the skin with a size of 6 cm × 4 cm was harvested, and the peritoneal skin flap with a size of 9 cm × 6 cm was harvested. (**e**) The composite full-thickness abdominal wall tissue flap pedicled with the inferior epigastric artery was harvested (the composite tissue flap contains skin, subcutaneous tissue, the anterior sheath of the rectus abdominis muscle, part of the rectus abdominis muscle, the posterior sheath of the rectus abdominis muscle, peritoneum). (**f**) Free transplantation of the composite full-thickness abdominal wall tissue flap pedicled with the inferior epigastric artery to repair the perforating defects in right buccal area; the skin surface was used to repair the facial buccal area, and the peritoneal surface was used to repair the oral buccal area

3 cm × 3 cm in size was observed in right soft palate, and its margins were irregularly uplifted, which reached outward to the pterygomandibular fold and reached inward to the uvula; the soft palate movement fair seemed fine. Pathology: highly differentiated squamous cell carcinoma. The patient underwent extensive resection of soft palate cancer + resection of the right margin of the mandible + right cervical functional lymph node dissection + the repair with pedicled submental flap + skin transplantation under general anesthesia (Fig. 7.12).

At present, although there are more methods for repair of perforating defects in the oral and maxillofacial area, because of the complexities of the perforating defects in the oral and maxillofacial region, which often involve defects in multiple organs and tissues, now all repair methods are far from achieving the purpose of functional reconstruction, particularly for a large area of complex defects; after surgery, the flap contracture causes limited mouth opening, the large bone volume loss leads to the

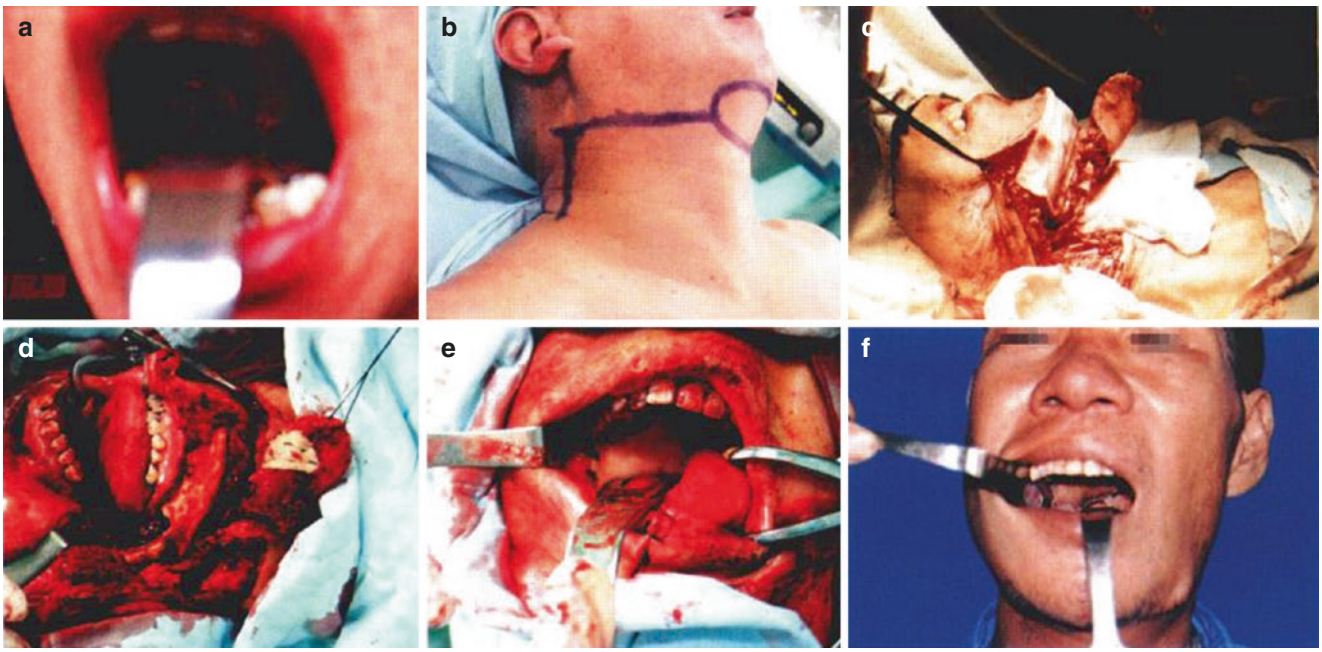

Fig. 7.12 Case X. (**a**) Before surgery. (**b**) Skin incision; the submental flap was designed as about 6 cm × 4 cm in size. (**c**) The submental flap pedicled with submental artery and vein was prepared. (**d**) The patient underwent extensive resection of soft palate cancer + resection of the right margin of the mandible + dissection of the right cervical functional lymph node + repair of perforating defects in soft palate; the skin was transplanted onto the back of the submental flap, and the transplanted skin was sutured by a few stitches to make the skin graft closely cling to the submental flap. (**e**) The vascular pedicle of the submental flap was passed through from the surface of the mandible and was transferred to the soft palate for repair of the soft palate defect, the flap surface was used to repair the defects in the oral surface of the soft palate, and the transplanted skin area on the back of the flap was used to repair the defects in the nasal surface. (**f**) The reexamination was carried out at 3 months after surgery, the flap in soft palate healed well, the palatopharyngeal closure was good, and the patient spoke clearly and eat well without nasal regurgitation

facial collapse after surgery, and the problems such as repairs of lip and corner of the mouth and the lower eyelid ectropion remain to be further solved.

All surgical photographs published in this chapter have been approved by the patients themselves.

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Repair and Reconstruction of Maxillary Defects

8

Jian Sun and Yi Shen

1 Overview

The maxilla is the cornerstone of the appearance and function of the midface and has important functions such as supporting the skull base, eyeballs, and midface, bearing the chewing force, and separating the oral and nasal cavities. The main causes of maxillary defects include acquired defects caused by tumor-reductive surgery and severe trauma and the congenital developmental malformations. The effect of the maxillary defect on the appearance and function of the patient counts for much, the maxillary defect is often accompanied by the destruction or deletion of surrounding vital structures, and therefore it will cause facial deformities and severe loss of oral functions, bring catastrophic blow to the patient's physiology and psychology, and seriously affect the quality of life of patients.

Because the maxilla is connected to adjacent various bones in the middle and upper parts of the face, the maxillary defect is often accompanied by defects in the ethmoid bone, nasal bone, cheekbones, palate bone, orbital bone, and skull base bone. The resection range for the maxillectomy performed due to tumor often includes part of cheekbone, and sometimes it still needs to include the nasal bone, ethmoid bone, and orbital bone depending on the specific situation; the subtotal or total maxillary resection often leads to palatomaxillary defects; for example, when carrying out the craniomaxillofacial combined resection, it is often needed to remove the skull base bone, including the anterior cranial fossa and middle cranial fossa, even occasionally also involving backward the posterior cranial fossa; the extended radical resection of the malignant advanced tumor in the middle part of the face will lead to defects which are usually perforating defects, while the defects caused by trauma or war injury are combined with varying degrees of soft and hard tissue defects according to different injury causes, state of injury, and wound tract, which increase the difficulty of maxillary defect reconstruction to some extent. Therefore, the repair and reconstruction of the maxillary defect, especially the functional reconstruction, have been a challenging task faced by surgeons in departments of maxillofacial and oral head and neck surgery, plastic surgery, and prosthodontics.

So far, domestic and foreign scholars still have controversies on the reconstruction of maxillary defect, and its treatment still remains in the level of maxillofacial prosthetic treatment and the repair with free composite tissue flap [1–20]. In recent years, along with the improved consensus of both doctors and patients on increasing the survival rate and survival quality, coupled with increasingly sophisticated microsurgical techniques, widely used medical biological materials, and the introduction of digital medicine, especially the development of rapid prototyping technology, the ideal or proper functional maxillary reconstruction proposed and implemented by domestic and foreign scholars is made possible. For this purpose, on the basis of obtaining a lot of successful experiences after years of unremitting efforts, they gradually promote the in-depth researches in this area. On that account, this chapter is intended to take the surgical reconstruction as the fundamental key, give consideration to both appearance and function combined with the authors' experience and knowledge, emphatically introduce the reconstruction and repair of defects after maxillary tumor surgery, and discuss issues of common concern.

1.1 Maxillary Defect Classification

Since the sites and contents of maxillary defect caused by tumor resection or severe trauma are often not the same, the methods for repair of maxillary defect reconstruction selected by the surgeons as well as the appearance and functional effect after reconstruction are also somewhat different. Meanwhile, there are a wide variety of methods for maxillary reconstruction, and currently, there is no uniform standard to follow; thus, it is necessary to classify the maxillary

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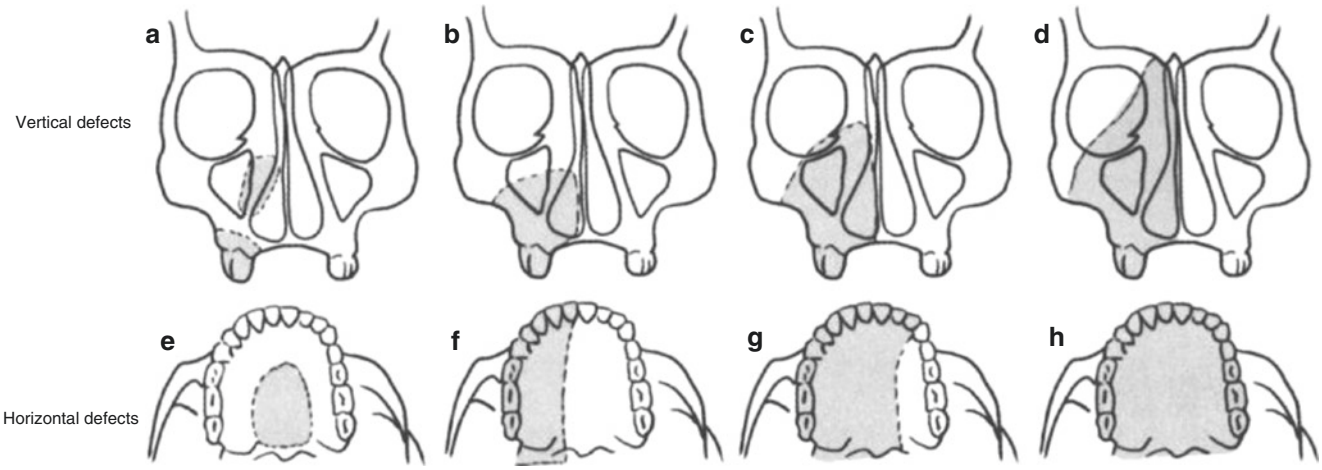

Fig. 8.1 Brown classification of maxillary defects (2000). (**a**, **e**) Class 1, (**b**) Class 2, (**c**) Class 3, (**d**) Class 4, (**f**) Subclass a, (**g**) Subclass b, (**h**) Subclass c

defects, in order to seek methods which are not only beneficial to clinical diagnosis, treatment plan development, and postoperative functional evaluation but also are helpful in carrying out discussions on the reconstructive method for maxillary defects on the same platform and setting up selection criteria for a variety of methods for maxillary reconstruction while can also effectively evaluate and compare the efficacies. According to domestic and foreign reports, the methods for maxillary defect classification mainly include HS classification, Fan Sen classification, Zhao Yimin classification, Brown classification, Cordeiro and Santamaria classification, Okay classification, Triana classification, and Yamamoto classification. In these classifications, the first three classifications are based on the perspective of prosthodontic rehabilitation and thus have relatively limited application; the later several classifications are proposed by surgeons from the perspective of surgical reconstruction. Given the limited space available, this chapter describes only the more popular and widely used Brown classification (2000) and the modified classification by Brown (2010).

Brown classification (2000) is a classification system proposed by British scholar Brown et al. [21] according to maxillary defects, respectively, in the vertical and horizontal planes (Fig. 8.1).

Vertical defects (the English word of 垂直缺陷)
Horizontal defects (the English word of 水平缺陷)

1.1.1 Classification of Vertical Defects

The vertical defects are divided into four classes according to the status of unilateral maxillary defect, of which they are divided into Class 1 and Class 2 according to whether there exists an area of oronasal fistula and they are divided into Class 3 and Class 4 according to the degree of orbital invasion. Specific classification is as follows:

1. Class 1 defects – Maxillectomy without involvement of the sinus cavity.
2. Class 2 defects – Low maxillectomy, including resection of walls of maxillary sinus and alveolar processes with preservation of the orbital floor and part of orbital tissue.
3. Class 3 defects – High maxillectomy, including orbital floor or part of orbital tissues; the skull base may be involved, but the eye ball is preserved.
4. Class 4 defects – Radical maxillectomy includes orbital exenteration, and the anterior skull base resection may or may not be included.

1.1.2 Classification of Horizontal Defects

The horizontal defects are divided into three subclasses according to the extent of resection of alveolar bone and palate:

1. Subclass a – Unilateral resection of alveolar bone and palate without exceeding the midline and involving the nasal septum
2. Subclass b – Resection of alveolar bone and palate exceeding the midline and involving the nasal septum
3. Subclass c – Resection of total alveolar bone and palate

The vertical defects in the maxilla will make a huge impact on the appearance of the midface, while the horizontal defects will cause more functional disorders in chewing, swallowing, and pronunciation.

Brown classification covers the two aspects such as deformity and dysfunction (teeth occlusion, chewing, and pronunciation) in the midface (nose and paranasal sinuses, eyeballs) caused by the maxillary defects.

After Brown classification had been applied in clinic for years, Brown et al. (2010) also proposed a modified classification on this basis (Fig. 8.2). In addition to the original

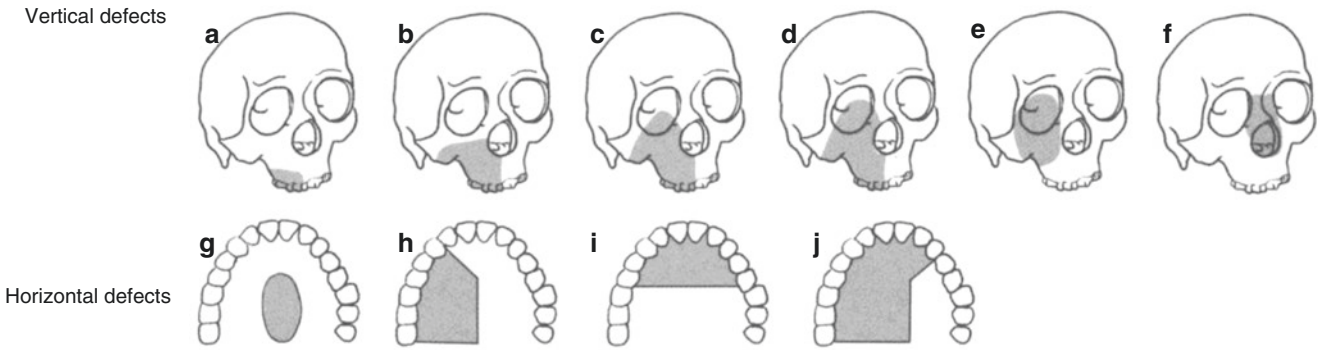

Fig. 8.2 Brown modified classification of maxillary defect (2010). (**a**) Class 1, (**b**) Class 2, (**c**) Class 3, (**d**) Class 4, (**e**) Class 5, (**f**) Class 6, (**g**) Subclass a, (**h**) Subclass b, (**i**) Subclass c, (**j**) Subclass d

four classes, the vertical defects additionally include Class 5 defects that there exist the orbital and maxillary defects, but the alveolar process and palate are intact, and Class 6 defects that there exist nasal and surrounding maxillary defects; the horizontal defects additionally include a subclass of transverse defects that are less than or reach half of the hard palate. Since this modified classification is latestly proposed and has not yet been acknowledged by scholars worldwide, this chapter still uses Brown classification (2000).

Vertical defects
Horizontal defects

1.2 The Principles for Repair and Reconstruction of the Maxilla

1.2.1 The Open Repair Should be Applied in Patients with Primary Maxillary Sinus Cancer and Highly Malignant Tumor

Because of the importance and complexity of the invasion range and the adjacent area of primary maxillary sinus cancer, and its poor biological behavior and survival rate, there is a certain difficulty in controlling the radical resection and safety margin. In view of such principles for facilitating the timely detection and treatment of postoperative recurrence of maxillary malignant tumor, the authors suggest that, for some maxillary tumors with higher malignant degree such as primary maxillary sinus cancer and osteosarcoma and combined with sinus wall damage, at the same time of performing radical tumor resection, the open repair methods of using the man-made support such as titanium mesh to maintain the appearance of the midface and wearing a prosthesis can be applied firstly, and then the surgical reconstruction can be implemented at 2 years after surgery when there is no local recurrence and distant metastasis.

1.2.2 The Patients with Tumors Which Can Be Radically Resected Can Be Treated with Immediate Closed Repair and Reconstruction

After radical maxillary tumor resection, due to simultaneous defects in bone tissues such as the orbital bone, cheekbone, and nasal bone, the patient's appearance can be affected in different degrees. With the development of CT, MRI, and endoscopic techniques, the concerns in the past that the immediate use of autologous tissue to repair and reconstruct the maxilla may affect the examination of tumor recurrence are gradually eliminated, and there is no data to support that the prognoses of patients with surgical reconstruction are poorer than those of patients without surgical reconstruction. Therefore, for patients with tumors of higher malignant degree that primarily occurred in the palate and gingiva, the lesions are relatively limited and do not invade the maxillary sinus; for patients with tumors which can be completely removed or some patients with tumors of low malignant degree, the lesions invade the maxilla but do not invade through the sinus wall; the authors advocate that the closed repair and functional reconstruction are performed at one stage, according to the defect statuses in maxilla and adjacent bones; the artificial prosthesis (biological material or titanium mesh) can be used as scaffolds to reconstruct the anatomical shape, and then the oral surface or nasal surface is covered with the free composite tissue flap to restore the alveolar crest and palate and reconstruct the nasal passage and separate the oral and nasal cavities. The implants can be transplanted immediately or delayedly to restore the patient's chewing function finally.

1.3 The Objectives and Requirements for Repair and Reconstruction of Maxillary Defects

The repair and reconstruction of maxillary defects should also take into account the recovery of function and appearance,

and the effective targeted measures should be taken in accordance with the cause, location, extent, and type of the defect. The ideal reconstruction method must meet the following objectives and requirements [22]:

1. Fill the defects caused by tumor surgery or trauma.
2. Separate the oral and nasal cavities.
3. Restore the support structure of the maxilla.
4. Recover the function of tissues and organs of midface such as chewing, pronunciation, and swallowing.
5. Reconstruct the position of the eye or fill and beautify the orbit after eye enucleation.
6. Maintain a specific nasal airway.
7. Provide necessary bony support for midface tissues such as the upper lip, nose, and cheek, thus avoiding the lower eyelid ectropion.
8. Repair and reconstruct the appearance of the midface.

However, to date, there is no any kind of reconstruction method which can reach the objectives of all these maxillary reconstruction. For this purpose, the scholars from various countries continue to explore the ideal method of reconstruction.

1.4 The Basis for Repair and Reconstruction of Maxillary Defects and Its Meaning

At present, the method and timing of repairing the defects after resection of maxillary tumor remain controversial. For a very long time in the past, the traditional prosthesis occupied a dominant position in the repair of maxillary defects, and a surgery on donor site can be omitted. The prosthesis can fill the dead space, separate the nasal and oral cavities, and restore some chewing function and can be removed and put on at will, which is very favorable for observing whether there is early tumor recurrence. But its disadvantages are also obvious. Due to the fact that its retention condition is poor and it is not closed with the surrounding tissue, its adhesive force and attachment force are reduced accordingly; it tends to produce leakage and tilting, thereby affecting the functions such as sucking, chewing, and speech; and it is also not conducive to cleaning the oral environment; the long-term compression of prosthesis can cause secondary trauma and form the traumatic ulcers, so the postoperative recovery of the patient is not satisfactory.

In recent years, the vascularized tissue is transplanted to repair the maxillary defect, and this has been accepted by a growing number of physicians and patients; these techniques also make up the flaws of repair of maxillary defects with prosthesis fundamentally [5, 7–12, 17, 18, 22]. Therefore, the immediate repair with free composite tissue flap combined with the endosseous implant appears; thereby, not only the oronasal fistulas in the patients can be immediately closed, but also the chewing function, phonetic function, and nasal ventilation function of the patients after surgery can be recovered to varying degrees because of the repair with bone graft and the implant of better quality. In the past, the main concerns against the immediate repair are the worries that due to the covering of the dead space after maxillectomy by tissue flap, if the tumor recurs in future, the recurrent tumor foci cannot be directly observed with the naked eye, which may delay the diagnosis and treatment of the patient. With the development and popularization of modern medical imaging such as nasal endoscopy, CT, and MRI, it is possible to find the recurrent tumor foci earlier and earlier, which is conducive to the monitoring of early disease recurrence. Meanwhile, there is no literature suggesting that the survival rate of patients with immediate reconstruction is lower than that of the patients without immediate reconstruction; on the contrary, the survival rate of patients with immediate reconstruction is greater than that of the patients without immediate reconstruction.

For the ideal timing for repair and reconstruction of maxillary defects, the author thinks it should be performed immediately as soon as possible after surgery, because the immediate repair after surgery is conducive to early functional recovery and prevention of scar contracture; otherwise, the surgical reconstruction at the second stage will be harmfully affected, and the scar contracture will be more serious during postoperative radiotherapy. The long-term scar contracture and no hard tissue support in the infraorbital region after surgery often result in collapse and deformity of the midface of the patient, and it also brings some difficulties to the second-stage reconstruction. For the patients with defects in the intraoral mucosa, especially at the rear of the soft palate, if the tissues are not fixed and the muscle bundles are not accurately aligned during surgery, the obvious postoperative contracture can also occur. Therefore, the soft palate function will gradually decline and even is lost, and this leads to secondary velopharyngeal insufficiency and hypernasality in the patients after surgery, even if the second-stage surgery is performed in such patients, and it is quite difficult to improve the soft palate function after surgery. Therefore, the author believes that it should be advocated that the maxillary defects are immediately repaired with vascularized composite tissue flaps on the basis of strictly following the surgical indications and ensuring the safety margin.

2 Method for Repair and Reconstruction of Maxillary Defects

Because the pathological patterns and size ranges of various tumors involving the maxilla are different, and the anatomical structure of the maxilla itself is complex, the types and

respective contents of the maxillectomy are different; thus, the resulted maxillary defects are not confined to a single defect and are complex series of diverse areas including small communication between the mouth and nose, and even the larger cranio-maxillofacial defect and the defects of different types and in different sites require different methods for repair and reconstruction; the surgeons engaged in the repair and reconstruction should select the most appropriate method for maxillary reconstruction according to the respective needs of each type of defects and each patient and reach the doctor-patient consensus as far as possible. So far, a lot of methods for repair and reconstruction have been used in repair and reconstruction of maxillary defects by various scholars worldwide, and they have gone through the test of time and practice, and especially the long-term effects are evaluated. Under the premise of strictly selecting indications, all the properly selected methods for repair and reconstruction will play their respective roles. These methods include skin graft transplantation and prosthesis repair, local tissue flap repair, regional tissue flap repair, artificial implant material, free bone (autograft, allograft, xenograft bones) transplantation, and vascularized tissue flap (fascia skin flap, myocutaneous flap, osseous myocutaneous flap, sandwich tissue flap, perforator skin flap, prefabricated or pre-formed tissue flaps, etc.). Of course, some of the abovementioned methods have gradually been eliminated, while other methods are being vigorously promoted by various scholars worldwide.

2.1 The Traditional Methods for Repair and Reconstruction of Maxillary Defects

The prosthodontic repair is mainly used for limited maxillary defects such as Class 1 defects of Brown classification, and the patients who are not suitable for repair with vascularized tissue flap and whose remaining teeth have enough support strength. The local tissue flaps such as palate island flap and buccal fat pad flap allow the surgeons to exchange for repair of smaller maxillary defects with minimal damage; some regional tissue flaps such as temporalis muscle flap and submental island flap have all been successfully used to reconstruct relatively larger defects in midface and maxilla. But because the regional tissue flaps often lack sufficient amount of tissue to fill the defect, as well as the length of the vascular pedicle is insufficient to reach the defect area, it is subjected to certain restrictions in application in repair and reconstruction of larger maxillary defects.

The artificial implant materials used in the reconstruction of the maxilla include titanium mesh, titanium, and biomaterials, of which the titanium mesh is most widely used and reliable. The safety of maxillary reconstruction with titanium mesh has long been recognized by the majority of scholars, because the titanium and titanium alloys have stable physical, chemical, and biological properties, good biocompatibility, light weight, high strength, corrosion resistance, and low conductivity and have the advantage of being transmitted by X-ray which other metals do not have. The application of titanium mesh in repair and reconstruction is dated back to its application in repair of defects in the skull, skull base, and orbital floor caused by tumors or trauma, and some scholars use it for reconstruction of maxillary defects, and the titanium mesh can be used alone and can also be used in combination with soft tissue flaps or free bone transplantation. Because the titanium mesh has a better image quality on CT and MRI, therefore, the use of the titanium mesh to reconstruct the mandible does not have an effect on the monitoring of tumor recurrence. Another advantage of the titanium mesh is that it has sufficient strength to support the midface and orbital contents. Tideman (1993) [3] first performed repair of maxillary defects by means of casting titanium mesh scaffold, filling it with autologous iliac bone, and wrapping it with temporalis myofascial flap; its recent application in four cases has obtained satisfactory results. But the shaping precision and flexibility of the casted titanium mesh are poor; there is a certain difficulty in making relatively great adjustment during surgery, coupled with reasons such as inadequate tissue volume in single temporalis myofascial flap; and it may result in exposure of titanium mesh after surgery; therefore, the technology has not been promoted. In addition, although the postoperative appearance of titanium mesh is generally satisfactory and the operation is relatively simple, however, if the surgeon is inexperienced and local blood supply and decreasing tension are ineffective, this can cause postoperative wound infection, fistula formation, and increase the probability of exposure of titanium mesh; it should be used with caution especially in patients with Class 3–4 defects of Brown classification or in patients who have received radiotherapy or need to have postoperative radiotherapy.

2.2 Reconstruction of the Maxillary Defect with Vascularized Free Tissue Flap

The vascularized free tissue flap can be used to reconstruct simultaneously the compound and complex defects in maxilla and midface and is not affected by the location of the donor site, and the vascularized free tissue flap includes two types such as soft tissue flap and hard tissue flap. The soft tissue flap mainly plays roles in covering or filling the defects and eliminating the dead space, but the soft tissue flap cannot be used for bone reconstruction of the maxillary defect and therefore cannot achieve the purpose of implanting artificial tooth for repair. The new alveolar crest repaired by soft tissue

flap is relatively blunt, and at the same time, it is more difficult to restore the shapes of the buccal gingival sulcus and palatal arch, showing a trampoline-like form, and most patients are unable to wear partial or half mouth denture. In addition, although the recent results are often unsatisfactory, because of factors such as muscle atrophy and gravity action, the long-term effect of soft tissue flap reconstruction, especially the recovery of appearance, will be far less than expected. Since the 1990s, along with the application of vascularized composite bone muscle (skin) flaps in reconstruction of maxillary defects by various scholars worldwide, the vascularized composite bone muscle (skin) flap combined with the planting techniques are extensively used, which opens up a new era for repair and reconstruction of maxillary defects. The advantage of vascularized composite bone muscle (skin) flap is that it can reconstruct the osseous pillar and appearance of the midface and make up the shortcoming that the soft tissue flap cannot serve as the support due to the long-term atrophy; the chewing function can be reconstructed combined with the implant denture technique, so as to achieve the true meaning of the functional reconstruction of maxilla.

2.2.1 The Indications for Maxillary Reconstruction with the Vascularized Free Tissue Flap

The related indications for maxillary reconstruction with the vascularized free tissue flap are a problem worthy to be discussed. Although a variety of pedicle or free soft tissue flaps were used to fill or cover the dead space caused by maxillary defects, the author thinks it can only be called as repair; contemporarily, the application of composite bone muscle (skin) flap combined with implant placement recovers the occlusal relationship and the chewing function of the maxilla. Since both the function and appearance are recovered, it can only be called as reconstruction.

In the following circumstances, it may be considered that the vascularized free flaps are used for maxillary reconstruction:

1. The patients have concomitant oral mucosa (skin) defects in the adjacent site and the defects are larger, for example, the concomitant larger tissue defects in sites such as the buccal mucosa (skin), soft palate, and lateral pharyngeal wall can be repaired with the latissimus dorsi muscle, pectoralis major muscle, transverse rectus abdominis myocutaneous flap, or anterolateral thigh skin flap.
2. For the patients with more limited range of tumor, such as Class 2 defects of Brown classification and with younger age, the authors advocate that the fibula composite flap is used for repair; if the bilateral defects exist, it is also considered that the iliac bone muscle (skin) muscle flap or the shoulder blade myocutaneous flap is used for repair, and the implant denture repair can be performed immediately or at the second stage.
3. The resection range is larger; for the patients with Class 3 defect of Brown classification, the authors recommend that the titanium mesh is taken as the support frames of the anterior wall of maxillary sinus and the inferior wall of orbit; the fibula composite flap is used to close the communication between mouth and nose simultaneously in the tooth socket area.
4. The follow-up has been performed for 2 years after maxillectomy, and there are no patients with recurrent tumors who ask for autologous tissue repair.

2.2.2 The Common Methods for Maxillary Reconstruction with Vascularized Free Tissue Flap

As mentioned earlier, currently, the common methods for maxillary reconstruction with vascularized free tissue flap are divided into two types, soft tissue flap and hard tissue flap, and the soft tissue flaps include the radial forearm skin flap, anterolateral thigh skin flap, pectoralis major myocutaneous flap, transverse rectus abdominis myocutaneous flap, and the transverse rectus abdominis myocutaneous flap; the hard tissue flaps include the fibula myocutaneous flap, iliac osteo-myocutaneous flap, shoulder blade myocutaneous flap, and radial forearm osteocutaneous flap. Various methods have their own indications and advantages and disadvantages. Given the limited space, this section will focus on the reconstruction of the maxilla with more commonly used radial forearm osteocutaneous flap and the fibula myocutaneous flap.

2.3 Application of the Computer-Aided Design/Computer-Aided Manufacturing Technology in the Maxillary Reconstruction

Although the vascularized composite bone flap has played a dominant role in the reconstruction of maxillary defects, for bone graft shaping and facial appearance reconstruction, except on the basis of skull specimens, the previous operators always carried out estimation according to individual clinical experience, whose subjectivities can be imagined, so that the repeatability was poor, and it was difficult to recover the ideal appearance of the midface, which had a certain distance from the requirements for reconstruction of maxillofacial appearance and function. Therefore, how to achieve the optimum combination and have a good construction and prediction before surgery? The appearances and the application of technologies such as the rapid prototyping and computer-aided design (CAD)/computer-aided manufacturing (CAM) provide reliable guarantees for

reconstructing new ideal morphology of the maxilla to restore its original appearance and function and realize individualized reconstruction in the true sense. The rapid prototyping is a high-tech manufacturing technology which started to be commercialized at the end of the 1980s. Since the CAD/CAM system had characteristics such as precision, visualization, and strong operability, this technology was introduced into surgery soon and gradually showed its advantages in the field of oral and maxillofacial surgery. For example, Tideman et al. (1993) performed immediate repair for the defect after maxillectomy using combined methods such as pure titanium mesh scaffold casted by CAD/CAM technology, filling with autogenous iliac bone block and the transfer of temporalis myofascial flap to cover the inner and outer layers of the scaffold, which recently received satisfactory results. Since 2000, the author [10, 11] had been applying the CAD/CAM technology as the means of model surgery for reconstruction of large maxillary defects (Class 2–3 defects of Brown classification), had been using the preoperative prefabricated titanium mesh to recover the appearance of the maxilla, and thus had achieved a good reconstruction effect through reconstructing the anatomical shape of the maxilla. The specific surgical approach will be detailed later.

The application of CAD/CAM technology in the reconstruction of maxillary defects has the following advantages compared with the traditional method: First, it can more accurately recover the appearance of the maxilla and thus effectively carry out anatomical reconstruction. Secondly, the osteotomy guide is designed preoperatively according to the model to determine the fixed locations of osteotomy line, titanium mesh, and titanium plate, which is conducive to guiding the accurate placement of the bone graft and the axial direction of implant placement during surgery to prevent postoperative deviation, in addition, which can effectively save time and attain the result with half effort. But it still has disadvantages such as longer production cycle, weakened bone area which is not conducive to stent bending, and slightly higher costs.

2.4 Reconstruct of the Maxilla Using the Radial Forearm Skin Flap Combined with CAD/CAM Prefabricated Titanium Mesh

The radial forearm skin flap was formed initially by a Chinese scholar Professor Yang Guofan (1978). Because it has advantages such as long vascular pedicle, thick diameter, larger area for harvesting the skin and fascia, and simpler preparation, it is considered to be a good choice for the reconstruction of oral mucosa and has been widely used. In the reconstruction of maxilla, the radial forearm skin flap is used previously to mainly reconstruct the soft palate defects and the limited Class 1 defects of Brown classification. Since 2000, the author had been applying the CAD/CAM technology as the means of model surgery for reconstruction of large maxillary defects – Class 2–3 defects of Brown classification – and had been using the preoperative prefabricated titanium mesh to recover the appearance of the maxilla. The anatomic structure of the maxilla at one stage was reconstructed with the method of folding the free radial forearm skin flap to repair the oral and nasal wounds, and thus the functions such as chewing, speaking, and ventilation were restored. To 2002, it had been clinically applied in 19 cases, and the satisfactory results had been obtained. This method makes the three-dimensional reconstruction of large maxillary defects more accurate and more individualized. This method will be introduced in the following paragraph through taking the reconstruction of Class 3 defects of Brown classification for an example.

2.4.1 Preoperative Preparation

1. In addition to routine preoperative examination to exclude systemic disease and other surgical contraindications, the patients with the maxillary cancer should undergo three-dimensional CT examination to determine the lesion range and the invasion status in the adjacent tissues; the patients with malignant tumors should be examined to determine whether the cervical lymph node metastasis exists and to exclude the possibility of distant metastasis.
2. Allen's test is performed in the forearm, the refluxes of the superficial palmar arch and deep palmar arch are inspected, and the patency of the cephalic vein is also inspected. One side with better reflux and no history of previous surgery, trauma, and intravenous chemotherapy is selected as the donor site and is protected.
3. Three-dimensional CT data of the maxilla are recorded on a CD. The engineering technicians will read data via CAD/CAM software and then simulate the maxillary resection on the computer and form the maxillary defect images on the affected side. The maxilla at the healthy side will be copied to the affected side using the principle of mirror symmetry to produce a mirror image of the affected side after reconstruction, namely, the rehabilitation image. According to computer images, the rapid prototyping technology is used to produce the corresponding rehabilitation model. Three-dimensional titanium mesh stents of the orbital floor, the inner side of the nasal cavity, the maxillary anterior wall, and the bottom wall are prefabricated on the rehabilitation model of the maxilla before surgery.
4. Before surgery, the oral cavity clean governance is performed, and the skin in surgical area is shaved and cleaned, and the 400–600 ml of blood is prepared.

2.4.2 Surgical Procedures

1. The general anesthesia with tracheal intubation is carried out, and then the routine disinfection and draping are performed.
2. Incision design. The extraoral incision starts from the vermilion border of the lower lip at 1 cm from the medial side of the corner of the mouth, along the vermilion border, outward along the vermilion border to the corner of the mouth, then from the corner of the mouth and parallel to the nasolabial groove (correspond to the body surface projection of the posterior margin of deltoid muscle) and travels obliquely downward to cross the lower margin of the mandible and reach an area at 2 cm below the lower margin, and then a parallel incision is performed in the neck at 2 cm below the lower margin of the mandible, bypass the underneath of the mandibular angle. The cervical incision may be extended to a site below the mastoid tip, or an additional longitudinal cervical incision is performed for cervical lymph node dissection. The starting point of the intraoral incision is continued to the starting point of extraoral incision in vermilion border of lower li and travels obliquely downward to the upward side of the mandibular buccal gingival sulcus and then parallel to the mandibular buccal gingival sulcus and along pterygomandibular folds to bypass the maxillary tuberosity and then along the maxillary gingival sulcus to cross the midline (Fig. 8.3).
3. Firstly, incise the cervical and facial incisions along the deep surface of the platysma muscle and turn over the flap to the lower margin of the mandible. Dissect out the marginal mandibular branch of facial nerve in the range of at about 1 cm, respectively, above and below mandibular angle. Protect the marginal mandibular branch of facial nerve and trace it to the site where it enters into the lower lip, incise the orbicularis oris muscle on its top, and ligate the superior labial artery.
4. Incise the full-thickness intraoral lower lip incision, and incise the mandibular buccal gingival sulcus and pterygomandibular fold incisions as well as the maxillary buccal gingival sulcus incision, turn over upward the entire buccal flap along the superficial surface of the parotid masseter muscle fascia and under the periosteum of the anterolateral wall of the maxilla to reach the infraorbital margin, ligate the infraorbital neurovascular bundle, and expose the anterolateral wall of the maxilla.
5. Separate the nasal mucosa and the periosteum above the infraorbital margin, incise the mucoperiosteum in the midline of the palate, bypass the maxillary tuberosity along the posterior margin of the hard palate, and continue to the incision on the buccal-labial side. Use the electric motor saw to saw off, respectively, from the midpalatal suture, sutura nasomaxillaris, and sutura zygomaticomaxillaris, chisel off the root of the alar plate with a bone chisel, and perform en bloc resection of the lesion-affected maxilla. Ligate the internal maxillary artery, and pack the pterygoid plexus for compression hemostasis.

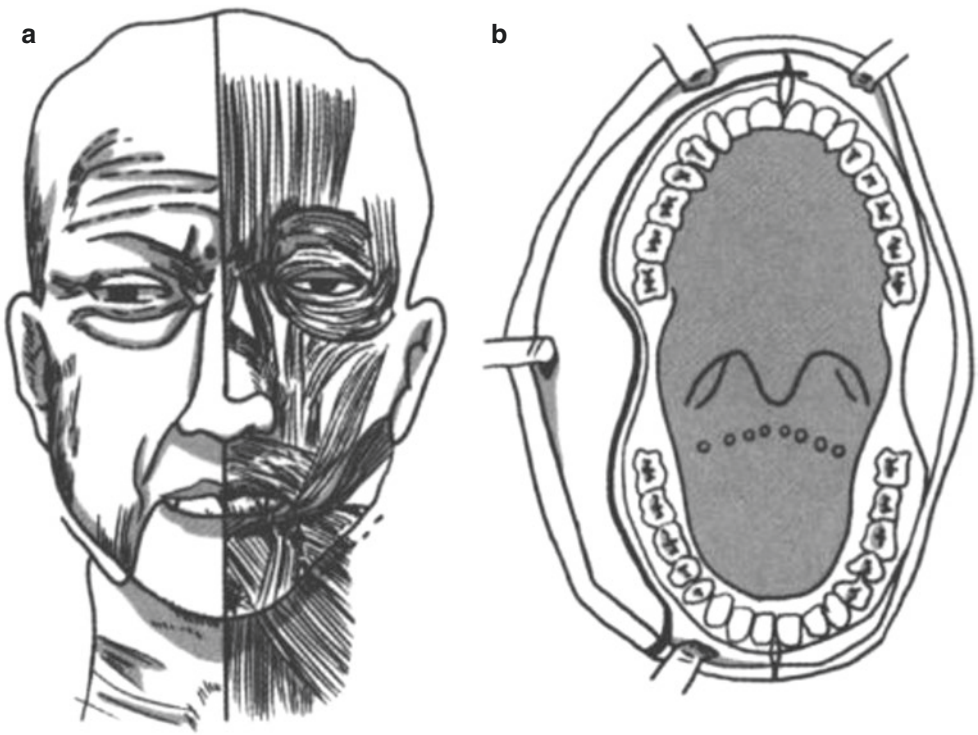

Fig. 8.3 Incision design. (**a**) Facial incision. (**b**) Intraoral incision

6. Place the prefabricated titanium mesh in the defect area at the affected side; select the root of nose, cheekbone, and contralateral alveolar bone as fixation sites; and perform fixation with titanium nails after drilling and restore the three-dimensional structure of the midface. It is appropriate to use two to three titanium nails for fixation in each site.
7. Prepare the forearm skin flap in another group, and design the skin flap according to defect size. Mark out the body surface projections of the radial artery and cephalic vein and the midpoint of the cubital fossa, and design the skin flap taking the midline of radial artery and cephalic vein as the axis; the distal end does not exceed the first transverse wrist crease; a S-shaped incision of about 10 cm is designed in the proximal end to expose the vascular pedicle, and the midpoint of the cubital fossa and its extended line.
8. Use the exsanguination band or pneumatic tourniquet to temporarily block the blood flow in the forearm. Firstly incise the proximal incision and S-shaped incision of skin flap, and bluntly dissect out the cephalic vein. Incise full-thickness S-shaped incision to expose the cephalic vein, and turn over the skin flap toward the both sides, so as to facilitate the exposure of the radial artery in later time.
9. Design the incision and incise along both sides of the skin flap, first at the inner side and then at the lateral side. Incise the skin and subcutaneous tissue to reach between the deep fascia and the myolemma; the inner side reaches the radial wrist flexor tendons, and the lateral side reaches the brachioradialis tendon. It should be avoided that the fine branches given off from the radial artery are damaged during surgery. Incise the skin and subcutaneous tissue in the distal skin flap; ligate and cut off, respectively, the radial artery, accompanying veins, and cephalic vein in the distal skin flap. Dissociate and protect the radial cutaneous nerve, and separate it from the skin flap; if it is needed to carry the radial cutaneous nerve, this nerve can be included in the skin flap.
10. Lift up the skin flap along the superficial surface of the myolemma, and prevent the detachments of the vascular pedicle of radial artery and vein from the skin flap. Isolate the vascular pedicle firstly, and ligate the radial artery perforators one by one. After being completely dissociated, the vascular pedicle is wrapped with warm saline gauze along with skin flap, and the vascular pedicle is not cut off temporarily. The exsanguination band is removed, and the blood supply situation of the skin flap is observed.
11. Prepare the blood vessels of the receptor site; separate the facial artery and vein from anastomosing with the blood vessels of the donor site.
12. The required length of the vascular pedicle is examined before being cut off, the artery is ligated at first, and then the vein is ligated. The time for cutting off the pedicle and implanting the skin flap into the receptor site should be shortened as far as possible. And then thorough hemostasis is carried out for the wound after cutting off the pedicle, the full-thickness skin graft is harvested from the abdomen for transplantation, and the pressure dressing is performed.
13. The forearm skin flap is transferred to the receptor site, is covered with titanium mesh after placement according to the defect shape, and is sutured, respectively, with mucosas around the defect to repair the soft tissue defect at the oral side of the palate. The vascular pedicle of radial artery and cephalic vein is passed out from intraoral area to the submaxillary area, the vascular torsion is prevented, and the artery and vein are anastomosed successively under the microscope; the good venous reflux is confirmed by blood vessel patency test.
14. The complete hemostasis is carried out for the cervical wound; after placement of drainage tube, the buccal flap is put back into place, and the intraoral and extraoral incisions are sutured, respectively.

2.4.3 Postoperative Care

The patient can usually wear the removable partial denture at 6–12 months after reconstruction.

From 2000 to 2002, the author reconstructed 19 cases of Class 2–3 maxillary defects of Brown classification according to the abovementioned method, including nine cases of Class 2 defect and ten cases of Class 3. All free radial forearm skin flap survive, and the facial appearances of the patients are satisfactory. The pronunciation is clear, and the degree of mouth opening ranged from 2.5 to 4.0 cm. Of all patients, 16 patients undergoing repair with removable partial denture can have a full diet or soft diet. Ten patients underwent detection of bite force and occlusal function before and after surgery. The results indicated that the recovery rate of the bite force of full mouth was between 27.05% and 74.06% after the occlusion of dentures was restored. The speech intelligibility tests showed that the value of speech intelligibility of patients was between 92.5% and 99.5%, compared with the control group consisting of normal person (99.0% ± 0.71%), and there was no significant difference.

2.5 Reconstruction of the Maxilla with Fibular Myocutaneous Flap Combined the Titanium Mesh Produced by CAD/CAM Technology

Since 2001, the author [20, 22, 23] has designed the method for the new individualized closed three-dimensional

reconstruction of Class 2–3 defects of Brown classification using the fibular myocutaneous flap combined with titanium mesh and has performed implant denture repair at the first or second stage, now which are briefly described as follows:

2.5.1 The Method of Producing the Titanium Mesh to Reconstruct the Maxilla

1. Production of maxillary model and prefabrication of titanium mesh. The operations for using CAD/CAM technology to produce the maxillary model and prefabricate the titanium mesh are the same with the former, which are not repeatedly described here.
2. Preparation of fibular myocutaneous flap. Generally the fibular myocutaneous flap in the ipsilateral lower limb is selectively used to facilitate the placement of the vascular pedicle. The length of the harvested fibula refers to the length determined on the maxillary model before surgery; the skin island is usually designed in the lower one third of the lower limb and is harvested along the deep surface of the deep fascia of the lower limb, and the perforator of skin island is carefully protected. The skin defect is closed by transplantation of the abdominal full-thickness skin graft.
3. Shaping and fixation of fibula. The biteplate made before surgery is used to guide the osteotomy and placement of the fibula and determine the implantation site of the implant. For Class 2a and 3a defects of Brown classification, the fibula is cut into two sections, which are, respectively, used to reconstruct the infrazygomatic crest and zygomaticomaxillary pillar at the affected side; and for Class 2b–2c and Class 3b–3c defects of Brown classification, the fibula is cut into two to three sections, which are, respectively, used to reconstruct the bilateral infrazygomatic crest and the pterygomaxillary pillar at the affected side (Fig. 8.4). The fibula is fixed with the contralateral alveolar crest or cheekbone and the ipsilateral alveolar crest using mini titanium plates. For Class 3 defects of Brown classification, the titanium mesh is additionally used and fixed onto the fibula and the remaining pillar in midface to reconstruct the outer wall of the maxillary sinus and the orbital floor.

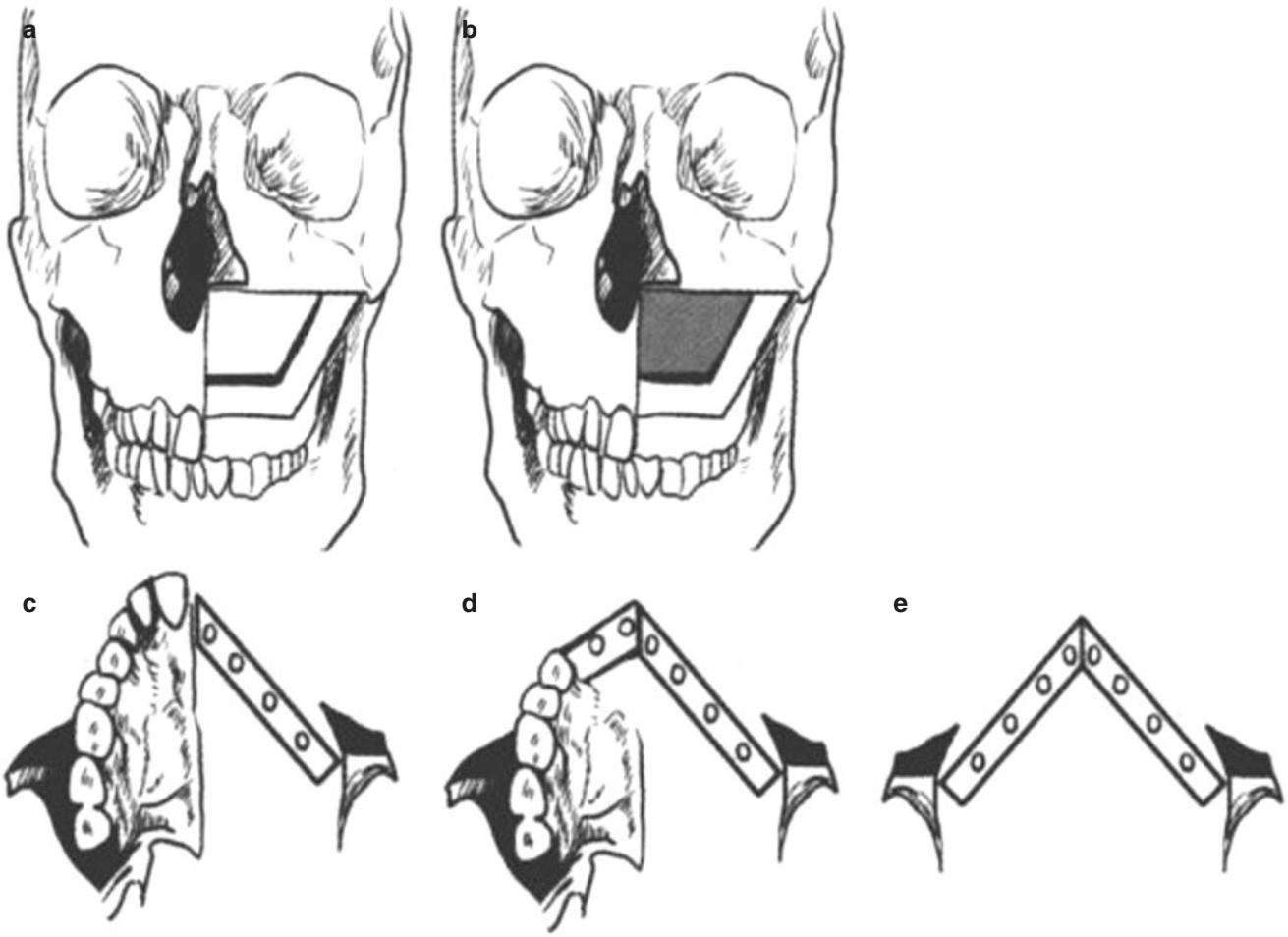

Fig. 8.4 Shaping of fibula and titanium mesh in reconstruction of Class 2–3 defects of Brown classification using fibular myocutaneous flap combined with titanium mesh. (**a**) Class 2 defects, (**b**) Class 3 defects, (**c**) Subclass a defects, (**d**) Subclass b defects, (**e**) Subclass c defects

4. Reconstructions of soft palate and nasal passage. The skin island fibular myocutaneous flap is cut into two parts, and each part carries a separate perforating branch and is used to reconstruct the soft palate and nasal airway, respectively. If there is a large amount of soft tissue defects, the free radial forearm skin flap and fibular myocutaneous flap can be harvested for repair by series connection. Among the blood vessels in receptor site, the external maxillary artery and the anterior facial vein are usually used for anastomosis; when the external maxillary artery and the anterior facial vein cannot be used, it can also be considered that other blood vessels such as the superior thyroid artery, lingual artery or superficial temporal artery, common facial vein, and external jugular vein can be selectively used.
5. Reconstructions of chewing function. After the completion of the reconstruction of the maxilla, in order to restore the full chewing function, the implant can be implanted at the first or second stage according to the need. If the implantation is performed in the same period, the implanting direction and angle of the implant will be determined by referring to the implanting direction reserved during making the biteplate before surgery and the direction and angle of antagonistic teeth. The implantation at the second stage can be performed at 6 months after reconstruction of 6 months, and it is needed to trim the thick soft tissue before implantation. The patients without conditions for implant denture repair can undergo repair with removable partial denture at 6 months after surgery.

2.5.2 Typical Case

1. Case I Immediate reconstruction of maxillary defects of Class 3 of Brown classification.
    1. Incision design: Consistent with the foregoing, the admission passage was still split in lateral lip in this case; the extraoral incision started from the vermilion border of the lower lip at 1 cm on the medial side of the corner of the mouth and outward along the vermilion border to the corner of the mouth and then started from the corner of the mouth and parallel to the nasolabial groove (corresponding to the body surface projection of the posterior margin of the deltoid muscle) and diagonally downward across the lower mandible to 2 cm below the lower margin, and then a parallel incision was made in the neck at 2 cm below the lower margin of the mandible (Fig. 8.5a).
    2. Incised and exposed the maxilla: Firstly incised the cervical incision, and then turned over the skin flap along the deep surface of platysma muscle to the lower margin of the mandible; dissected out the marginal mandibular branch of the facial nerve in the range of about 1 cm above and under the mandibular angle, and protected the marginal mandibular branch of the facial nerve and traced it. Incised the skin incision in the facial buccal area, and traced the marginal mandibular branch of the facial nerve to the point where it entered into the lower lip and protected the marginal mandibular branch of the facial nerve. Incised the orbicularis oris muscle, and ligated the superior labial artery. Incised the full-thickness intraoral incision in the lower lip, and made an incision, respectively, in the mandibular buccal gingival sulcus and pterygomandibular fold. Turned over the whole buccal flap upward along the superficial surface of the parotid masseter muscle fascia to the level of the maxillary buccal gingival sulcus, and attentions should also be paid to the protection of the buccal branch of the facial nerve if encountered in this process. Separated and dissected the facial artery and facial vein for being anastomosed with the blood vessels in donor site. Designed and incised the incisions in maxillary buccal gingival sulcus and palatal side, separated and exposed the anterolateral wall of the maxilla, and ligated the infraorbital neurovascular bundle (Fig. 8.5b).
    3. Total maxillectomy: Separated the nasal mucosa and the periosteum above the inferior orbital rim; made an incision in the midpalatal suture to reach the level of the junction of the hard and soft palate and then turn

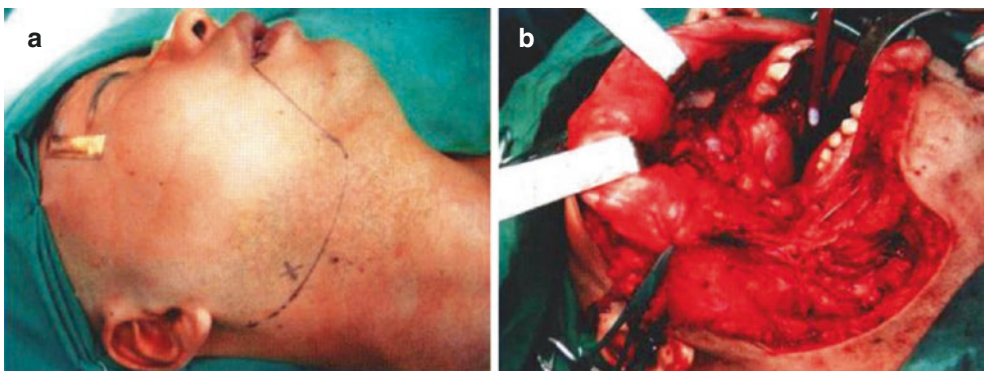

Fig. 8.5 Designed the incision, incised the skin flap, and separated and exposed the anterolateral wall of the maxilla. (**a**) Designed the incision. (**b**) Exposed the anterolateral wall of the maxilla

outward, which is continuous with the incision on the buccal side. Used the electric motor saw to saw off, respectively, from the midpalatal suture, sutura nasomaxillaris, and sutura zygomaticomaxillaris, chiseled off the root of the alar plate with a bone chisel, and performed en bloc resection of the lesion-affected maxilla. Ligated the internal maxillary artery, and packed the pterygoid plexus for compression hemostasis. The status of the right maxillary defect was revealed after the wound was washed (Fig. 8.6).

4. Harvesting of fibular myocutaneous flap: The incision in the lower limb was made (Fig. 8.7a); the skin island was designed along the position of the skin perforator marked by the ultrasound before surgery. The incision in the lower limb was incised by layers; the separation was performed along the clearance between the long peroneal muscle, the short peroneal muscle, and the soleus muscle; the long peroneal muscle and the short peroneal muscle were stripped off; the fibula was exposed; and attentions were paid to protecting the perforator. After the fibular myocutaneous flap was made, the vascular pedicle was cut off when the receptor site was readily prepared, and the fibular myocutaneous flap was harvested for transplantation (Fig. 8.7b).
5. Fixation: The harvested fibula was cut into two segments, which were fixed, respectively, with the contralateral maxilla and the ipsilateral cheekbone to reconstruct the right maxillary alveolar crest and infrazygomatic crest, and the two bone segments needed to be fixed between each other (Fig. 8.8a). The titanium mesh prefabricated on the model was used to reconstruct the anterolateral wall of the maxilla; the titanium mesh was fixed, respectively, with the fibula for reconstructing the alveolar crest, ipsilateral maxillary process in frontal bone, and cheekbone; it was appropriate to use two to threetitanium nails for fixation in each site (Fig. 8.8b). The vascular pedicle of peroneal artery and vein was passed out from intraoral area to the right submaxillary area; the vascular torsion was prevented. Under the microscope, the facial artery was anastomosed with the peroneal artery, and then the facial vein was anastomosed with the peroneal vein in turn. Good venous reflux was confirmed by blood vessel patency tests for three times. The skin island of the fibula myocutaneous flap was placed in the palate and was sutured with the surrounding mucosa to repair the soft tissue defect. The complete hemostasis for the cervical wound was performed, and the layered suture was performed after being put back original place; a rubber drainage sheet was placed in submaxillary area.
6. Postoperative treatment: The head was immobilized for 7 days after surgery; the routine anti-infection, anticoagulation, and support treatment were carried out; and the patient received the nasal feeding of liquid food. The submandibular rubber drainage sheet was removed at 3–5 days after surgery, and the stitches in wound were taken out at 7–10 days after surgery.
7. The reexamination was carried at a year and a half after surgery, and the positive profile of the patient showed that the bilateral zygomaticofacial region was symmetrical; the three-dimensional CT showed that the appearance of the right maxilla after reconstruction

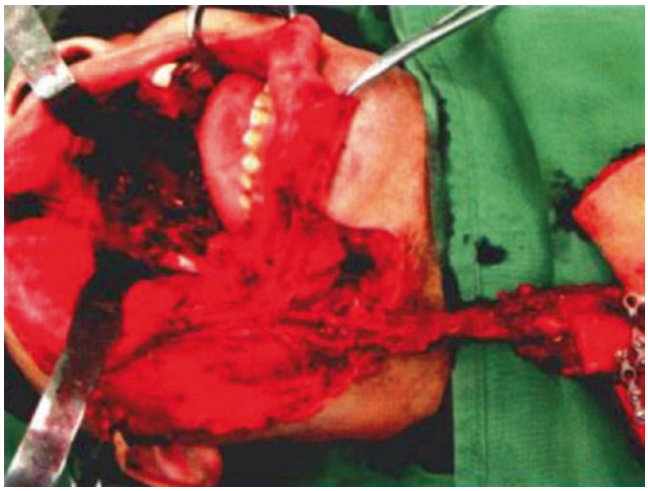

Fig. 8.6 The defect status after maxillectomy

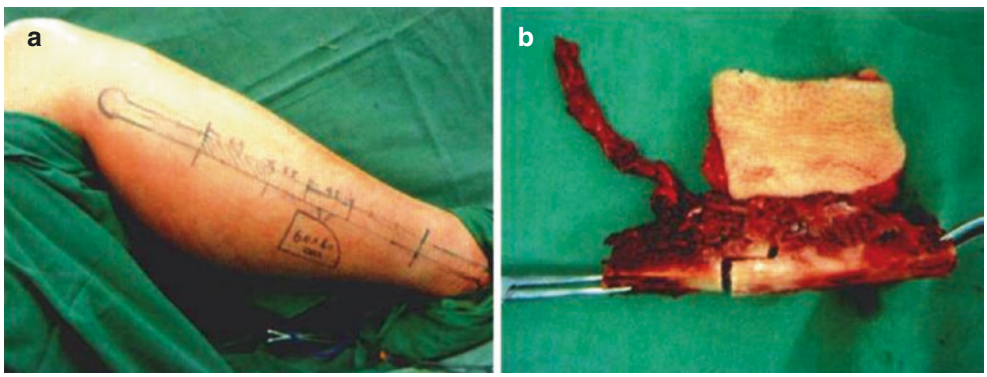

Fig. 8.7 Harvesting of fibular myocutaneous flap. (**a**) Design of the incision in the lower limb. (**b**) The prepared fibular myocutaneous flap

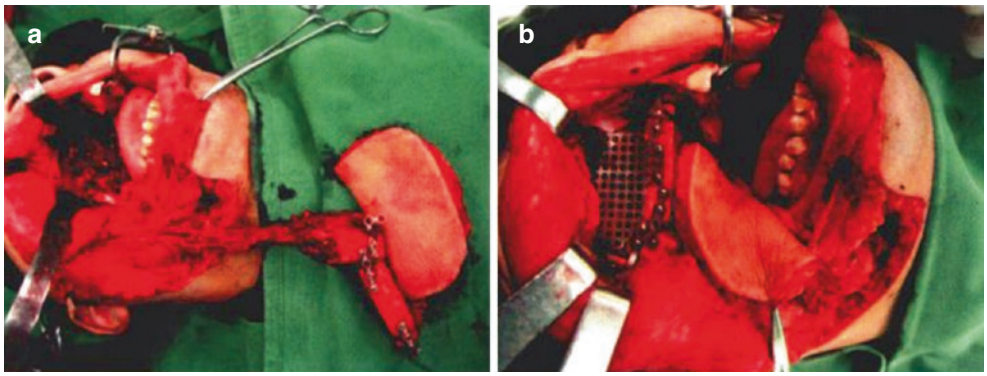

Fig. 8.8 Reconstruction of the right maxillary alveolar crest, infrazygomatic crest, and maxilla. (**a**) Reconstruction of the maxillary alveolar crest and infrazygomatic crest with the fibula. (**b**) Reconstruction of the anterior wall of the maxilla with the titanium mesh

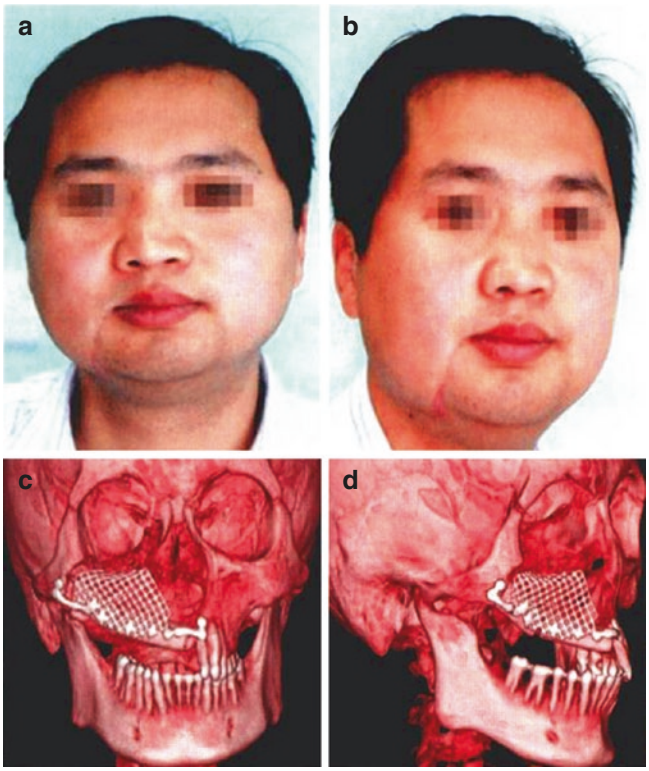

Fig. 8.9 The positive profile at a year and a half after surgery and the appearances of the right maxilla on three-dimensional CT after reconstruction. (**a**) Positive profile. (**b**) Lateral profile. (**c**) The appearance of positive side of the right maxilla on three-dimensional CT after reconstruction. (**d**) The appearance of the lateral side of the right maxilla on three-dimensional CT after reconstruction

was satisfactory, and bilateral sides were symmetrical (Fig. 8.9).

2. Case II Second-stage reconstruction of Class 3 maxillary defect of Brown classification.
   1. Incision design: because the patient had a history of left total maxillectomy, it was proposed that the subtotal resection of the right maxilla was performed at this time; therefore, the admission passage in the right lateral lip was split selectively combining the incision scar in the original left nasal side; the right submaxillary area was taken as the receptor site (Fig. 8.10a). Incised the right extraoral incision at first, and turned over the skin flap along the deep surface of the platysma muscle to the lower margin of the mandible. Dissected out the marginal mandibular branch of facial nerve within the range of about 1 cm, respectively, above and below the mandibular angle, and protected the marginal mandibular branch of facial nerve and traced it to the site where it entered into the lower lip (Fig. 8.10b).
   2. Then the intraoral incision was incised, the detailed surgical procedure is the same as in Case I, and the subtotal resection of right maxilla was performed. Attentions should be paid to protecting the nasal cannula, loosening scar, and lifting up the collapsed upper lip and nosewing (Fig. 8.10c); removed the residual palatine bone (Fig. 8.10d).
   3. Harvesting of fibular myocutaneous flap: the skin island was designed along the position of the skin perforator marked by the ultrasound before surgery. The procedures for designing the incision (Fig. 8.11a) and harvesting the skin flap were the same as those in Case I, the vascular pedicle was cut off when the receptor site was readily prepared, and the fibular myocutaneous flap was harvested for transplantation (Fig. 8.11b).
   4. At the same time, incised the original surgical scar along the left face, and turned over the skin flap to expose the left maxillary defect. The harvested fibula was cut into four segments, which were fixed, respectively, with the bilateral cheekbones to reconstruct the bilateral alveolar crests and infrazygomatic crests, and the four bone segments were fixed between each other. The prefabricated titanium mesh was used to reconstruct the anterolateral wall of the maxilla, and the titanium mesh was fixed, respectively, with the fibula for reconstructing the alveolar crest and the ipsilateral cheekbone; it was appropriate to use two to three titanium nails for fixation in each site (Fig. 8.11c). The vascular pedicle of peroneal artery and vein was passed out from intraoral area to the right submaxillary area,

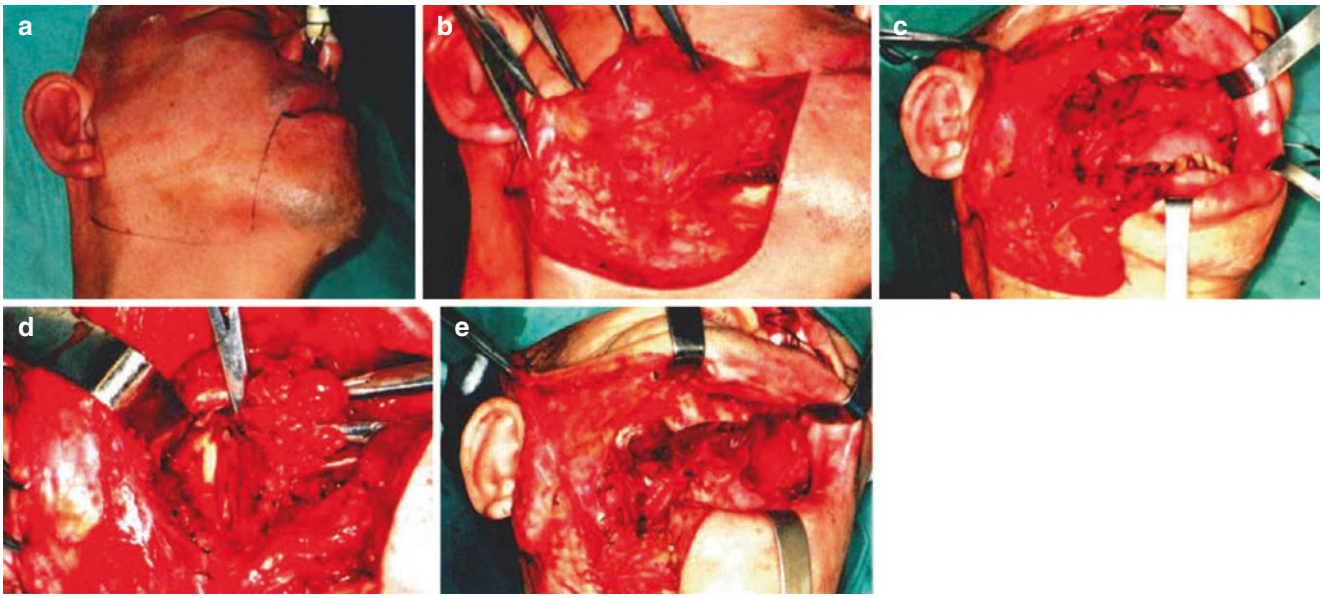

Fig. 8.10 Designed the incision, and carried out subtotal resection of the right maxilla. (**a**) Incision design. (**b**) Incised the right extraoral incision; turned over the skin flap along the deep surface of platysma muscle to the lower margin of the mandible. (**c**) Lifted up the collapsed upper lip and nosewing. (**d**) Resected the residual palate bone. (**e**) The maxillary defect status

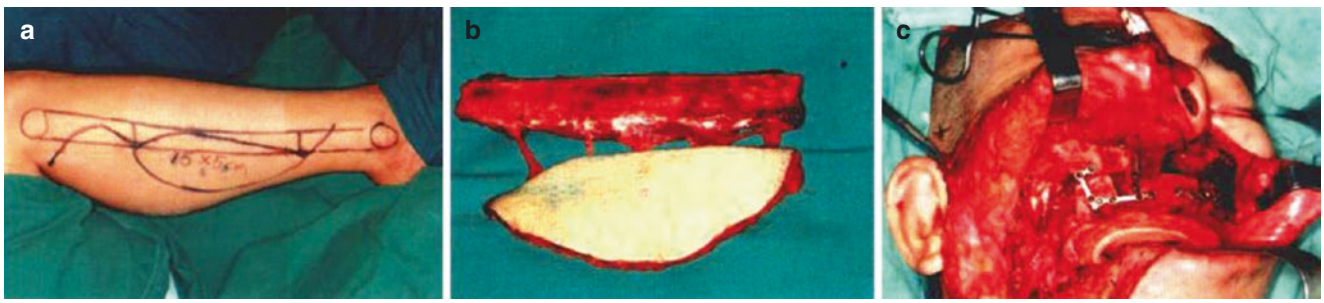

Fig. 8.11 Harvesting of fibular myocutaneous flap and reconstruction of bilateral maxilla. (**a**) Incision design. (**b**) The fibular myocutaneous flap after the pedicle was cut off. (**c**) The fibula after shaping was fixed to reconstruct the maxilla

the vascular torsion was prevented. The facial artery was anastomosed with the peroneal artery and the facial vein was anastomosed with the peroneal vein in turn under the microscope; the good venous reflux was confirmed by three blood vessel patency tests.

5. The skin island of the fibula myocutaneous flap was placed in the palate and was sutured with the surrounding mucosa to repair the soft tissue defect. The complete hemostasis for the cervical wound was performed, and the layered suture was performed after being put back to its original place (Fig. 8.12), and a rubber drainage sheet was placed in submaxillary area.
6. The positive profile at 3 months after surgery showed that the bilateral zygomaticofacial regions were symmetrical; the three-dimensional CT showed that the appearance of bilateral maxilla after reconstruction was satisfactory (Fig. 8.13).

3. Case III Second-stage reconstruction of Class 2 defect of Brown classification under the assistance of virtual operation plan.
   1. Preoperative computerized surgery simulation and surgical program design.
      1. The maxillofacial CT scan data were read by and maxillofacial CT scan data by SurgiCase 5.0 medical image processing software (Materialise Company, Belgium); the three-dimensional reconstruction was carried out using the scanned sequential tomographic images. Three-dimensional reconstructed images of the jawbone were as shown in Fig. 8.14a–c.
      2. The CT scan data of the lower limbs were read with SurgiCase 5.0 software, and the three-dimensional reconstruction was carried out on the scanned sequential tomographic images. Harvesting of the

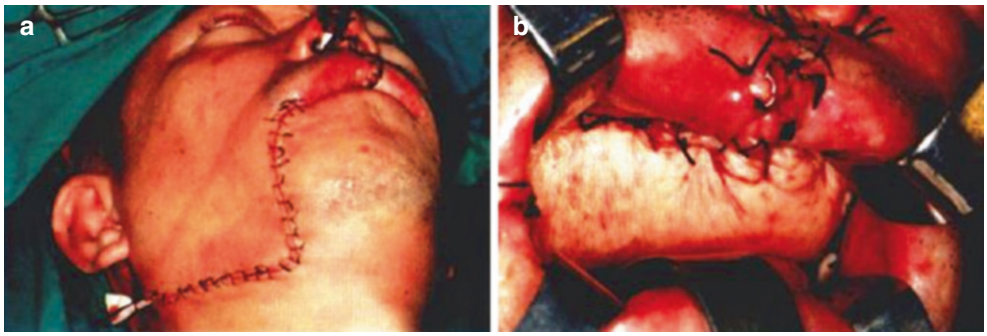

Fig. 8.12 After suture. (**a**) Front appearance after the suture. (**b**) Intraoral appearance after the suture

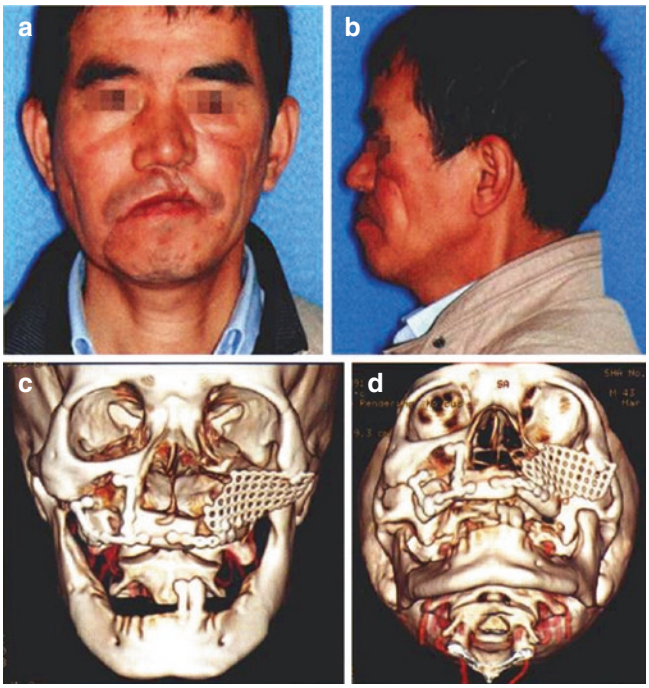

Fig. 8.13 The positive profile at 3 months after surgery and the appearances of the bilateral maxilla on three-dimensional CT after reconstruction. (**a**) Positive profile. (**b**) Lateral profile. (**c**) The appearance of positive side of the maxilla on three-dimensional CT after reconstruction. (**d**) The appearance of the maxilla from the perspective of looking up on three-dimensional CT after reconstruction

fibula was simulated on three-dimensional reconstructed images, and the length of the fibula to be harvested was determined. The fibula bone segment harvested by the computer was transferred onto the maxilla at the affected side, the adjustment was carried out according to the appearance of maxillary alveolar crest after image restoration, the shaping curve for harvesting the fibula was determined, and the position and direction of the implant were designed with reference to the tooth along axial of maxillary teeth after image restoration. The front, lateral, and bottom images after fibula reconstruction and implantation were shown in Fig. 8.14d–f. Finally, the fibular graft after shaping was compared with the original model, the final effect images of computerized surgery simulation were obtained after adjustment, and the rapid prototyping was made in accordance with the final image.

2. The surgery was performed in accordance with preoperative computerized surgical program design.
    1. Defect exposure: designed the incision along the original surgical scar (Fig. 8.15a), made a full-thickness incision flap to expose the bilateral maxillary defect, loosened the scar (Fig. 8.15b, c), and lifted up the collapsed upper lip and nosewing.
    2. Used a chainsaw to trim both broken ends until the blood oozed out, and avoided punching through the maxillary sinus. Designed the incision along the front of left antilobium, incised and turned over the skin flap, and dissected and protected the superficial temporal artery and vein as the blood vessels in receptor site (Fig. 8.15d).
    3. The titanium plate was prefabricated on the reconstruction model of maxilla produced with rapid prototyping technology, and the fixation position of the titanium plate was identified (Fig. 8.16a). According to the fixation position of the titanium plate determined on the model, the maxillary buccal cortical bone was drilled and fixed with the prefabricated titanium plate, and both broken ends of the maxilla were connected (Fig. 8.16b).
    4. The fibular myocutaneous flap was prepared in another group, and the fibula was harvested according to the required length by preoperative computer simulation. The steps for designing the incision (Fig. 8.17a) and harvesting the skin flap (Fig. 8.17b) were shown in the above article.
    5. The vascular pedicle was cut off when the receptor site was readily prepared, and the fibular myocutaneous flap was harvested for transplantation (Fig. 8.17c). According to the shaping guide plate, the prepared and shaped fibular myocutaneous flap was cut into three segments. The fibular myocutaneous flap after shaping was placed in the maxillary defect area and was drilled and fixed (Fig. 8.17d).

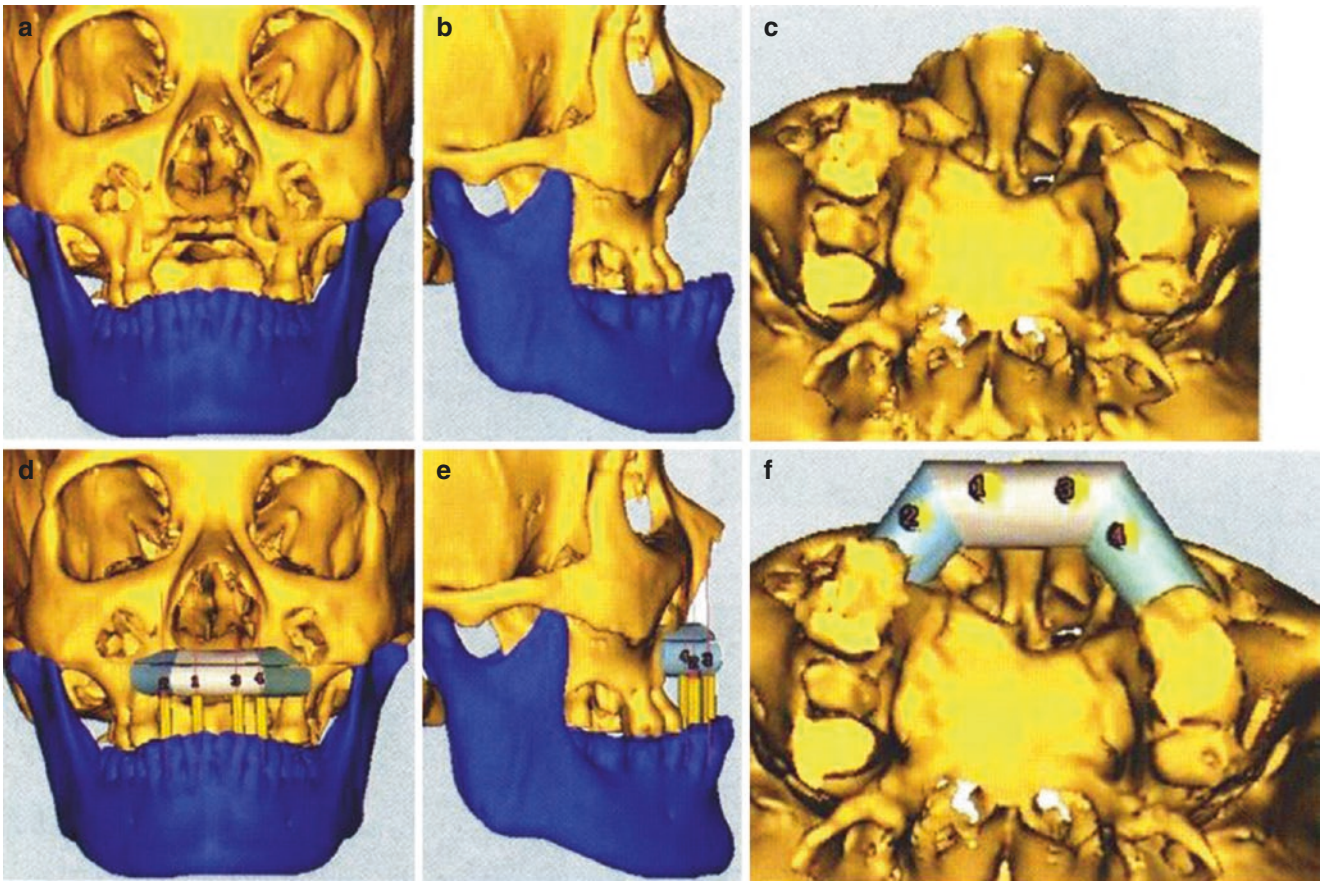

Fig. 8.14 Images of patients after three-dimensional reconstruction of jawbones, fibula reconstruction, and implant implantation. (**a**) Front image. (**b**) Lateral image. (**c**) Bottom image. (**d**) Front image after reconstruction. (**e**) Lateral image after reconstruction. (**f**) Bottom image after reconstruction

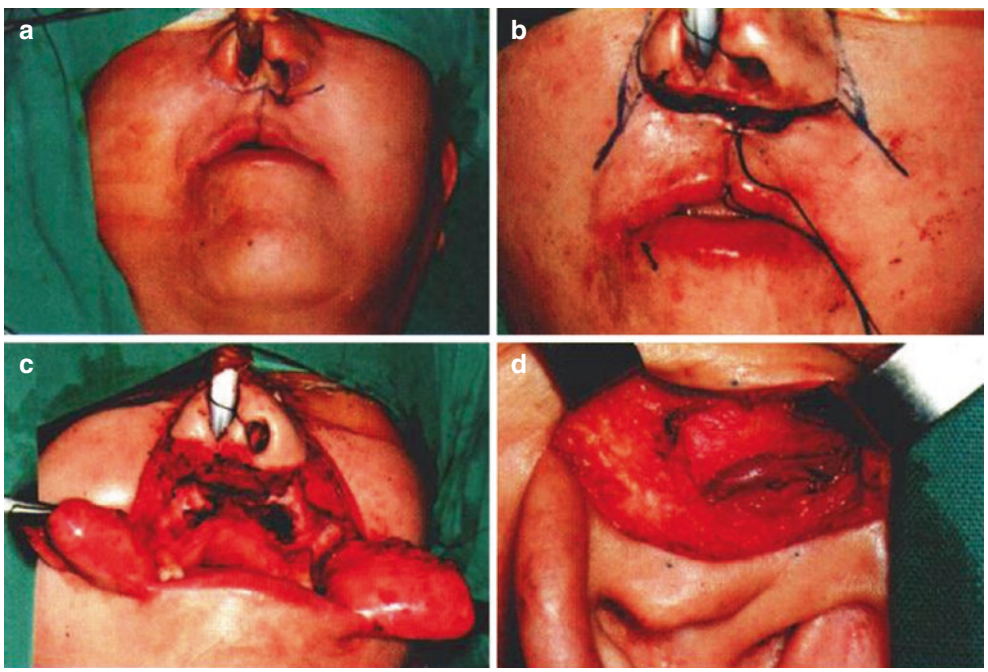

Fig. 8.15 Designed the incision along the original surgical scar, loosened the scar, exposed the defect area, used a chainsaw to trim both broken ends until the blood oozed out, designed the incision along the front of left antilobium, incised and turned over the skin flap, and dissected out and protected the superficial temporal artery and vein as the blood vessels in receptor site. (**a**) Designed the incision along the original surgical scar. (**b**) Loosened the scar. (**c**) The defect area after complete loosening of the scar. (**d**) Dissected out the blood vessels in receptor site

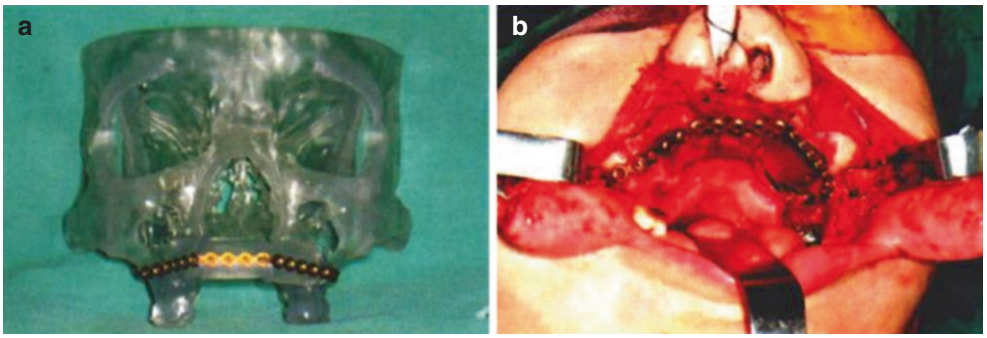

Fig. 8.16 The reconstruction model of maxilla was used to prefabricate the titanium plate and determine the fixation position of the titanium plate. (**a**) Determined the fixation position of the titanium plate. (**b**) The maxillary buccal cortical bone was drilled and fixed with the prefabricated titanium plate, and both broken ends of the maxilla were connected

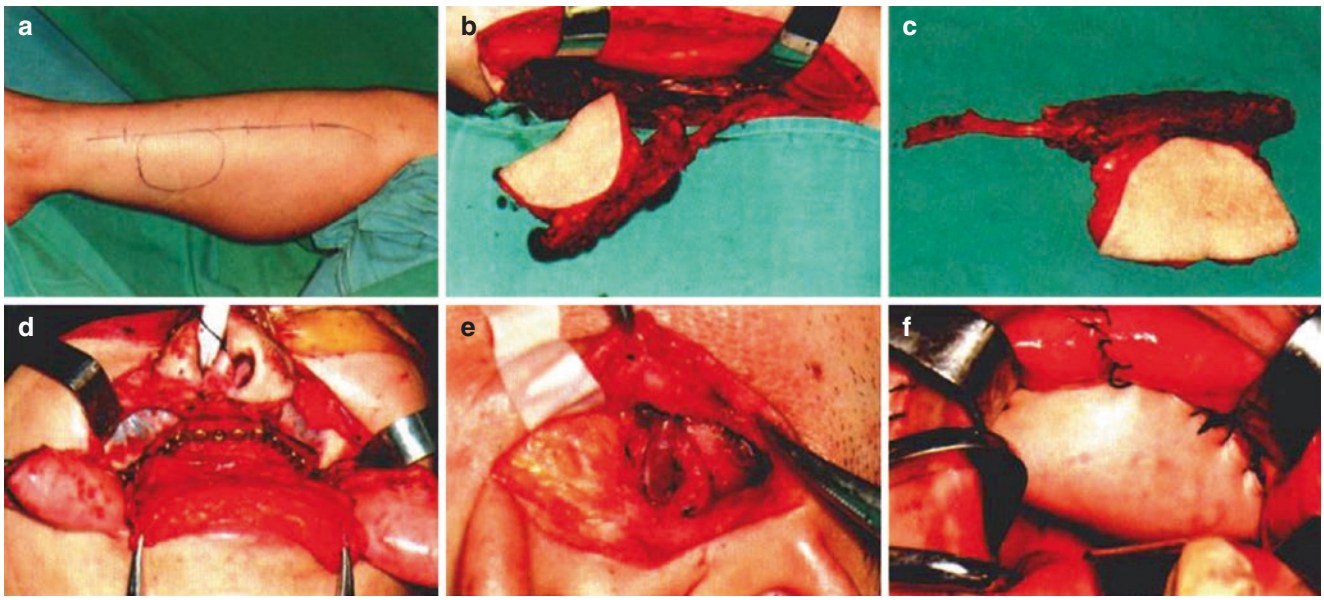

Fig. 8.17 The fibular myocutaneous flap was prepared; the fibular myocutaneous flap after shaping was placed in the maxillary defect area and was drilled and fixed. (**a**) Incision design. (**b**) The prepared fibular myocutaneous flap. (**c**) The fibular myocutaneous flap after the vascular pedicle was cut off. (**d**) The fibular myocutaneous flap was shaped and fixed. (**e**) The vascular anastomosis was performed and good venous reflux was confirmed. (**f**) The appearance after repair of the intraoral mucosa defect with the skin island

6. The superficial temporal artery and vein were anastomosed with the peroneal artery and vein in turn under the microscope, and the good venous reflux was confirmed by three blood vessel patency tests (Fig. 8.17e). The skin island was used to repair the intraoral mucosa defect (Fig. 8.17f).
7. The complete hemostases for bilateral upper lip wounds were performed, and the layered suture was performed after being put back to its original place (Fig. 8.18); a rubber drainage sheet was placed in front of the left ear.
8. At 3 months after surgery, the positive and lateral profiles showed that bilateral upper lips had no collapse and the intraoral wound healed well. The three-dimensional CT and panoramic radiograph showed that the appearance of the maxilla after reconstruction was satisfactory and the bilateral sides were symmetrical (Fig. 8.19).

From 2001 to 2008, the authors had reconstructed a total of 28 cases of maxillary defects of Class 2–3 of Brown classification according to abovementioned methods, of which there were 9 cases of Class 2 defects and 19 cases of Class 3 defects; 6 patients with extensive soft tissue defects were repaired using series connected radial forearm free skin flap. In addition to that, one patient had skin island necrosis due to the compression of the perforator of the skin flap; all the remaining 27 fibular myocutaneous flaps and 6 radial forearm free skin flaps survived. The imageological examination showed that the bony fusions between the bone segments of

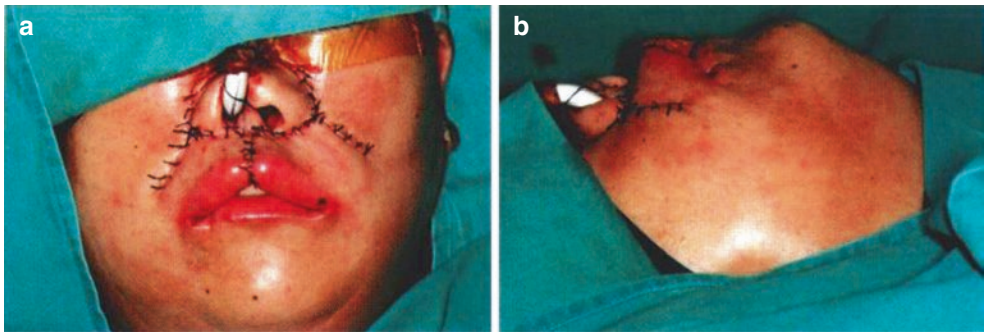

Fig. 8.18 After suture. (**a**) Positive profile after suture. (**b**) Lateral profile after the suture

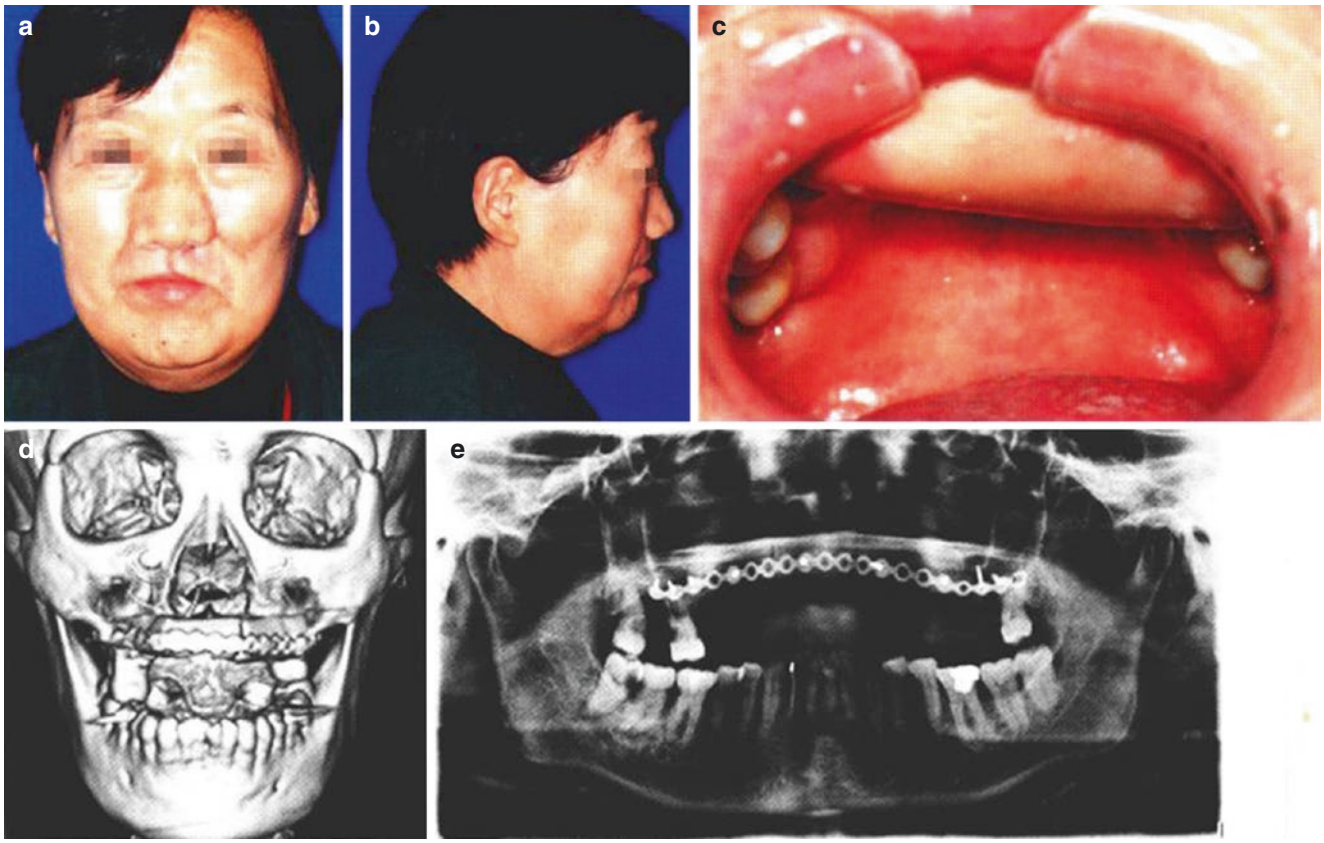

Fig. 8.19 Positive profile at 3 months after surgery, three-dimensional CT, and panoramic radiograph. (**a**) Positive profile. (**b**) Lateral profile. (**c**) The intraoral wound healing well. (**d**) Three-dimensional CT. (**e**) Oral panoramic radiograph

fibula and the adjacent bones were good. After a follow-up of 9–72 months, the appearance of the midface of the patient was satisfactory, and the bilateral sides were basically symmetrical, the oral and nasal cavities were completely separated, and the pronunciation was clear. The speech intelligibility test showed that the speech intelligibility values of the patients had no significant difference compared with the people in normal control group, all patients could have a full diet or soft diet, three patients underwent implant-supported denture restoration, and 15 patients underwent removable partial denture restoration. The detections of bite force and occlusal function were performed before and after surgery; the results indicated that, after restoring the occlusion of dentures, the recovery rate of the bite force of full mouth was between 42.50% and 79.28% with an average of 61.35%, which was greater than that in the patients undergoing reconstruction using the titanium mesh scaffold combined with the radial forearm free skin flap (50.15% ± 14.59%). Among the 15 patients with Class 3 maxillary defect of Brown classification in whom the titanium mesh was used to reconstruct the lateral wall of maxilla and support the eyeballs, two patients undergoing second-stage reconstruction had exposure to part of the titanium mesh under the inner canthus and in buccal gingival sulcus, respectively, at 4 months and 36 months after surgery

and thus needed to undergo the second surgery to eliminate the exposure of the titanium mesh, and the remaining 13 patients had no exposure of the titanium mesh; the probability of titanium mesh exposure was 13.3% (2/15), which was significantly lower than that in patients undergoing reconstruction with the aforementioned titanium mesh combined with the transverse rectus abdominis myocutaneous flap or the anterolateral femoral skin flap (27.8%, 5/18) and was also lower than that in patients undergoing reconstruction with the titanium mesh combined with radial forearm free skin flap (21.1%, 4/19) [22].

The authors' experiences show that the fibular myocutaneous flap combined with the titanium mesh can effectively reconstruct the Class 3 maxillary defect of Brown classification. The fibula can be used to reconstruct the alveolar crest and the zygomaticomaxillary pillar, and the titanium mesh can be used to reconstruct the lateral wall of the maxillary sinus and inferior orbital rim and orbital floor, of which the alveolar crest, the inferior orbital rim, and orbital floor are the horizontal pillars of the midface, and the zygomaticomaxillary pillar is the vertical pillar of midface. In addition to the nasomaxillary pillar, a few major pillars which maintain the appearance and function of the midface have been effectively restored. Upon completion of implanting dentures or partial dentures, the chewing stress is not only distributed onto the new alveolar crest and the zygomaticomaxillary pillar, and the lateral wall of the maxillary sinus reconstructed by the titanium mesh can also play a role in conducting part of the stress. The stress distribution is very similar to the normal maxilla which is extremely similar to the stress distribution of the normal maxilla. Thus, it can be seen that the fibular myocutaneous flap combined with titanium mesh is a relatively simple and reasonable method for reconstruction of Class 3 maxillary defects of Brown classification. But for the patients with Class 4 defects of Brown classification, whether this method is applicable or whether it is needed to be in combination with other methods still requires further study and discussion.

3 Related Problems and Prospects for Maxillary Reconstruction

3.1 Application of Functional Surgical Concepts in the Maxillary Reconstruction

Oral and maxillofacial functional surgery refers to a new surgical connotation and category which carries out immediate or deferred reconstruction of tissue defects and organ loss in oral and maxillofacial area caused by tumors or trauma to achieve the purpose of restoring the function and appearance. The oral and maxillofacial functional surgery mainly includes the following three aspects: (1) The diseased tissues are removed and the normal tissues are preserved under the premise that the principles of surgical oncology are not violated. (2) The immediate repair and reconstruction should be performed after removal of defects caused by the diseased tissues. (3) The functional repair should be promoted on the basis of tissue repair and anatomical reconstruction, including sensory or dynamic reconstruction. The authors believe that the application of functional surgical concepts in the reconstruction of the maxilla should follow the following aspects and should be comprehensively considered combined with the demand of patients:

3.1.1 Facial Appearance

After preoperative CT information of the patients is input into the CAD system, the rapid prototyping technology is used to make the maxillary virtual model with defects. According to the principle of facial symmetry, maxillary model for rehabilitation is designed, which thus accurately guide the individualized shaping and placement of the maxilla. The upper and anterior walls of the maxillary sinus can be supported with the prefabricated titanium mesh, and the retentive force can be strengthened, and thus the patient's appearance can be effectively restored.

3.1.2 Chewing Function

The functional reconstruction of maxilla is performed with free composite osseous myocutaneous flap combined with the CAD/CAM technology, the accurate three-dimensional bony structure of the midface is reconstructed anatomically, and the original appearance of the maxillary alveolar crest is restored, so that the reconstructed tissues can withstand a certain chewing pressure. For patients with defects equal to or greater than Class 3 according to Brown classification, the zygomatic implant can also be implanted to strengthen and effectively conduct the biting force. The CAD/CAM technology can also guide the surgeon to design the osteotomy line and the fixation sites according to the model before surgery, which is conducive to guiding the accurate placement of the transplanted bone and thus maximizes the possibility of appearance of the stress concentration regions when performing function after surgery; the planting technology can provide reliable retention, stabilization, and support for the dentures, so that the optimal chewing efficiency can be achieved in the maxilla after reconstruction.

3.1.3 Voice Function

The free radial forearm skin flap or composite osseous myocutaneous flap can be used to repair the bottom wall of the maxilla completely and tightly and close the oral surface and nasal surface at the same time, thus preventing the occurrence of the oronasal fistula. The radial forearm skin flap sometimes overcomes the limitation that the tissue volume is

insufficient when the larger soft tissue wound is repaired simply with the fibular myocutaneous flap. Its sufficient length ensures a good adhesion of the soft palate and also ensures the accuracy of the tongue-palatal contact in the process of pronunciation; therefore, the soft palate will not shrink back at the same time, and the occurrence of velopharyngeal incompetence can be maximally prevented and the incidence rate of hypernasality can be greatly reduced in patients after maxilla resection.

3.1.4 Ventilation Function

Because the free radial forearm skin flap can be prepared according to required sufficient length, and its placement also has considerable flexibility, the use of the radial forearm skin flap can not only close the wound at the oral side but also reconstruct the nasal air passage of the patient through folding the skin flap to recover the nasal ventilation function of the patient after surgery.

3.2 The Factors to be Considered in Maxillary Reconstruction

The maxillary reconstruction is a very challenging and complex issue; the reconstruction surgeon should fully consider the various factors when making a surgical plan, such as the site and volume of the maxillary defect, whether combined with the surrounding tissue defect, the structural condition of the remaining bone, the general condition of the patient, the need for adjuvant radiotherapy, the technological level of the operator, the location of the tissue flap to be harvested, the scope available for harvesting, and the situation of the vascular pedicle. The relevant parameters needed to be taken into full account when the maxilla is reconstructed are listed in Table 8.1, which are available for consideration by the surgeons engaged in repair and reconstruction when making a surgical plan, in order to select the most effective and appropriate reconstruction method to obtain the best aesthetic and functional results.

3.3 The Prospect of the Functional Reconstruction of the Maxilla

At present, the maxillary defect reconstruction has achieved considerable progress, the postoperative problems on basic oral functions and aesthetic requirement in patients with maxillary defects have also been better resolved, and the composite osseous myocutaneous flap combined with planting technology has established its dominance in functional reconstruction of maxilla and will continue to be improved in the future. Of course, the combined use of multiple repair methods such as composite osseous myocutaneous flap, local tissue flap, and prostheses to reconstruct the maxillary defect can get better results than the reconstruction with single technology, but the current functional maxillary reconstruction still has the following deficiencies to be improved: how to further restore the sinus cavity structure within the maxilla, how to solve the problem of taking the inner mucosa to replace the current skin tissue to repair the intraoral defect, and how to reconstruct more accurately the osseous pillar in the midface, the soft tissue coverage in the surface, and related dentures. Solving these problems not only depends on the continuous improvement and upgrading of the existing biological materials and technology but also places the hope on that some subjects which are still at the experimental stage are solved one by one, such as vascularized transplantation of ligamental tissues and application of in situ tissue-forming techniques. The functional reconstruction of the maxilla still requires careful planning and close cooperation among surgeons in department of surgical oncology, department of reparative and reconstructive surgery, department of prosthodontics, and department of radiotherapy to achieve the satisfactory long-term outcome in function and appearance. To this end, scholars from various countries are constantly working hard to achieve the same goal, that is, to reconstruct the appearance and function of the maxilla and reproduce the original structure and stomatognathic system in the midface of the patient.

Table 8.1 The relevant parameters needed to be taken into full account when the maxilla is reconstructed

Defect	Skin flap	Related conditions
Position	Location	Systemic conditions
Volume	Size	Systemic diseases
Whether it is three-dimensional defect	Volume and thickness	Radiotherapy
Bone structure support	Tissue structure (bone, muscle, skin)	Previous surgery
The appearance of the patient	The vascular pedicle length and diameter	The patients' requirement
Bacterial infection	Complications at the donor site	Economical condition

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Repair and Reconstruct of Mandibular Defects

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1 Overview

The oral and maxillofacial region is one of the main factors that constitute the human facial appearance. The mandible is located in the lower one third of the face, and it has a major impact on the appearance characteristics of the person. The facial appearance plays a major role in the human body shape, and a small change in facial appearance can cause the attention of other people. The mandibular defect occupying the lower one third of the face will cause marked facial deformity, in addition to the appearance of damages in a series of physiological functions, and the patient will suffer from diminished quality of life due to varying degrees of disfigurement. All kinds of social activities of the patient will be seriously affected, which will lead to varying degrees of psychological trauma.

The mandibular defects caused by head and neck tumor surgery are often accompanied by defects in surrounding soft tissues such as the floor of the mouth, tongue, and buccal area. The impact on the chewing function occurs at first. A change in pronunciation and the digging language will be resulted due to the lack of coordination of the surrounding soft tissue, and the swallowing, sucking, and respiratory functions will be affected to varying degrees. The composite tissue defects in the lower face have a greater impact on the facial appearance of the patient, and thereby the psychological and mental traumas are very serious. Therefore, high attentions must be paid to the repair and reconstruction of the mandible. During treatment, we should consider not only the functional reconstruction of the mandible and relevant tissues but also pay attention to the improvement and repair of the facial appearance, try our best to apply the existing technologies in maxillofacial surgery and plastic surgery to make each patient get perfect repair and reconstruction, and lay a good foundation for their future reintegration into society.

For the repair and reconstruction of the mandible, one of its main contents is to reconstruct the occlusional relationship. If the occlusional relationship is not repaired and reconstructed, only partial recovery of appearance and function is achieved in patients after mandibular reconstruction. The lack of occlusional relationship will cause the loss of chewing function on the one hand; on the other hand, the facial soft tissues will have a different degree of invagination due to the lack of support of the teeth, and it makes the face look older than the actual age. Therefore, the repair and reconstruction of the mandible not only aim to restore mandibular continuity and integrity but also must establish conditions for denture retention, bearing the bite force, and performing chewing function, in order to restore the physiological function of the oral cavity. In clinics, the buccal labial sulcus and the hyomandibular canal in local area often become shallow or disappear after repair and reconstruction of the mandible, the alveolar crest is missed, or the height of the reconstructed mandible is inadequate; all these cause difficulties to oral denture restoration, and the chewing function cannot be recovered effectively. Since the 1970s, the scholars at home and abroad have carried out the denture restoration successively which takes the endosseous implant as the retention and bearing foundation. In addition, in order to increase the height of the reconstructed mandible, the continuous innovations in surgical techniques are pursued, so that the technological level of repair and reconstruction of the mandibular defect is increasingly improved and the dual purposes of appearance recovery and functional reconstruction are achieved to a large extent. Therefore, it is very necessary to develop and popularize the technologies for repair and reconstruction of the mandible in surgical oncology clinics, and it can benefit the majority of cancer patients [1–9].

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1.1 Classification of the Mandibular Defects

To facilitate the gradient classification of mandibular defects caused by tumor and trauma and the statistical analysis of follow-up data, and facilitate guiding clinical treatment at the same time, a number of scholars at home and abroad have put forward a variety of different classification methods for mandibular defects since the 1980s.

The classification methods which are more commonly used in foreign countries include HCL [7] and CRBS [27] classification methods. Many domestic scholars have presented different classification methods from different angles, of which Zhang Chenping put forward a new functional classification method for mandibular defects characterized by functional zoning.

Zhang Chenping et al. divided the mandibular defects into three classes according to the frequency of occurrence of mandibular defect:

1. Class I defects: The defects which are limited to the mandibular body (occlusion area)
2. Class II defects: The defects in muscle area – occlusion area
3. Class III defects: The defects in condyloid process – muscle area – occlusion area

Three classes of mandibular defects all have two subclasses 1 and 2: I1, alveolar defects; I2, the segmental defect in occlusion area; II1, the defects in coracoid area; II2, the segmental defect in muscle area; III1, the defects in condyloid process; and III2, the defects in condyloid process and muscle area.

To further refine the description of defects in occlusion area, it is stipulated that the occlusion area is divided into two tooth position areas such as anterior tooth position area and posterior tooth position area; a (anterior) represents three tooth positions in anterior tooth area, and p (posterior) represents three tooth positions in posterior tooth area, namely, the bilateral occlusion areas which are divided into four quadrants. In this way, the defect record of the defects in bilateral occlusion areas can be expressed as pa-ap, and "-" indicates crossing the midline. In addition, in order to reflect the defect morphologies in jaw-lifting muscle group and adjacent organs such as the lips and tongue, it is stipulated that the italic letters m (muscle group), l (lip), and t (tongue) indicate the defect morphologies in the jaw-lifting muscle group, lips, and tongue and are labeled respectively at the end of the abovementioned classifications.

This classification method can relatively comprehensively reflect the morphologies of mandibular defects, which is conducive to clinical comparative studies while helping to choose different reconstruction methods.

1.2 Indications, Objective, and Preoperative Preparation for Repair and Reconstruction of Mandibular Defects

1.2.1 Indications

In the field of repair and reconstruction of defects after head and neck tumor surgery, the repair and reconstruction of mandibular defects have been one of the focuses. Before carrying out the microsurgical techniques, the repair and reconstruction of mandibular defects have been at a low level. As technology advances, the technological level of repair and reconstruction of mandibular defects has been greatly improved, the mandibular reconstruction which needed to be completed by multiple operations in the past is now basically completed at one time, and both the appearance and function after reconstruction have a qualitative leap compared with before. For surgical treatment of malignant tumors in head and neck soft tissue or the mandible, due to the development of the microscopic technology, the surgeons are no longer worried about the difficulties in repair of oral and maxillofacial defects; therefore, the surgical safety margin is more assured compared with that in the past, and the surgical indications for mandibular reconstruction are also greatly expanded.

Currently, it is basically advocated that the immediate repair and reconstruction of intraoperative defects of the mandibular benign tumors are performed with different approaches. The controversial issue in indications for repair and reconstruction of mandibular defects is mainly whether the defects after malignant tumor surgery are repaired at the same period. The conventional wisdom holds that the patients should be observed for 2 years and, if no recurrence occurs, the repair and reconstruction will be performed; but along with the viewpoint of ensuring the quality of life getting accepted, more and more scholars approve the viewpoint that one-stage reconstruction is performed intraoperatively. After all, both the appearance and function in patients undergoing repair are much better than those in patients without undergoing repair or with other alternative products. One-stage simultaneous reconstruction has obvious advantages compared with second-stage reconstruction, which are mainly reflected in the following aspects:

1. There is no apparent scar tissue.
2. The local vascular conditions are good, which is conducive to microsurgical operation.

3. The position of the mandible has no significant change, which will help reestablish the occlusional relationship.
4. It is much easier to recover the appearance and function before the patients fall ill.

But the premise is that there must be enough safety margins in tumor resection and the patients can withstand long-time operation.

1.2.2 Objectives of Repair and Reconstruction

1. The continuity of the mandible is restored.
2. The occlusional relationship is reestablished at the same time or second stage, and the dentition is reconstructed.
3. The bone and soft tissue profile and the normal anatomical landmarks in the lower one third of the face are reconstructed.
4. The physiological functions such as chewing, swallowing, and breathing and other physiological functions are restored to improve the quality of life.

From the functional point of view, restoring the continuity of the mandible is very important, because the mandible is the support structure of soft tissues such as the mouth floor, lips, and tongue. Once the mandible is lost, there will be occurrence of various degrees of functional disorders, such as chewing, swallowing, and articulation disorders. From the viewpoint of the facial appearance, because the osseous mandible and the adjacent tissues jointly form the lower one third of the face, the relationships between the nose, lips, and mandible constitute one of the main features of facial appearances of individuals, and restoring the continuity of the mandible will help to restore the facial symmetry and balance, while the osseointegration implant or postoperative buccal gingival sulcus plasty is applied in the denture repair to restore the chewing function of the patient and also improve the recovery of the facial appearance.

1.2.3 Preoperative Preparation

The radical resection of oral mandibular malignant tumor is often accompanied by adjacent soft tissue defects, the soft tissue repair performed at the same period is crucial to restore the appearance of soft tissues and ensure the healing of reconstructed mandible, and the preoperative comprehensive consideration should be carried out from the perspectives of the head and neck surgery and the repair and reconstruction of oral and maxillofacial area [9–12].

The repair and reconstruction of defects after mandibular tumor resection are a delicate operation, which requires that the operators not only have good microsurgical techniques but also have good aesthetic point of view, grasp the structural characteristics of normal facial appearance, and have a more in-depth understanding on the concept of the occlusional relationship. At the same time, it is also needed to make evaluations on the patient's medical history, the general condition and range of local lesion, and the intraoperative defect statuses of soft tissues and bone tissues, in order to understand whether it is needed to simultaneously perform the repair and reconstruction of defects with other soft tissue myocutaneous flaps [2, 12–17]. The operators must have a clear understanding of the situation of blood vessels in receptor site and prepare well accordingly.

The preoperative preparations include the further examinations of the general condition of the patient, such as heart and lung function, surgical tolerance indicator inspection, and the exclusion of distant tumor metastasis. At the same time, the mandible panoramic radiograph and CT examination must be carried out before surgery, and the two imageological examinations are the bases to determine the range of the mandible resection. The soft tissue surrounding the mandible can be evaluated by MRI to better determine the resection range of the soft tissue. At the same time, attentions should be paid to the patient's oral hygiene, and the patients with poor oral hygiene may undergo periodontal scaling before surgery. While the situations of the temporomandibular joint, the full mouth dentition, and the occlusional relationship should be examined, the appropriate preparation should be made for edentulous patients before surgery, such as temporary retention plate. For difficult cases with mandibular displacement, CAD/CAM technology can be used to prefabricate personalized mandible models of the patients, so that the reconstructed mandible is coordinated.

2 Application of Vascularized Osseomyocutaneous Flap in Mandibular Reconstruction

The bone transplantation is a method mostly used in repairs and reconstructions of various types of mandibular defects. The experimental study and clinical application of the bone transplantation have a history of nearly 200 years. Although greater progresses have been made in aspects such as the understanding of the biological physiology of bone transplantation, the concepts of immunology of bone graft, the treatment and preservation of allogeneic bones, the application of heterogeneous materials and the improvement of surgery, and the repair and reconstruction of function and appearance for patients with mandibular defects and have obtained more satisfactory results, the complications such as delayed union, nonunion, and bone resorption still exist in many aspects, which are not satisfactory. In the early 1980s, the development of microsurgical techniques and the clinical application of vascularized bone transplantation symbolized that the mandibular defect repair had entered into a stage of functional repair. The vascularized transplantation has

advantages that it can repair large complex defects at one stage, is not subject to the constraint of the blood vessel condition in receptor site, and has strong resistance to infection, less transplanted bone resorption, and strong biological and mechanical properties, so that the indication range for bone transplantation is continuously expanded. Therefore, we can say that vascularized bone transplantation is a milestone in the treatment of mandibular defect.

For the donator selection for the bone transplantation, the autogenous bone transplantation is still the bone transplantation most widely used in mandibular reconstruction. The fibula and ilium are the main bone donor sites, and in addition, there are also the ribs, tibia, scapula, mandible, and skull. The autogenous particulate marrow-cancellous bone transplantation and the replantation of frozen autologous diseased bone also have been applied in clinical practice. In recent years, the tissue-engineered bone also has been tried in clinical practice and has achieved preliminary results. Under some circumstances, the heterogeneous materials such as titanium reconstruction plate still have a useful value. However, among a variety of methods, the vascularized autologous bone transplantation is still the main method for mandibular reconstruction [18–26]. In this article, the authors will make a brief introduction to some methods commonly used in clinics at present.

2.1 Application of the Iliac Osseo-myocutaneous Flap in Mandibular Reconstruction

The iliac osseo-myocutaneous flap plays a very important effect in repair and reconstruction of mandibular defects, and it is one of the donor sites which are most commonly used at present. Manchester firstly reported that the shape of curved front part of the ilium was very similar to the shape of the unilateral mandibular body and, because of its adequate bone mass, it became the most commonly used donor site of non-vascularized bone block and cortical cancellous bone in the early stage. In 1979, the researches performed respectively by Taylor from Australia and Magou from the United Kingdom confirmed that the deep circumflex iliac artery (DCIA) and the deep circumflex iliac vein (DCIV) were the most reliable vascular pedicles for vascularized iliac transplantation. The research of Taylor indicated that the deep circumflex iliac artery and vein system provides blood to the entire ilium and periosteum and its range is from the anterior superior iliac spine to the sacroiliac joint. DCIA also provides blood to the skin on the surface of the ilium. In 1984, the research of Ramasamy indicated that the ascending branch of DCIA was the main blood vessel supplying blood to the obliquus internus abdominis muscle and thereby the modified iliac osseo-myocutaneous flap occurred. Its main characteristic is that, in addition to the iliac bone flap, the internal oblique muscle flap is also included and the single pedicled two skin flaps can be formed in most cases. The mobility of the muscle flap is better, which is very beneficial for repair and reconstruction of oral and maxillofacial soft tissue defects.

2.1.1 The Applied Anatomy

The ilium is located in the upper part of the hip bone and is a fan-shaped irregular bone. It is mainly consisted of cancellous bone, and its surface is thinner cortical bones. The ilium is divided into the hypertrophic iliac body in the lower part and the abducent and flat wide iliac ala in the upper part. The iliac body mainly constitutes the acetabulum and participates in the composition of the hip joint; the lower posterior side of the iliac ala is the rough auricular surface, which participates in the composition of the sacroiliac joint. The upper margin of the iliac ala is fat and thick, slightly arched, and called as the iliac crest, its front and rear ends are thicker, and the middle part is slightly thinner. The morphology of the iliac crest is similar to that of the lower margin of mandible. The anterior part of the iliac crest protrudes toward the lower anterior side and is known as the anterior superior iliac spine (ASIS). ASIS is attached to the inguinal ligament, sartorius muscle, and tensor fasciae latae muscle. Close to the body surface, the tubercle of iliac crest is the protuberance at 5–7 cm from its posterior side, so it is the preferred donor site of the free bone grafts due to its flat surface and the thick cancellous bone. The posterior end of the iliac crest is the posterior superior iliac spine (PSIS). In adults of China, the average length between ASIS and PSIS is 24.4 cm (20.1–28.8 cm). The range for bone harvesting in clinics is generally within 10–12 cm backward from ASIS, so as to avoid damage to the posterior part of the iliac ala which can affect the stability of the sacroiliac joint.

The inner surface of the iliac ala is a shallow nest which is known as iliac fossa, and it is the attachment site of the iliac muscle. DCIA and DCIV run at the medial side of the iliac fossa. The lower boundary of iliac fossa is a blunt round bone crest, which is called as the arcuate line, and is the bony boundary between greater pelvis and small pelvis. The outer side of the iliac ala is the gluteal surface, which is attached to gluteus. The upper half of the lateral gluteus maximus muscle, gluteus medius muscle, the piriformis muscle, and gluteus minimus muscle in the underneath and the musculus iliacus at the medial side are mainly involved in the movements of the hip joint. The front end of the iliac crest is attached to the tensor fasciae latae muscle and the sartorius muscle; the former is participated in the movements of the hip joint; the latter stops at the tibia and is participated in the movements of the knee joint. After bone harvesting, these muscles should be put back to their original place and sutured to avoid affecting the activities of the

abovementioned joints. The upper part of the iliac crest is attached to the abdominal muscles, which are the abdominal external oblique muscle, abdominal internal oblique muscle, and transverse abdominal muscle, respectively, from the shallower to the deeper. The anterior end of the iliac crest is the end point of inguinal ligament consisting of aponeurosis transmigrated from the muscles, and the posterior end of the iliac crest is attached to the latissimus dorsi fascia. Of which the abdominal internal oblique muscle is usually used in combination with the iliac bone flap to repair the composite head and neck defects. The abdominal internal oblique muscle is the flat wide muscle located between the abdominal external oblique muscle and transverse abdominal muscle; starts from the thoracolumbar fascia, iliac crest, and inguinal ligament; and is attached to the tenth to twelfth rib muscles and the sheath of rectus abdominis muscle. The ascending branch of DCIA is its main blood supply, and in addition, it also receives the blood supply from the inferior epigastric artery, the lumbar artery, and the branch of thoracic artery. The diameter of the ascending branch given off from DCIA is 1–2 mm, which passes through the transverse abdominal muscle to reach the deep surface of the abdominal internal oblique muscle. According to related studies, it is found that the abdominal internal oblique muscle in about 80% of persons is supplied with blood from a main blood vessel given off from the medial side of the ASIS and therefore the abdominal internal oblique muscle can be used as an axial pattern flap to operate; the remaining 20% of persons have no separate branches, but only some small branches at the outer side of ASIS enter into abdominal internal oblique muscle, and in the operation, the muscle can only be attached to the inner table of the iliac crest.

DCIA is given off from the outer side of the external iliac artery above the inguinal ligament, and the inferior epigastric artery is given off below it. DCIA runs toward the outer upper side between the abdominal muscle and the iliac muscle, and it, namely, runs within the fiber channel fused by the transverse abdominal muscle membrane and fascia iliaca, with a distance of 0.4–2.2 cm from the inner side of the iliac crest. It gives off multiple perforating branches along the way to feed various layers of abdominal muscles and the iliac crest, and its terminal branches are anastomosed with the iliolumbar artery and the fourth lumbar artery. The diameter of DCIA is 2–3 mm. The length from the connection point of the external iliac artery to ASIS is 5–7 cm. The initial part of DCIA varies greatly; the highest point reaches up to 1.3 cm above the inguinal ligament, and the lowest point reaches down to 2.4 cm below the inguinal ligament (i.e., originating from the femoral artery).

DCIV is usually composed of two accompanying veins, which are merged into one DCIV before meeting the external iliac vein, and accompanies the DCIA in the inguinal ligament. The femoral vein is constantly located in the medial side of the femoral artery.

According to the running direction of DCIA and the situation of giving off perforating branches along the way, when the iliac bone flap is prepared, attention must be paid to retaining the myocardial sleeves of the abdominal external oblique muscle, abdominal internal oblique muscle, and transverse abdominal muscle where the perforating branches pass through, that is, to retain the myocardial sleeves within 3 cm from the inner table of the iliac crest and keep away from the abovementioned perforating branches.

Meanwhile, the area for flap harvesting mainly involves the iliohypogastric nerve, the ilioinguinal nerve, the lateral femoral cutaneous nerve, and the femoral nerve, which are mixed nerves issued by the lumbar plexus. The former three nerves mainly control the movements of the abdominal muscles and the cutaneous sensation in the lower abdomen and inguinal area and at the anterolateral side of the thigh and the lateral hip. After they are injured, the main performances are presented as the decreased muscular tension in inguinal area and reduced cutaneous sensation in corresponding areas. The femoral nerve in the deep surface of the inguinal ligament travels at the lateral deep surface of the femoral artery and participates in movements of hip and knee joints and the cutaneous sensation in the leg. Therefore, the operators must have a clear understanding on the running directions of these nerves to facilitate intraoperative identification and protection.

2.1.2 Design and Application

Since the anatomical characteristics of the iliac crest are similar to those of the mandible in many respects, and the cancellous bones are rich, it is more commonly used for repair of the mandibular segmental defect at one side.

Currently, the iliac bone flaps mainly include nonvascularized iliac bone flap, free vascularized iliac bone flap, and the iliac osseo-myocutaneous flap with the abdominal internal oblique muscle or transverse abdominal muscle or skin. When the skin flap is designed in clinics, the following factors should be considered according to the specific circumstances: (1) these include designs of incision, bone flap, and muscle flap and the location and shape of the flaps; (2) for the vascularized osseo-myocutaneous flap, the running direction of vascular pedicle must be considered at first; and (3) when the skin incision is designed, the medial side above the inguinal ligament at the femoral pulse point can be taken as the starting point of the incision, and the incision runs upward and presents as S-shaped curve and reaches to the site for bone harvesting.

If it is needed to prepare an osseo-myocutaneous flap, the blood vessel characteristic of the flap must be considered at first, because its blood supply comes from the myocutaneous perforators of DCIA, and the direction of the flap must be

parallel to the inner margin of the iliac crest to ensure that a sufficient number of myocutaneous perforators are included. The island is usually designed as spindle shaped to facilitate direct suture closure of wounds. In addition, in order to ensure the blood supply to the skin island, it is required to retain 3 cm wide of abdominal internal and external oblique muscles and transverse abdominal muscle between the iliac crest and the flap as muscle sleeves. According to our experience, after such a bloated flap is placed in the mouth, almost all patients will require a second surgery. Therefore it is best applied for repair of defects combined with extraoral skin defects.

Generally, the length of the iliac bone flap is determined based on the mandibular body defect. The length of iliac crest bone graft is generally 11–12 cm, and the longest is no more than 15 cm, so as to prevent the occurrence of significant complications in donor site. The height of bone flap is usually within 2–3 cm; if necessary, the bone flap is cut off from the lateral surface and is reshaped to recover the appearance of the mandible; and the cancellous bones must be filled into split bone seams to prevent the occurrence of nonunion.

If it is needed to repair the mandibular ramus with processus condyloideus, the iliac skin flap can be designed to be L-shaped. If the ipsilateral iliac bone is harvested, the mandibular ramus can be designed in the anterior end of the bone flap, and ASIS can be reconstructed into the shape of the lower oblique angle and also can be retained. To avoid the deformity and dysfunction in donor site caused by the excessive defects in the anterior end of the iliac crest, the contralateral iliac bone can also be harvested, the mandibular ramus can be designed in posterior end of the bone flap, and the height of the mandibular ramus is determined based on the defect, usually downward to 4–6 cm below the upper margin of the iliac crest. Attentions must be paid to trying not to strip off too much muscle attachments.

2.1.3 Preparation of the Internal Oblique-Iliac Crest Flap

The general preparation is the same as that for the abovementioned iliac bone flap. An S-shaped incision from the medial side of the femoral artery pulse point to the iliac crest is made, and if the cutaneous flap is harvested at the same time, the connecting line between ASIS and the inferior angle of scapula can be taken as the central axis to design the skin flap including main myocutaneous perforators. The skin, subcutaneous tissue, and abdominal external oblique muscle and its aponeurosis are incised, and 3 cm width of muscle tissue is retained and connected to the iliac crest to protect myocutaneous perforators. Subsequently, the abdominal external oblique muscle is turned over to the costal margin level to expose the entire abdominal internal oblique muscle. The size of the muscle flap is designed according to the size of defects in receptor site, and the abdominal internal oblique muscle is incised and turned over from the surface of the transverse abdominal muscle. Near the 12th rib, the plane between the abdominal internal oblique muscle and the transverse abdominal muscle are most easily identified and separated, because the direction of the muscle fiber is different between the two muscles. The operation must be carefully performed at the plane to fully lift up the abdominal internal oblique muscle, the integrity of the transverse abdominal muscle must be maintained in this process, while the dissection is carefully performed to identify and protect the ascending branch of DCIA and the nerve vessel bundle across the plane from the outside to the inside. The terminal branches of the subjacent nerve vessel bundles are intertwined together, with the ascending branches, and thus must be cut off. The ascending branches of DCIA are visible at the deep surface of the abdominal internal oblique muscle, the trunks of the ascending branches pass through the transverse abdominal muscle and then converge into DCIA and DCIV, and whereafter, DCIA and DCIV are dissected to the site of the external iliac blood vessel. At the moment, the iliac muscle and the lateral femoral cutaneous nerve can be exposed. DCIA and DCIV travel within the fibrous sheath formed by the fusion of the transverse abdominal muscle and iliac fascia sheath fibers. A 2 cm muscle sleeve should be retained at the inner table of the ilium to protect them. After the operation in medial side of the ilium is completed, the dissection in outer side of the ilium can be performed. The outer table of the ilium is sharply dissected for osteotomy, while the lateral femoral cutaneous nerve is dissected in the vicinity of ASIS and is protected. The iliopsoas muscle and sartorius muscle at the medial side of the ilium are carefully cut off. After dissection and separation are completed, the abdominal contents, DCIA, and DCIV are well protected.

If the abdominal internal oblique muscle is supplied with blood by a single ascending branch, it can be incised parallelly through the iliac crest to vascular ascending branch from outside to inside, and thus the abdominal internal oblique muscle flap can be further dissociated. At the same time, attention should be paid to retaining 3 cm width of lateral myocardial sleeves to avoid damage to the myocutaneous perforators passing through the abdominal muscles.

In order to prevent the occurrence of incisional hernia, the thorough hemostasis and washing must be performed in the wound after skin flap harvesting, and then the wound is sutured close by three layers. The transverse abdominal muscle is sutured with the iliac muscle in the first layer, and then the abdominal external oblique muscle and its aponeurosis are sutured with the tensor fascia lata tendon and gluteus medius tendon in the second layer; finally, the skin and subcutaneous tissue are sutured after the negative pressure drainage is placed. For a period of time after surgery, it is required that the pillows are padded under hip and popliteal space at the side of bone donor site, and the flexed positions

of the ilium and the knee joint are maintained. The off-bed activities are gradually resumed 5–6 days later.

2.1.4 Typical Case

Case I The patient, male, 51 years old, had clinical diagnosis which is right lower gingival carcinoma, $T_3N_1M_0$. The patient underwent radical resection of right lower gingival carcinoma under the general anesthesia, the primary focus in right mandible was treated with the segmental osteotomy, and the mandibular defect was repaired and reconstructed with the iliac osseo-myocutaneous flap (Fig. 9.1).

2.1.5 Common Complications and Its Prevention

The ilium is taken as the bone donor site for mandibular defect, which has a history of more than 30 years. Because its bone quantity is large and the morphology of the iliac crest is similar to that of the lower margin of mandible, the repair of unilateral mandibular defect can achieve satisfactory appearance effect and also is conducive to intraoperative or postoperative implanting to restore the chewing function after surgery. But it also has some complications in the donor site; according to statistics, after harvesting the flap, the incidence rate of abdominal external hernia is approximately 9.7%, the incidence rate of local long-term pain and discomfort is 8.4% [13, 24], and furthermore, there exists peripheral nerve degeneration and postoperative limp. In addition, the iliohypogastric nerve and ilioinguinal nerve distributed in the surgical area pass through the three layers of abdominal muscle, and their damages often occur, which causes skin numbness in the corresponding area. Therefore, the abovementioned factors must be taken into account during the operation to avoid damages of related nerves, the wound in donor site after harvesting the flap should be sutured well, and the patient is immobilized within a period of time after surgery and avoids load bearing at an early period. The local area is treated with appropriate physiotherapy to promote recovery.

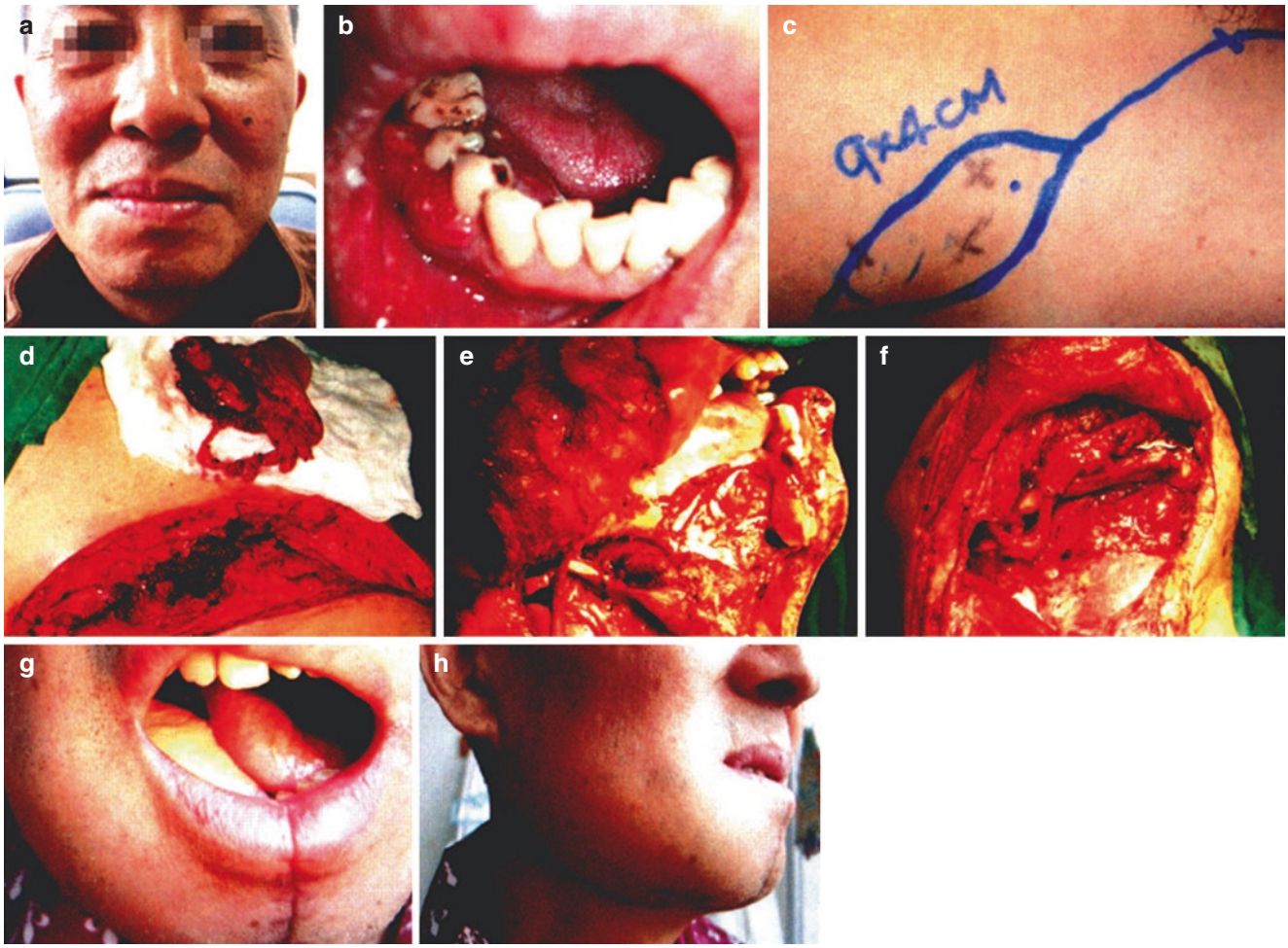

Fig. 9.1 Case I. (**a**) Positive profile before surgery. (**b**) Primary focus before surgery. (**c**) Incision design of iliac osseo-myocutaneous flap. (**d**) Intraoperative preparation of iliac osseo-myocutaneous flap. (**e**) Intraoperative resection of the primary focus. (**f**) Placement and fixation of iliac osseo-myocutaneous flap. (**g**) The flap survived well at 10 days after surgery. (**h**) Lateral profile at 10 days after surgery

2.2 Application of Fibular Myocutaneous Flap in Mandibular Reconstruction

2.2.1 Applied Anatomy

The fibula is located at the lateral side of the calf, and it is not the important load-bearing bone of the calf. Its lower one fourth participates in the composition of the ankle joint and plays a role in strengthening joint stability. The average length of fibula is about 34 cm, the upper end of fibula is expanded into the fibular head and is not directly involved in the composition of the knee joint, and it can be used in condylar reconstruction in clinics. The maximum length of fibula available for harvesting is 26 cm. The fibula has dual bone cortexes, the upper segment of its cross section is quadrilateral, the lower segment is triangular, and the appearance is constant. The average diameter of the middle segment of the fibula in Chinese people is 12.8 ± 2.4 mm in males and 11.1 ± 2.0 mm in females, respectively, which can meet the need of the implant retention. The bicortical structure can also enhance the stability of the implant.

The blood supply of the fibular osteocutaneous flap comes from the peroneal artery and its two accompanying veins. Under normal circumstances, the popliteal artery is bifurcated into the anterior tibial artery and the posterior tibial artery, and the posterior tibial artery gives off the peroneal artery; the peroneal artery and its accompanying veins run down between the flexor pollicis longus and posterior tibial muscle at the medial side of the calf. However, the blood supply of the fibula sometimes has some anatomical variations according to researches by scholars at home and abroad. Understanding these anatomical variations helps to avoid ischemic complications in feet.

The study of Wu Yongmu et al. on 100 Chinese peoples showed that the peroneal arteries are divided into four types according to different starting points: type I is given off from posterior tibial artery, accounting for 90%; types II and III are given off separately from the anterior tibial artery and the popliteal artery, each accounting for 1%; and type IV peroneal artery is absent and is replaced by the posterior tibial artery, accounting for about 8%. If the blood vessels are blindly ligated, the blood supply disorder of posterior calf muscle group may occur; at the same time, if the diameter of the anterior tibial artery is small, a phenomenon such as foot ischemia may occur. The blood supply of the fibula is characterized by the dual blood supply system of periosteum and bone marrow; namely, the fibular nutrient artery and the arcuate artery reach the bone marrow cavity, periosteum, and bone cortex of the fibula, respectively. In most cases, there is only one fibular nutrient artery; it passes through the nutrient foramen at the medial side of the fibula to enter into the bone marrow cavity to constitute the blood supply of the fibular bone marrow, providing nutrition to the bone marrow and a part of the bone cortex. There are 4–15 arcuate arteries, which are segmentally distributed along the fibula and clinging to the periosteal surface and constitute the periosteal artery network, and they are the sources of blood supply to adjacent periosteums and muscles. Even if the single source of blood supply such as the periosteum branch of the arcuate artery is retained, the fibula still can survive. This is also the anatomical basis for that multiple segmental wedge resections of the fibula flap which can be performed in clinics, and each bone segment still has sufficient blood supply.

In addition to the nutrient artery of the fibula and the muscle – periosteum vessels, it is observed that the peroneal artery and its veins also include the fasciocutaneous perforator traveling within the intermuscular space at the posterior side of calf to feed the skin in this region. Wherein, there are three thick and constant cutaneous branches at 9–20 cm below the fibular head, and the outer diameter is about 1.6 mm, which is the anatomical basis for clinical preparation of fibular flap. The in-depth studies of many scholars prove that the lateral calf skin is fed by the intermuscular space perforators of the peroneal artery; these perforators are divided into the following three types: type A, the intramuscular perforator, passes through the long peroneal muscle to reach the lateral calf skin, with no muscle branches, and is located mostly in the proximal and middle one third of the thigh; type B is also an intramuscular perforator, passes through the gastrocnemius muscle and long peroneal muscle, and gives off muscle branches before reaching the skin; and for type C, its running direction is similar to that of the type B, but it gives off the space perforator instead of the intramuscular perforator, which is mostly located in the middle and distal one third of the calf.

The study of Beppu on the distribution of blood vessel perforators in lateral calf skins of 23 patients showed that a perforator was located very constantly in the midpoint of connecting line between the fibular head and the lateral malleolus. Among the 23 patients, it was found that a perforator was located at a site within 2 cm near the midpoint in 21 patients and the blood supply provided by the peroneal artery to the proximal one third of the lateral calf skin was not constant. In the anatomies of 23 patients, the peroneal artery had no perforator supplying blood to the proximal one third of the lateral calf skin in 5 patients. While in the anatomies of 23 patients, there was at least one skin separating perforator at the middle one third of the calf. But the anatomical studies of some authors suggested that about 20% of the samples did not support the existence of the skin separating perforator and 6–25% of the samples had no muscle and muscle separating blood vessels at the same time. Therefore, it is now considered that the absolute confidence level of fibular flap is 93–94%. Although the reliability of the blood supply to the skin island is still controversial, according to Wei's report, in which the fibular flap was used in the reconstruction of 80 cases of limbs and 27 cases of mandible, the

skin island had achieved a 100% successful survival rate. The author designed the center of the island design at the junction of middle one third and distal one third of the fibula and emphasized that the intermuscular space at the posterior side of calf must be included in the skin island; the operator should not pull too much in the process of flap preparation and wound closure, so as not to damage the blood supply of the skin island. Currently, most scholars adopt the method of Fleming for preparing the skin island of fibular flap, and that is to dissect at the level under the fascia from anterior to posterior. In order to be able to adapt to and accommodate possible variation in the position of intermuscular space perforators, a longer skin island can be designed. If there is no existence of the skin separating perforator, it is required to look for the myocutaneous perforator supplying blood to the skin. If there is no myocutaneous perforator given off from the peroneal artery, it indicates a need to select another separate soft tissue flap to repair the soft tissue defects. In the patients with skin separating perforators, part of muscular sleeves of flexor hallucis longus muscle and soleus muscle should also be carried, because when converging into the peroneal artery, these perforators may pass through these muscles, but the sizes of the harvested muscle sleeves should be appropriate.

The results of the study on injecting dye into the peroneal artery indicate that the average width of stained skin area is 9.9 cm and the length is 21.4 cm. Fleming successfully divided the skin island into two parts through incising the skin instead of incising the fascia.

The sensation in lateral calf skin comes from the lateral sural cutaneous nerve, which comes from the common peroneal nerve, while the common peroneal nerve is divided into the deep peroneal nerve and the superficial peroneal nerve at the fibular neck, which control, respectively, the anterior muscle group and lateral muscle group in the calf. The common peroneal nerve gives off a pair of cutaneous nerves at the outer side of the popliteal space, namely, lateral sural cutaneous nerve and the sural communicating nerve; the lateral sural cutaneous nerve controls the lateral and posterior skins in the calf. But some scholars have reported that the large lateral sural cutaneous nerve has a great variation; 22% of people lack this nerve. The sural communicating nerve is the second sensory nerve crossing the area of fibular flap, and it combines with the medial sural cutaneous nerve into the sural nerve. In clinic, according to this dissection method, the lateral sural cutaneous nerve or sural nerve is anastomosed with the lingual nerve or inferior alveolar nerve, which may restore sensory function.

There are three types of anatomical variations:

1. Fibula variation: The fibula may be absent or replaced by the ligament due to significant changes in size, which is often accompanied by abnormal tibia.
2. Blood vessel variation: The studies of scholars at home and abroad show that there is no phenomenon of the absence of the peroneal artery, and there are also no reports of the absence of anterior tibial artery. But the diameter of anterior tibial artery may be significantly reduced. Under the circumstances, only a traffic branch from the peroneal artery can provide blood supply to distal limbs with narrowed or missed arteries; therefore, the ligation of the peroneal artery may lead to ischemia in the foot.
3. Nerve variation: The lateral sural cutaneous nerve and the communicating branch of peroneal nerve have great variations, and multiple scholars have reported that these two kinds of nerves are absent in a considerable proportion of people.

2.2.2 Design Principles

The harvested fibular myocutaneous flap needs to be fixed with the reconstruction plate or the titanium plate, the fibula can be fixed only at the outer side of the fibula. And because the vascular pedicle of fibular flap is relatively short, the location needs to be designed near the mandibular angle as much as possible. Therefore, under normal circumstances, the repair of the unilateral mandibular body requires taking the contralateral calf as the donor site; the calf at the side with more defects will be selected as the donor site for repair of the anterior mandibular defect; the calf at the side of the cervical blood supplying vessels will be selected as the donor site for repair of the bilateral defects. The positioning can meet the requirement that the strong internal fixation is performed in lateral side, and the implanted implant in the upper margin does not damage the blood vessels.

Due to the limitation of the anatomical structure, the vascular pedicle of the fibular myocutaneous flap is generally shorter. The more distal osseo-myocutaneous flap will be harvested in clinics. Meanwhile, the mesial parts of periosteum and the vascular pedicle are stripped off downward, and the proximal middle bone segment is removed, so that the vascular pedicle may be extended. Hidalgo et al. [3] reported that a vascular pedicle of approximately 13 cm long can be obtained using this method. In addition, there is no significant difference in diameter between the proximal and distal ends of the peroneal artery and vein, so that the fibular flap can be used as a bridge flap. To repair a greater range of soft tissue defects, the tandem skin flap is formed when a free soft tissue flap is connected at the distal ends of the peroneal artery and vein on the fibular flap.

In order to meet the requirements for denture repair or requirements for implantation of bone fusion implant after surgery, the scholars at home and abroad increase the height of alveolar crest with the method of placement and fixation

of double layers of fibula, so that the requirements for facial appearance and function after repair can be satisfactorily met. In addition, in China, Zhang Chenping applied the distraction osteogenesis techniques in stretching of the fibular flap, designed the vertical distraction of fibula built-in dental implant combining two technical advantages such as implantation and distraction osteogenesis, achieved the purpose of increasing the height of alveolar crest, and obtained ideal results.

If it is needed to prepare the fibular myocutaneous flap with sensory nerve, the osseo-myocutaneous flap with sural nerve can also be prepared, and the traffic branch of the nerve can be anastomosed with the inferior alveolar nerve to restore the sensation of fibular myocutaneous flap.

2.2.3 Preparation of the Fibular Myocutaneous Flap

According to the anatomical characteristics of the lateral calf, the corresponding anatomical landmarks are marked on its outer side. The landmark points of the muscular clearance are the fibular head in the upper part of the calf and lateral malleolus in the lower part of the calf, and the connecting line between two points is the position of the intermuscular space at the posterior part of the calf. If the skin island is needed simultaneously, it can be designed as spindle shaped, and its midline is the position of the intermuscular space. Since the main perforator of the skin flap is usually located in a slightly remote location of the calf, the central point of the skin flap is typically designed at the junction of middle and distal one thirds of the calf.

After the landmark points are drawn, that is, the dissection is started after the 350 mmHg balloon or tourniquet is wrapped around the thigh (the time of usage of tourniquet is controlled within 1–1.5 h). According to the designed incision line, incise the skin and subcutaneous tissue and the fascia on the superficial surface of the long and short fibular muscles; after that, dissect at the deep surface of this fascia from anterior to posterior and toward the direction of intermuscular space; at the moment, it is easy to find the myocutaneous perforator given off from the area near the inferior margin of fibula; the position of the skin island can be redefined according to the position of the flap perforator. After that, sharply dissect along the superficial surface of the outer periosteum of fibula, and turn up the long fibular muscle, short fibular muscle, and extensor hallucis longus; the osteotomy is performed, respectively, at the proximal middle and distal middle part of the fibula, the interosseous membrane is further dissected and exposed along the medial surface of the fibula, and the distal portions of the peroneal artery and vein are dissected out through pulling the fibula and then are ligated and cut off. Afterward, the posterior margin of the skin flap is incised at the surface of the gastrocnemius muscle and the soleus muscle to reach to the deep surface of the fascia, and the dissection is performed along this surface, and the skin island with myocutaneous perforator can be formed. This skin island can be temporarily fixed on the fibular bone flap with a needle for fear that the perforator is pulled to affect the survival of the skin island. Then the bone flap is pulled outward, and the interlaced posterior tibial muscle fibers are incised along the inner side of the peroneal artery and vein toward the direction of the proximal middle part, while the branches of the peroneal artery and vein between and within the muscle fibers are ligated and cut off to the bifurcation site of peroneal artery and the posterior tibial artery. The flexor hallucis longus must be cut off in this process, only part of the muscle sleeve is retained on the fibula, the vascular pedicle is cut off, and the fibular myocutaneous flap with a peroneal artery and two accompanying veins is formed. Because of the need to protect the vascular pedicle, the tissue flap carries part flexor hallucis longus and tibialis posterior muscle sleeves.

In the preparation of fibular bone flap, in order to avoid damage to the peroneal nerve and maintain the stability of the ankle joint, about 7 cm long bone segments must be retained, respectively, at the proximal and distal ends of the fibula. Attention must be paid to protecting the deep peroneal nerve passing through the neighboring area.

If it is needed to prepare the fibular myocutaneous flap with sensory nerve, the lateral sural cutaneous nerve given off by the common peroneal nerve must be tracked toward the mesial direction before the posterior margin of the skin flap is incised. After this nerve is found, the skin island can be reached along the nerve. The sural communicating branch can be given off at this site from the common peroneal nerve, but this nerve does not control the sensory function of this skin island and can be included into the skin island for vascularized nerve transplantation [2, 13].

2.2.4 Fibular Shaping and Vascular Anastomosis

1. Fibular shaping: In order to match the morphology of the mandible, the fibula must be shaped through closing wedge osteotomy in its lateral side; the fibula after shaping can mimic the morphology of the mandible more accurately; if the periosteum is not damaged, the multiple fibular osteotomies still will not affect its distal blood circulation. The studies of Jones et al. showed that the fibula after osteotomy may be folded to form double tubular vascularized graft and the blood supply of the distal fibula can be preserved through the intact periosteum. Sodare and Powell made improvements to the technology. They removed the middle bone segment under the periosteum, so that the remaining mesial and distal bone segments can be rotated and placed in two different three-dimensional spaces, and the fibula after shaping can undergo rigid internal fixation

with the titanium plate or reconstruction titanium plate. The accuracy of shaping is often ensured with the help of the surgical resection specimens or intraoperative prefabricated titanium plate or template. The arteriovenous preparation in the receptor site must be completed before the vascular pedicle of the fibular myocutaneous flap is cut off. The facial artery is usually selected as the artery of the receptor site, and the superior thyroid artery is selectively used in few cases. The branches of internal jugular vein or the external jugular vein are usually selected as the veins of the receptor site; if the length of the vein is not enough, the method of venous bypass can be selectively used to extend the vein in the receptor site. Under normal circumstances, two veins are anastomosed as far as possible; if the condition is not allowed, only a vein of larger diameter can be anastomosed.

2. Vascular anastomosis: Domestic and foreign scholars have different views on the sequencing of shaping and vascular anastomosis [14, 15]; at present, there are basically three types of sequencing, and these are as follows:
   (1) Shaping – cutting off the pedicle – anastomosis: The advantage of this method is that the ischemia time of the bone flap is short and there is sufficient time for vascular anastomosis, and the disadvantage is that there is no reference to the adjacent upper and lower jaw bones and the shaping operation is more difficult.
   (2) Cutting off the pedicle – shaping – anastomosis: The advantage of this method is that the shaping is mostly convenient and the method is conducive to operations such as shaping and placement; the disadvantage is that the ischemia time of the bone flap is long and the technical requirements for shaping and vascular anastomosis are higher.
   (3) Cutting off the pedicle – anastomosis – shaping: The advantage of this method is that the ischemia time of the bone flap is short, and the disadvantage is that the vascularized pedicle after shaping will have a certain limitation on shaping.

At present, most domestic scholars adopt the latter two methods; now the selection can also be based on the habits, experiences, and skill levels of the surgeons.

3. Typical Cases

Case II The patients, male, 58 years old, visited the hospital where the author was working due to having mandibular mass for 10 years; the clinical diagnosis was mandibular ameloblastoma. The preoperative examinations were performed, the preoperative CT data were input into CAD system, the mandibular model after rehabilitation was designed and produced, and the forming plate was bent on this model.

The subtotal resection of the mandible was performed under the general anesthesia, and the resection range of the mandible was from the whole left mandible to the lower right area. The mandibular defects were repaired and reconstructed with fibular myocutaneous flap. The reexamination was performed at a month after surgery, and the facial appearance of the patient was satisfactory (Fig. 9.2).

2.2.5 Treatment of Donor Site

Treatment of skin flap donor site in calf is related to the width of skin island. If the width of the skin island of the fibular flap is less than 4–6 cm, the wound in donor site can be directly closed and sutured. But the far closer to the distal middle part the position of skin island is, the greater the difficulty of suture closure is. For the skin defect with a larger donor site, the split-thickness skin graft should be transplanted to close the wound. The surgical cavity should be built in a negative pressure drainage tube before suturing the skin, and the light compression bandage is performed after suture closure. The affected limb is lifted to alleviate the foot edema at the side of skin flap donor site.

2.2.6 Common Complications and Their Prevention

1. Foot ischemia and necrosis: They are mainly due to lack of collateral circulation in the foot, which leads to the phenomenon that the foot ischemia occurs after occlusion of the peroneal artery. Detailed preoperative examination and evaluation are conducive to avoiding this danger. Most scholars advocate that detailed preoperative examination on bilateral calves is performed to determine whether there are anatomical variations caused by various factors and the preoperative angiography of the calves is important for determining whether there are anatomical variations in the peroneal artery and vein. Some scholars also believe that it is not necessary to list the preoperative angiography as a routine examination. If the pulsations of posterior tibial artery and dorsal pedal artery pulse are normal and there is no injury in the calf, it is only needed to perform an examination of color Doppler flowmetry to understand the status of the blood supply of the peroneal artery and the situation of peroneal artery perforator in lateral calf skin. If the intraoperative findings show that the peroneal artery takes the place of the posterior tibial artery, the surgeon should try to block the peroneal artery and can continue the operation after confirming the normal blood circulation in the foot toes. In addition, the preoperative MR angiography in the calf can provide the same anatomical information as the angiography.
2. Common peroneal nerve injury: The incorrect dissection or excessive pulling can cause the common peroneal nerve injury, and this leads to varus foot deformity and the numbness in the front and lateral sides of the calf and

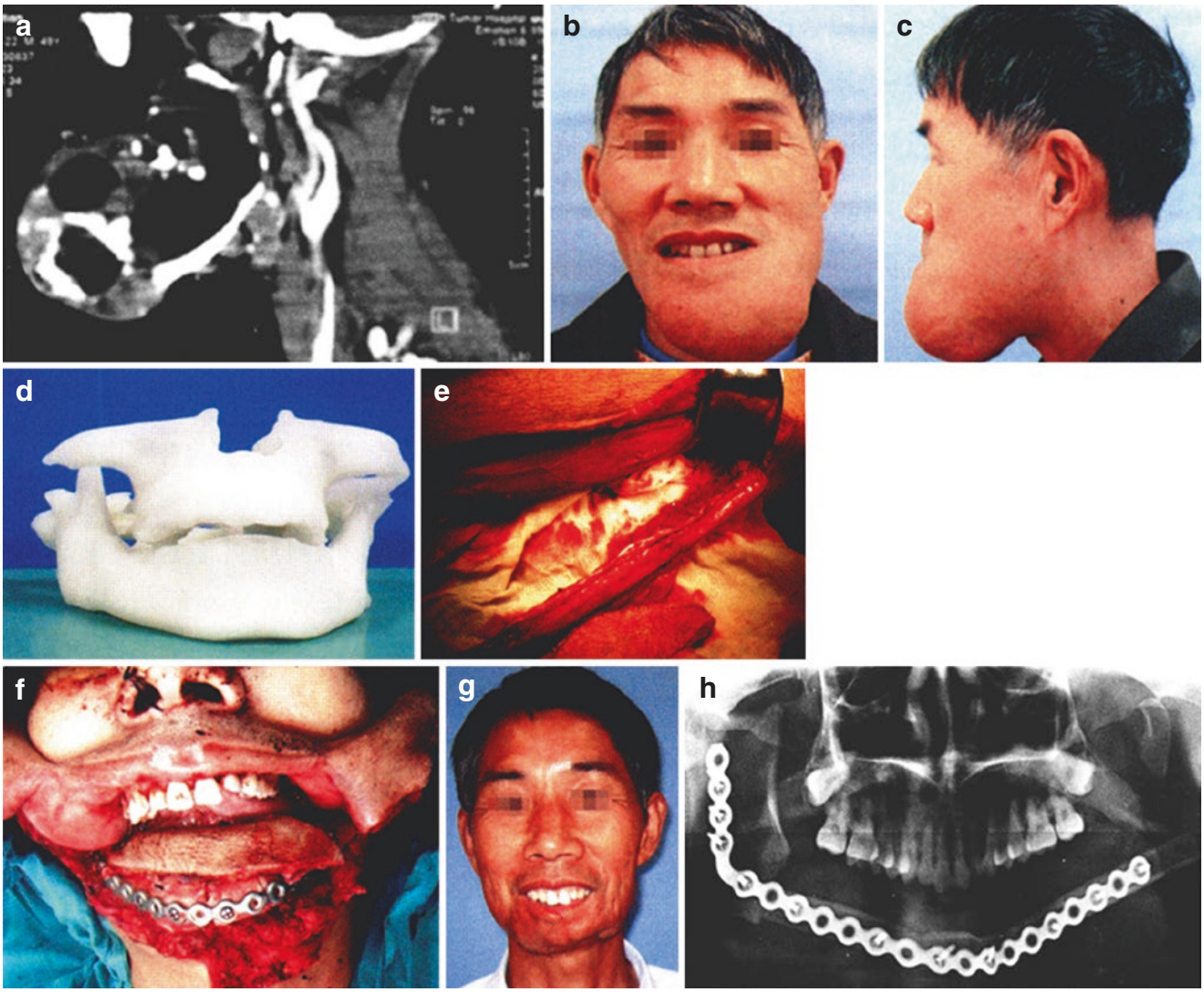

Fig. 9.2 Case II. (**a**) Preoperative CT image. (**b**) Preoperative positive profile. (**c**) Preoperative lateral profile. (**d**) Preoperative rehabilitation model made by CAD. (**e**) Intraoperative preparation of fibular myocutaneous flap. (**f**) Fibular shaping and fixation during surgery. (**g**) Positive profile at 1 month after surgery. (**h**) Panoramic radiograph of the mandible at 1 month after surgery

in the dorsum of the foot in patients. To carefully locate and expose the nerve during surgery can avoid such a situation, and the extreme familiarity with the anatomy of the calf and the fine operation are the keys to avoid complications.

3. The bone compartment syndrome of the calf: It is required to avoid excessive tension when suturing the skin in the donor site, the wound can be closed at one stage by skin transplantation, or the dilator can also be embedded in the calf, and then the wound is closed at the second stage.
4. Other negative phenomena and dysfunctions: For example, the cold intolerance and edema and weakened bending capability in the back side of the great toe are related to the injury of the branches of the peroneal nerve or the scar contraction of the muscle, especially flexor hallucis longus. Some patients have the phenomenon of pain and weakness when walking within a few months after surgery. The muscle weakness is considered to be due to the muscles being attached to the fibula, and the interosseous membranes are stripped off and thus lose the attachment points. The detailed gait analysis shows that the patients have abnormal changes in pace, joint angle, and ground reaction force, which are related to the muscle weakness and the change in load transmission.

2.3 Application of Scapular Flap in the Mandibular Reconstruction

The history of the scapular flap applied in repair of the head and neck defects is relatively short. It began in the 1980s, but since this area can provide the skin flap, muscle flap, and

bone flap simultaneously, the tissue flap in the scapular region has a repairing ability. In the head and face, it is especially suitable for repair and reconstruction of compound tissue defects involving the mandibular body, the tongue, the mouth floor, and the face, neck, and skin; namely, it is mainly used in repair and reconstruction of compound tissue defects with less bone defect which require a large volume of soft tissue. But the analysis of the application situation at home and abroad shows that it is mainly used in repair of mandibular ramus defects with more soft tissue defects among the aspects of the mandibular repair; therefore, for most mandibular reconstruction, the scapular flap is not the first method of choice.

2.3.1 Applied Anatomy

The scapula is an irregular triangular flat bone, including two surfaces, three margins, and three angles. The ventral surface or the costal surface is opposite to the upper posterior chest wall, and it is a large shallow fossa and is called the subscapularis fossa; there is a horizontal ridge at its dorsal side, which is known as the mesoscapula. The outwardly extending projection is called the shoulder peak, and the juncture of the upper margin and the vertebral margin is called the superior angle, which is at the same level of the second rib; the inferior angle is at the juncture of the vertebral margin and the axillary margin, which is at the same level of the seventh rib or the seventh intercostal space; the lateral angle is at the juncture of the axillary margin and the upper margin. The upper margin is short and thin; the medial margin is thin and sharp and is also known as the vertebral margin; the lateral margin is hypertrophical and close to the armpit and is also known as the axillary margin. Since the axillary margin of the scapula is more hypertrophical, the bone volume available for donation is larger, and the axillary margin of the scapula is usually selected as the bone donor site for repair of mandibular defects.

The blood of the scapula is mainly provided by the circumflex scapular artery (CSA), namely, the branch of the subscapularis artery (SA). SA is given off from the third segment of the axillary artery. After being given off, it runs downward for 2–4 cm and is divided into CSA and the thoracodorsal artery (TA). TA is the feeding artery of latissimus dorsi myocutaneous flap. CSA is the feeding artery of the scapula and its attached muscles and skin. CSA passes through the trilateral foramen and then bypasses along the axillary margin of the scapula and is divided into two branches such as the deep and superficial branches, namely, the cutaneous branch and the bone branch. The deep branch (bone branch) enters into the deep layers of the shoulder-back to feed the scapula, supraspinatus muscle, infraspinatus muscle, and the teres major and minor muscles; the superficial branch (cutaneous branch) is divided into the horizontal branch and the descending branch to control the scapular skin. The length of the trunk of circumflex scapular artery from the bone margin to the subscapular artery is 4–6 cm, and the outer diameter of the starting point is 2–3 mm. There are two circumflex scapular veins, which are accompanied with the artery with the same name, with a larger diameter compared with the artery. The bone tissue in the inferior angle of the scapula is generally provided with nutrition by the branch of the thoracodorsal artery – the angular branch artery – and it can be used and combined with the latissimus dorsi myocutaneous flap.

2.3.2 Design Principles

The characteristics of distribution of the vascular system in the scapular area determine that the area can either be taken as a separate donor site of the scapular bone flap or be prepared as scapular bone flap which is used in combination with scapular skin flap, dorsal latissimus flap, and serratus anterior flap. If the scapular bone flap is used alone, the bone flap at the lateral margin of the scapula pedicled with circumflex scapular artery can be used. The length and width can reach 10–14 cm × 2–3 cm, and it is used for the repair of mandibular body defect. Scapular spine bone flap supplied with blood by the thoracodorsal artery can be used to repair the defects in the mandibular angle and ramus. But in general, the scapular bone flap is rarely used alone in clinics for repair of the mandibular defect, and the composite tissue flap is still used for repair in most cases. Depending on the defect statuses in the mandible and perimandibular soft tissue, the sizes and volumes of soft tissue flaps are assessed to determine which kind of soft tissue flap is to be used. Clinically, in most cases, the composite tissue flap pedicled with SA is mostly used. If the scapular skin flap combined with scapular bone flap is selected, CSA can be taken as the vascular pedicle; if the latissimus dorsi myocutaneous flap or serratus anterior myocutaneous flap is combined with scapular spine bone flap, TA can be taken as the vascular pedicle. When the skin flap is designed, it should be taken into account whether the donor site can be closed and sutured directly, and it is supposed to avoid the skin transplantation for closing the wound in the donor site as far as possible.

2.3.3 Preparation of Scapular Myocutaneous Flap

When the skin flap is prepared, the patient should take the lateral position with donor site in the upper site. The surgeons should be very familiar with the anatomy of this region. The medial margin, lateral margin, and inferior angle and mesoscapula must be marked out before skin flap harvesting. In addition, the teres minor muscle and teres major muscle must also be marked. The space enclosed by the teres minor muscle, teres major muscle, and the long head of triceps muscle is the trilateral foramen, and this is the place

where the CSA is given off. The ultrasonic Doppler can also be used to detect the trilateral foramen and the running direction of CSA. If the scapular skin flap is taken as the skin flap of the composite flap, the skin flap should be designed to take the horizontal branch of the superficial branches of CSA as the long axis and is parallel to the mesoscapula. In addition, the lateral side of the skin flap can reach the trilateral foramen; the medial site can reach the midline of the back; the upper boundary can reach the mesoscapula; the lower boundary can reach the inferior angle of the scapula. If the parascapular skin flap is taken as the skin flap of the composite flap, the descending branch of CSA should be taken as the long axis of the skin flap. The upper boundary is the trilateral foramen, and the lower boundary reaches the inferior angle of the scapula. The skin flap should be designed as spindle shaped, in order to be closed and sutured directly.

1. Surgical method: Incise the medial margin of the skin flap at first to reach the superficial surface of the muscular fasciae of the infraspinatus muscle, and separate outward along the level and turn over the skin flap. After reaching the outer margin of the scapula, locate the trilateral foramen enclosed by the teres minor muscle (the surface is covered by the luminous fascia), the teres major muscle (more muscle fibers and covered by less fascia), and the long head of triceps muscle, and pull open the teres major and minor muscles and then palpate the pulse of CSA in the adipose connective tissue of the trilateral foramen. Expose and separate the CSA and its accompanying veins; identify the muscular branch and the periosteal branch given off by CSA; ligate and cut off the muscular branch; protect the periosteal branch; separate downward the teres major muscle; expose the vascular pedicle; retain 2–3 cm of myocardial sleeve at the lateral margin of the scapula; cut off the muscles attached to the lateral margin of the scapula. At the moment, it is much more easily to expose the subscapular vascular pedicle. If the bone flap in the inferior angle of scapula is not needed, the thoracodorsal artery should be ligated; if the thoracodorsal artery is needed, it will be required to cut off the teres major muscle and dissect out the subscapular vascular pedicle at the deep surface of this muscle. This branch can be given off either by the thoracodorsal artery or by the vessel from the thoracodorsal artery which enters into the serratus anterior muscle.

After separation of the skin flap and the vascular pedicle flap, incise the teres minor muscle and the infraspinatus muscle to reach the bone surface at 2–3 cm on the medial side of the lateral margin of scapula. Strip off the periosteum at the osteotomy line, incise at 2–3 cm parallel to the lateral margin with the reciprocating saw to reach the area beneath the glenoid fossa, and then perform the transverse osteotomy. At this time, be careful to protect the vascular pedicle and the structure of the shoulder joint. Meanwhile, to ensure the blood supply, the reverse side and the ventral side of bone flap should be retained with a thin layer of muscle fibers, after dissociation of the bone flap, and the artery and vein can be ligated and cut off at the start of the subscapular blood vessels to the receptor site.

2. Typical cases: This was a case of repair of mandibular defects with vascularized scapular myocutaneous flap (provided by professor Sun Jian from the Department of Oral and Maxillofacial-Head and Neck Surgical Oncology of Shanghai Jiao Tong University Affiliated Ninth People's Hospital).

Case III The patient, female, 67 years old, had tumor recurrence and invasion of right tongue body after undergoing rib transplantation within another hospital due to mandibular ameloblastoma. The patient underwent segmental resection of the mandible, resection of the right half of the tongue, and the repair with the scapular myocutaneous flap under general anesthesia in our hospital. The facial appearance of the patient at 3 weeks after surgery was satisfactory (Fig. 9.3).

2.3.4 Treatment of Donor Site

After preparation of the composite scapular myocutaneous flap, since it is required to cut off more muscle attachments during surgery, the upper arm function may be affected after surgery, which is mostly obvious in the teres major muscle. Because it is the muscle responsible for internal rotation, outreach, and adduction of the upper arm, the function will be inevitably affected after its cutting off. Therefore, a hole must be punched in the broken end of the scapula, and the severed muscle attachment is fixed onto the bone hole with nonabsorbable suture lines, so as to achieve the purpose of fixing the scapula and preventing the drift. After harvesting of the soft tissue flap, the skin defect within the range of 12–15 cm can be closed and sutured directly, and the negative pressure drainage is carried out. The shoulder is immobilized for a week after surgery, and then the activities of the shoulder are gradually recovered 1 week later. After a period of time, then the strength-training exercises of the shoulder and upper limb are gradually increased, but it is supposed to avoid violent abduction and external rotation movements.

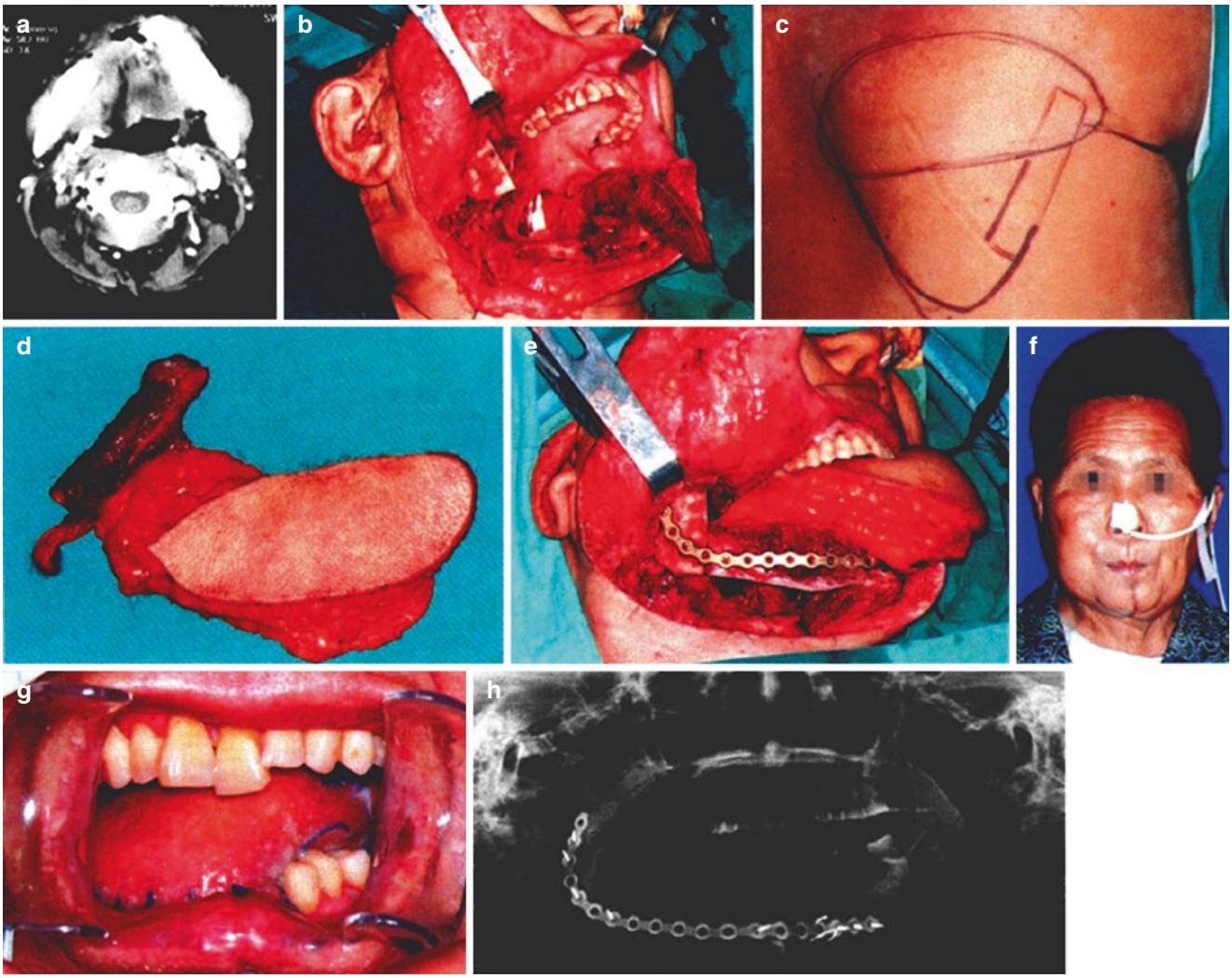

Fig. 9.3 Case III. (**a**) Preoperative CT scan showed that the tumor invaded the right tongue body. (**b**) The defect range after tumor resection. (**c**) Design of scapular myocutaneous flap. (**d**) The prepared scapular myocutaneous flap. (**e**) Reconstruction of the mandible with the scapula. (**f**) Positive profile at 3 weeks after surgery. (**g**) The intraoral image at 3 weeks after surgery. (**h**) Panoramic radiograph at 3 weeks after surgery

3 Application of Other Methods in Mandibular Reconstruction

3.1 Nonvascularized Bone Transplantation

Currently, the repair of the mandibular defect using the vascularized autologous bone transplantation has been the most commonly selected method in clinics, including the fibular myocutaneous flap with vascular anastomosis, the iliac bone flap, the scapular myocutaneous flap, and the tibial flap. In addition, in some circumstances, the nonvascularized autologous bone transplantation can be used to repair the mandibular defect in clinics; the autogenous particulate bone marrow-cancellous bone transplantation and the replantation of the autologous and freezed diseased bone have also been clinically applied. But compared to vascularized bone transplantation, the survival rate of such bone transplantation is significantly lower than that of the former, especially when applied to the wounds after radiotherapy. It is reported that, in these cases, the incidence rate of exposure, absorption, and infection of the transplanted bone is at least 58% and the incidence rate of local complications after radiotherapy can be up to 80%. While the main cause of failure is still the postoperative infections, therefore, this method is only applicable to those patients with good local blood supply, enough soft tissue covering the bone, and short defects (about 5 cm) and without a

history of local radiotherapy. Because the nonvascularized bone transplantation techniques are simple and easy to spread, the surgery time is short, there are some clinical applications, and the ilium and ribs are currently more commonly used.

3.1.1 Iliac Bone Transplantation

The ileum is a donor site which is more commonly used for bone transplantation and has abundant cancellous bone, in which there are many interspaces and viable cells, which can rapidly lead to revascularization and osteogenesis, and the new trabecular bone formation can be observed on the 10th day after transplantation. The adult ilium can provide a bone block of about 10 cm × 5 cm. When the iliac bone transplantation is selected, the ipsilateral iliac crest is usually selectively used, because the radian of the ipsilateral iliac crest is basically consistent with that of the inferior border of mandible but is slightly opposite to that of the contralateral one. Meanwhile, the morphology of the anterior superior iliac spine is perfectly matched with the mandibular angle. When the mandibular defect involves the mandibular angle, the anterior superior iliac spine can be used for repair of defects in the mandibular angle.

Currently the nonvascularized iliac bone is mainly used to repair defects in the mandibular chin-body, and the repair length is generally limited within 5–8 cm. But some scholars at home and abroad choose to use it in patients with bilateral body defect crossing the midline and have also achieved good results. But be sure to pay attention to selecting the patients with good local blood supply and without soft tissue defects [24].

Precautions for the implantation and fixation of the iliac bone block: before bone transplantation, the hydrogen dioxide solution and normal saline are used to wash the wound, and the complete hemostasis is carried out. Before suturing the oral mucosa, it is noted that the heights of the bilateral broken ends of the bone are slightly reduced, so that the surrounding oral mucosa and submucosal tissue are sutured without large tension. The oral mucosa should be sutured by layers, the mucous layer is sutured at first, and then the submucous layer is sutured with 3-0 absorbable suture line. After the suture is completed, the normal saline is used again to wash the wound and the hemostasis is performed. The wounds in the broken ends of the bone and the two ends of the implanted bone block are trimmed to realize the end-to-end joint. After the titanium plate fixation is performed, the local drainage is carried out, and the layer suture is performed.

3.1.2 Rib Transplantation

For patients with defects in mandibular body and ramus or defects in most of the mandible, the rib transplantation is a better approach under the condition that the vascularized bone transplantation technology can't be used, because the rib is long enough and is easy to bend and shape, and the complications in donor site of the rib are also very rare. In general, one of seventh, eighth, and ninth ribs is taken as the bone graft. If the mandibular defect needs to be repaired, it is advisable to take the contralateral rib. Currently the rib and costal cartilage are considered to be the most suitable tissue for condylar reconstruction.

1. Harvesting method: A curved incision is made at the anterior end of the costal cartilage and backward along the costal margin, and the skin, subcutaneous tissue, and deep fascia are incised to expose the muscle layer covering the superficial surface of the ribs, which is incised and separated slightly to expose the ribs. The periosteal incision is made along the central rib at the outer side of the bone, and then a vertical incision is made at both ends. The periosteal detacher is clung to the bone surface, and each surface of the rib is stripped off carefully under the periosteum. When the periosteum is stripped off, the stripping by the detacher should be performed following the direction of the intercostal space, so as to avoid the difficulty of stripping and damage to the surrounding structure and puncturing through the pleura. At the same time, a pivot should be found out during operation as far as possible, and the stronger operations should be avoided to prevent the slipping of detacher and the pleural or lung tissue damage. After stripping off, the rib with the desired length is cut off. If the pleuron has been punched through during operation, it should be repaired with timely measures, such as transfer of adjacent muscle flap. After the donor site of the bone is washed and the hemostasis is performed, the drainage tube is placed and the layer suture is performed, and the chest compression bandage is carried out. The patients should be encouraged to cough to avoid respiratory complications.
2. Implantation and fixation of the rib: Before implantation it should be clear that the hard rib is used to repair the mandibular body and the soft rib is used to repair the mandibular ramus and the processus condyloideus. The methods for combining with the remaining mandible include two methods such as inlay type and insert type. The former is that the part of the bone cortex at the buccal side of the broken ends of the mandible is removed, which is embedded and fitted into the rib with removal of same volume of bone cortex, and then is fixed with the titanium plate or steel wire; the latter is that the end of the rib is trimmed into sharp form and then is inserted into a space in the broken end of the mandible which is prepared in advance; it is generally required that the inserting depth is at least 1 cm. After the broken end is fixed, the lingual soft tissue should be fixed onto the rib with absorbable suture line to ensure no gap exists at the lingual side of the

implanted bone, then a drainage tube is placed into the operative cavity, and the intraoral soft tissue and the lateral soft tissue are sutured, respectively.

3.2 Application of the Reconstruction Plate in Repair of the Mandibular Defect

Since the 1980s, the immediate bridge repair of mandibular defect with the reconstruction plate has been widely used in the world. At first, this technology is a temporary repair method produced based on the consideration of the people whether the tumor recurrence is covered up due to the immediate repair after radical resection of mandibular malignant tumors and its surrounding area, which can retain the position of the residual mandible, maintain the facial appearance of the patient, and maintain some oral functions; it plays a very important role in maintaining bone shape to create conditions for second-stage bone transplantation, preventing the fracture or shift of the residual mandible and reducing the rate of tracheotomy.

But in clinical practice, the people have gradually discovered that a variety of clinical complications will appear after a period of time after the immediate bridge repair of mandibular segmental defect with the reconstruction plate, such as the loosening and falling off of the screw, the fracture of reconstruction plate, and the exposure of the reconstruction plate, which can easily lead to medical disputes. With the progress and popularization of microsurgical technique, and more emphases are put on postoperative quality of life in the current tumor treatment, therefore, the indications for the immediate bridge repair of mandibular segmental defect are controlled more strictly. Currently, this technology is mainly used in repair of mandibular segmental defect caused by malignant tumor with poor prognosis, but it is also used in patients with bad blood vessel condition or poor general condition, patients who can't tolerate the microsurgical operation, and patients with the preventive use of reconstruction plate to prevent the postoperative fractures caused by curettage treatment and marginal resection of the mandible.

3.2.1 Basic Principles of Operation

Reconstruction plates are divided into straight type, right and left single-curved type, and double-curved type, and the latter two types can be combined with artificial condyle prosthesis to be used for joint reconstruction. Generally the reconstruction is 2.0–2.5 mm in thickness, and the diameter of the retaining screw is 2.4 mm. Currently, there is a reconstruction plate of the screw head locking type. The screw locking between the screw and the plate hole is used to achieve stability between the plate and screws and prevent the friction between plate and screws and thus avoid the compression ischemia caused by the fixation achieved by pressing the reconstruction plate on the bone surface with screws and meanwhile avoid the displacement effect of the reconstruction plate without screw locking on the residual bone. The selection of the reconstruction plate is generally determined based on the location and extent of the bone defect. The reconstruction plate should be bent into shape during surgery along the external surface of the inferior margin of mandible and the posterior margin of the mandibular ramus. But the template is used for shaping on the surface of the bone at first, and then it is relatively easy to bend and make the reconstruction plate according to the template. If there is a mandibular model performed by computer-aided design/computer-aided manufacture (CAD/CAM) before surgery, the reconstruction plate can be bent into shape before surgery, which can greatly shorten the operation time, and at the same time, it is easier for the prefabricated reconstruction plate to cling to the bone surface.

In addition, if there is no lesion uplift in the outer and lower margins of the affected mandible, the reconstruction plate should be bent into shape according to the morphology of the mandible before lesion resection. After removal of the iconic lateral drill holes, at least two holes are drilled respectively on each side. The reconstruction plate is removed after the screws are fixed. In this kind of situation, it is best to use the lock screws, in order to prevent that when the screws are fixed again after osteotomy, the reconstruction plate loses its original position due to the pressurization of the screws, which leads to the displacement of bilateral bone segments.

If the osteotomy position is varied due to the tumor invasion, a reconstruction plate can be bent and made into the shape of arch and cross the osteotomy area to connect the remaining bone segments, and the positioning fixation is carried out, and then it is removed. After osteotomy, the reconstruction plate is reused to recover the position of the residual bilateral bone segments; at the same time, another reconstruction plate is used; the bridging fixation is performed along the lower margin of the residual bone segment, and then the retention reconstruction plate is removed again.

When the reconstruction plate is bent and made, it is required to avoid repeated bending and linear bending at the same site, so as to avoid creases in the reconstruction plate which leads to its premature breakage; meanwhile, it is necessary to appropriately reduce the degree of convexity of the appearance of the reconstruction plate at the areas of the chin and mandibular angle to avoid the occurrence of bedsore and ulcers caused by larger soft tissue tension and thus prevent the soft tissue from being penetrated and exposed.

When the screws are fixed, it should be ensured that the screws penetrate the contralateral bone plate and are held onto double layers of bone cortexes. Three or more screws are required for retention in the major load-bearing bone segment to spread the load stress and thus prevent screw loosening. In addition, after the reconstruction plates are fixed, the

appropriate suspension of the muscles in the floor of the mouth must be performed to recover the original position of the muscle group in the floor of the mouth and avoid shortness of breath caused by the soft tissue recession.

3.2.2 Soft Tissue Repair

The resection of soft tissue malignant tumor in mandible and its surrounding area inevitably causes the soft tissue defects, and the reconstruction plate requires tension-free suture and coverage; therefore, it must be considered simultaneously to carry out the repair and reconstruction of soft tissue defects. We usually use the pectoralis major myocutaneous flap or the free anterolateral femoral skin flap to repair the soft tissue defects and cover the reconstruction plate.

3.2.3 Common Complications and Their Related Factors

Postoperative complications include postoperative infection, soft tissue ulceration, the fracture of reconstruction plate, and screw loosening, and their related factors include the following main points:

1. Radiotherapy: The postoperative radiotherapy often causes blood supply obstacles in soft tissues around the titanium plate; at the same time, symptoms such as edema and fibrosis appear in the soft tissues; and all these are the main causes for ulceration of the skin and mucous membranes. Meanwhile, the radiation damage and local blood supply obstacles may also reduce the bone regeneration. The studies have shown that the radiotherapy dose of more than 40 Gy can cause irreversible changes in bone tissue and reduce the activity of the bone tissue, so that the titanium plate after implantation cannot cause the fusion between bone and screw as scheduled, with the effect of the functional load; the bone resorption occurs gradually around the screws, ultimately leading to screw loosening and local chronic infection. Studies have shown that there are significant differences in incidence rates of titanium plate exposure and screw loosening between patients with and without radiotherapy.
2. Insufficient retention stability: There are two major causes for insufficient retention stability. On the one hand, the operation is improper. For example, the excess temperature in the process of drilling bone hole causes the osteonecrosis at the surface of the bone hole, which affects the integration of bone and screw after implantation of titanium screw, or the retaining screw is not long enough, and it is not bicortical fixation; on the other hand, there is a structural difference in retention stability between retention devices.
3. Undue stress concentration: It is needed to use the reconstruction plate to replace the defected bone segment to bear and transmit the functional load during the mandibular movement. The load force is transferred to the bone end through the fixed structure and thus generates the combined stress in the bone. The stress is mainly concentrated on the bone tissues surrounding the retaining screws. When the stress exceeds the tolerance limit of the bone, the bone resorption around the screws will occur. This will lead to the retention screw loosening. In addition, the angle area and bending section of the reconstruction plate are stress concentration sites. For example, the long-term repeated stress accumulation in the mandibular angle and chin can cause the mechanical fatigue in the sites, which will lead to the fracture of the reconstruction plate.

4 Prospect on Repair and Reconstruct of Mandibular Defects After Tumor Surgery

After nearly a hundred years of continuous efforts by experts and scholars in the countries all over the world, the repair and reconstruction of mandibular defects after tumor surgery have achieved great progresses, which can cure the disease of the patient, repair the mandibular defects, reestablish the oral functions of the patient to varying degrees, and recover the normal morphology of lower one third of the face of the patient at the same time. In recent years, a new digital simulation technique combined with CAD/CAM has been used in reconstruction of mandibular defects, for, no matter what kind of mandibular defect, the digital model can be used to simulate the ideal mandibular morphology and create a solid model. According to the defect scope, the position and angle of the osteotomy line of the bone graft can be designed through preoperative virtual surgery on computer or 3D printing technology. Meanwhile, cutting guide plate of the bone graft is designed and manufactured. So the operative process of the mandibular reconstruction can be more programmed and standardized, and the operation time would be significantly shortened. An important step has been taken in achieving the purpose of refinement and individualization in mandibular reconstruction.

But there are still some problems in the mandibular reconstruction to be solved; for example, the main transplantation materials are the vascularized autogenous bones, which lead to a new trauma in patients. Meanwhile, there still exist some problems such as varying degrees of muscle power loss along with the mandibular defects. How to solve the issue of muscle power recovery after repair of large and complex mandibular defects has been one of the research directions for scholars from various countries.

In terms of alternative materials of autologous bones, current researches focus on the aspects such as tissue-engineered

bone and implantable prosthesis. The scholars from various countries have made some progresses in these areas through long-term efforts, but there are still a lot of basic researches to be made on repair of mandibular segmental defects. However, with the continuous development of science and technology, we believe that new breakthroughs will certainly appear in these areas in the near future, which will bring the Gospel to the patients.

All surgical photographs published in this chapter have been approved by the patients themselves.

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Defect Repair After Resection of the Tumor of the External Nose

10

Yixin Zhang, Yunliang Qian, and Zan Li

1 Overview

For the plastic surgeons, the nasal repair and reconstruction are one of the most challenging works, because that requires not only the reconstruction of a visually important and iconic facial organ but also the reconstruction of a functioning organ.

The nasal repair and reconstruction have a long history, dating back to 600 BC in India. It was firstly recorded in detail in the history book of Brahman that the forehead flap was used to repair the nasal defect in a patient whose nose was cut. Although the origin of the median forehead flap was not clear, Kanghiara family claimed that this surgical method had been carried out since 1000 BC. The nasal reconstruction of India was firstly applied and popularized in Europe by Branea family of Italy during the Renaissance. The Italians not only applied the forehead flap, but they also firstly reported that the upper arm skin tube was used for total nasal reconstruction). This method contained a lot of basic techniques currently used for repair and reconstruction in plastic surgery, including preparation of skin tube, pedicle division, transfer, delay, and fixation. Later in the nineteenth century, the Frenchman additionally used the local forehead flap for nasal repair and reconstruction on the basis. The forehead flap method had been promoted and reported widely in Britain and America in the eighteenth and nineteenth centuries.

The period from 1840 to World War I, along with the increase in the number of patients with wound repair, the plastic surgeons gradually recognized that if there was no suitable nasal lining structure and the support structure, the shape of the reconstructed nose would gradually change over time, and thus the nasal airway obstruction would occur. In 1956, Converse firstly introduced that the composite mucoperiosteal nasal septal flap was used for the reconstruction of the nasal lining and support structure. Ollier first reported that the bone tissue transplantation was used for reconstruction of the support structure in 1864, and he carried a piece of frontal bone in forehead flap for nasal reconstruction. Later, other authors reported in succession the patients who underwent nasal reconstruction with the ulna, tibia, skull, ribs, and iliac bone piece. At the end of the twentieth century, Von Mangoldt firstly reported the patients in whom the costal cartilage was transplanted as the nasal support. Other popular donor sites of cartilage support include the auricular cartilage and the septal cartilage [1–12].

1.1 Indications

The forehead flap of India was first used to repair the nasal defect in those patients who underwent nasal resection due to trauma. The trauma is still an indication for nasal repair and reconstruction, but the most common of which are the patients with nasal defects after tumor resection. With the popularization and application of Mohs surgery, more and more patients with nasal defects after tumor resection ask to undergo repair and reconstruction at second stage by plastic surgeons. Other indications for nasal repair and reconstruction also include the defects after nasal infection, the nasal defects after abuse of narcotics such as cocaine, rhinophyma, and congenital nasal deformities.

The surgical reconstruction of nasal defects has no absolute contraindication, including age, medical history (such as diabetes, high blood pressure), and even previous history of smoking. However, in these cases, the surgical techniques and surgical timing need to be adjusted according to specific circumstances. It can be considered that the second-stage repair will be performed after primary healing of the defected

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wound. Some patients can even undergo repair of healed defect area in a few years later. When other unexpected conditions such as nonsurgical contraindications including trauma and the requirement to wait for the final pathologic results and the nasal melanoma resection are encountered, the nasal repair and reconstruction should also be postponed.

1.2 Nasal Anatomy and Physiology

During the surgical planning for repair and reconstruction, it is required to accurately analyze the skin in nasal defect area and the lining structure. The nose can be divided into three parts according to its deep bone supports: the upper one third of the nose is supported by the cone-shaped bony structure, the middle one third of the nose is supported by the lateral nasal cartilages on both sides, and the lower one third of the nose is supported by the nasal alar cartilages (Fig. 10.1). The nasal alar cartilages support the nasal columellas via the medial cruses and support the nosewings via the lateral cruses. The lateral halves or posterior halves of the nosewings and soft triangular structure are not supported by deep cartilages. The bottom surfaces of the nostrils are the bases of the nose. Looking up from the bottom side, the ideal nose nostrils should occupy one half to two thirds of the entire height of the whole height of nosewings.

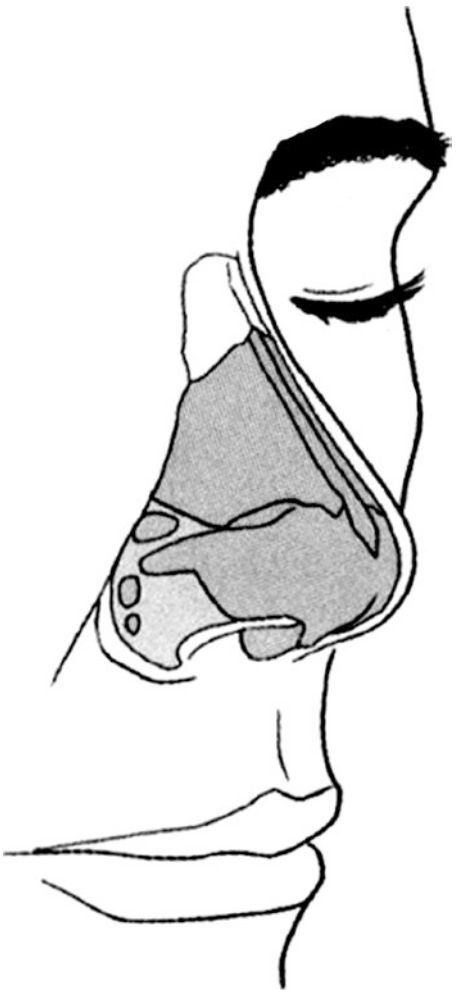

Fig. 10.1 The nose can be divided into three parts according to its deep bone supports

Table 10.1 The thicknesses of the skins in the upper and lower part of the nose and the different parts of the body

Location	Skin thickness	Location	Skin thickness
Nasal dorsum	1300 μm	Supraclavicular area	1800 μm
Nasal lobule	2400 μm	Submental area	2500 μm
Retroauricular area	800 μm	Nasolabial groove	2900 μm

One aim of the nasal repair and reconstruction is to provide a functional, open, and moist airway, which means that not only the external airway but also internal nasal valve must remain open. The nasal limen within the nasal cavity is an integral part of the airway in the middle dome, and in here, the lateral nasal cartilage and the septal cartilage join together at a 10–15° angle. When reconstructing this area, providing a sufficiently thin lining structure is very important, because it can not only keep the airway open but also provide appropriate vascular beds for any cartilage grafts to reconstruct the bony framework of the nose. The scars in the nasal limen or nostril area within the nasal cavity affect the nasal ventilation. In general, the difficulty level of nasal reconstruction increases with the structural complexity of the nasal lining. If there is no enough nasal lining, the reconstructed nose will inevitably shrink.

Another factor in the analysis of nasal defect structure that needs to be considered is different skin thicknesses in the upper and lower part of the nose. The skin in the upper two thirds of the nose is thin, with a thickness of about 1300 μm, and it is smooth and has movability; the lower one third of the nose is thick, with an average thickness of about 2400 μm, and it is rich in sebaceous glands and is adhered with the deep structures (Table 10.1).

1.3 Subunit Principles

The concept of facial aesthetic unit was firstly proposed by Gonzalez-Ulloa in 1956. He stressed that when the facial wounds are repaired, the repair should be performed according to the aesthetic unit, and the aesthetic unit is determined based on the skin thickness, histological features, and characteristics of the hidden scar in the border area [1].

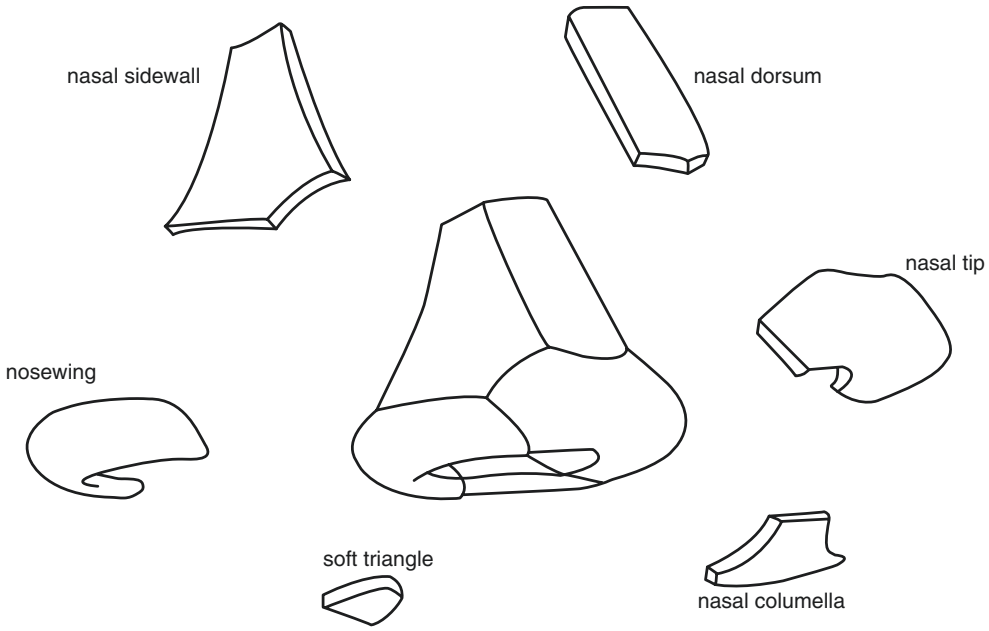

Fig. 10.2 Subunit principles for nasal repair

In order to better, more accurately repair this unique tissue, proposed the subunit principle for nasal repair and reconstruction, which was a new and improved specification [2]. They expanded the principles of Gonzalez-Ulloa on the facial aesthetic unit in facial repair, and the nose is divided into six subunits: nasal dorsum, nasal tip, nasal columella, nasal sidewall, soft triangle, and nosewing (Fig. 10.2). They further put forward that if the defect area in the nasal tip or nosewing is more than 50%, the entire subunit should be removed, and the final scars will be hidden in the shade or at the junction of neighboring subunits. At present, the clinical assessment of the nasal defect and the surgical repair also take this as the basis of theoretical guidance. Therefore, understanding the anatomic and histologic characteristics of the nasal substructure is the key to accurately repair the tissue of the nasal substructure and restore the morphology of the specific facial organ.

Recently, Singh, Bartlett, and Rohrich et al. reported that they proposed further improvements on the subunit principles; in addition that the defect area is assessed in both aspects of subunits and different layers (skin, supporting structure, and lining), it should also take into account other factors, such as skin color, texture, thickness, and extent of photochemical damage. They suggested that nasal repair and reconstruction should be performed based on the individual patients and the different local soft tissues, the location and range of the defect, and the patient's past medical history should be taken into account. All these can affect the complexity of the repair surgery. Of which, the selection of repair method by the patient is one of the main influencing factors, and especially the people in the eastern population are often reluctant to have additional scars left on their faces. Therefore, the application of forehead flap is often limited.

1.4 The Principles for Nasal Repair

1. In the practice of each nasal repair and reconstruction, three kinds of anatomical structures must be born in mind: skin cover, supporting structure, and lining [3–6].
2. The nasal subunit principles proposed by Burget and Menick should be taken as the guiding principles for nasal repair and reconstruction, but under the premise of reserving the skin color, texture, and nasal contour, it is not usually necessary to strictly adhere to the nasal subunit principles.
3. In the selection of methods for repair and reconstruction, the specific conditions of individual patients should be considered, not only their disease, skin color, and texture but also the defect range. It is not necessary to strictly comply with the subunit principles.
4. The similar tissue principle of tissue repair in plastic surgery should be followed during surgery, and the similar tissues are used as substitutes. In the selection of local skin flap, forehead flap, and free skin flap, the approximation of skin thickness and texture and the similarity of morphology are important factors to take into consideration.

5. In nasal repair and reconstruction, the precise planning and meticulous surgical operation can achieve both functional and aesthetic effects of the defect repair.

2 Reconstruction of the Nasal Covering Tissues

2.1 Repair of Small-Area Defect

Small nasal defects can be repaired with many methods, including skin transplantation, local skin flap, and composite transplantation. The local skin flaps in nasal, buccal, or forehead area are usually the best matches in the skin color and texture.

2.1.1 Skin Graft Transplantation

For the small and superficial nasal defects, the skin graft transplantation is a simple method with few complications. The skin in the lower one third of the nose is thick and contains more fat. In comparison, the skin in the upper two thirds of the nose is thinner and movable and contains less fat. These basic reference markers are very important.

For the defects in the thinner and flatter upper two thirds of the nose, the repair with full-thickness skin graft is a better method. The most commonly used donor sites of the skin flaps include preauricular and retroauricular skins, supraclavicular area, and the forehead area. However, the pigmentation of skin graft and the possible occurrence of a bright and smooth appearance and the secondary contracture in the process of healing often limit its clinical application.

2.1.2 Local Skin Flap

1. Banner flap. The banner flap was proposed by Elliot (1969). The method is suitably used in the upper part of the nose, where the skin tissue is relatively loose.

The method is to design the single triangular flap or banner flap along the cutting line of the defect; the skin flap is designed horizontally, which will be conducive to the closure of the donor site. The scars can be hidden within the stripe lines, and both sides of the nose are kept relatively symmetrical. This skin flap can be used for repair of the defects with a diameter of less than 1.2 cm in any part of the nose (Fig. 10.3).

When the skin flap is harvested, its pedicle is equivalent to the diameter of the defect, and its length should exceed one third of the diameter of the defect. The adequate dissociation is performed on the layers such as under the muscle and perichondrium and above the periosteum, in order to facilitate rotation of the skin flap, and then the skin flap is inserted into the defect area; at the moment, the small triangle at the distal end is usually removed.

2. Bilobed skin flap. The bilobed skin flap is commonly used in the repair of the defects in the lower one third of the nose and is also used for repair of the defects in nasal dorsum or nasal side. This skin flap is only used to repair the defects with a diameter less than 1.5 cm, and it is needed to use the tissues in the two thirds of the nose.

Firstly proposed by Esser and Zimary, the method is to design a bilobed skin flap with a total rotation angle of 180°. But this design is flawed, and it will lead to a significant projection of "orecchiette" or appearance of a protuberance in the position of the pivot point; after its removal, the base and pedicle of the skin flap will be narrowed, and thus the blood supply of the skin flap will be affected.

In 1989, Zitelli proposed the optimal design method of the bilobed skin flap: the maximum rotation angle of each flap of the bilobed skin flap is 45–50°, and the total rotation angle is 90–100°. Along the margin of the defect, the Burow triangle included in the design is resected, then the first lobe of the skin flap is advanced downward, and the top point of the Burow triangle is taken as the pivot

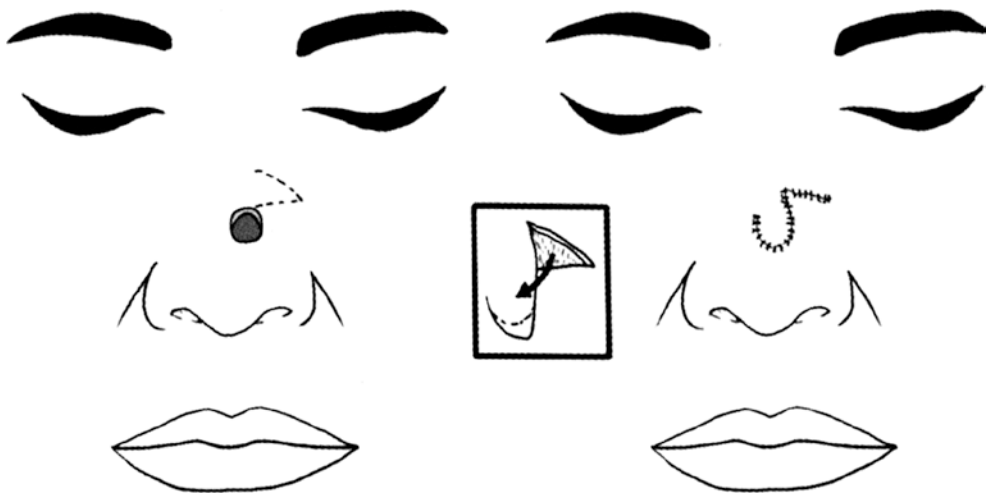

Fig. 10.3 Banner flap

point of rotation of the bilobed skin flaps. The first lobe and the nearest defect have the same diameter; the second lobe is slightly narrower (it is generally 80% of the first lobe), but it must be ensured that the defect left after rotation can be closed directly, while the final incision should be made in the site with a minimum of tension to facilitate reducing the scar, generally in the lateral nasal wall. The skin flap is fully dissociated at the layers such as under the muscle, perichondrium, and periosteal surface, so as to ensure the blood supply of the skin flap. After the complete hemostasis of the wound is performed, the first lobe is rotated by 45–50° to cover the original wound, and then the second lobe is rotated by 45–50° to fill the defect left after rotation of the first lobe. The second donor site can be closed directly with absorbable suture lines (Fig. 10.4). Usually the rotating shaft should not be close to the margin of the nosewing and the lower eyelid to avoid distortions.

Case I The patient, female, 21 years old, had had a mass in the nosewing for 21 years, whose growth was accelerated for 1 year. The extensive resection of the mass was performed, and the adjacent bilobed skin flap was used for repair (Fig. 10.5). Postoperative pathology: intradermal nevus.

3. Rhomboid skin flap. The rhomboid skin flap comes from the neighboring buccal area, and it was originally used for repair of defects in nasal sides. The first side of the skin flap is designed along the nasolabial groove, the other side is located at the margin of the defect, and the last side crosses the cheek. The skin flap is lifted up, and the extensive dissociation is performed in the subcutaneous layer. It is easy to advance the skin flap to cover the defect through adequate dissociation, and it is not necessary to perform the "orecchiette" resection (Fig. 10.6). The postoperative scar is located in the nasolabial groove, or in the folds of the nosewing, or at the junction of the nasal side and the buccal area. Because the tension line is not in the vertical direction, therefore, the possibilities of occurrences of the lower eyelid eversion and the elevation of the lip or nosewing margin are minimal.

   The buccal tissue can also be used as a simple advancement flap for nasal defect repair. Incise the skin to the subcutaneous layers at the nasolabial groove, the adequate dissociation is performed at 2.5 cm above the buccal area adjacent to the defect and the skin flap is advanced to cover the defect in the nasal side, and the donor site is closed directly. The buccal advancement flap can also be used in combination with other flaps for total nasal reconstruction, such as the median forehead flap.

Case II The patient, female, 70 years old, had had a mass in the right face beside the nose for 2 years. The extensive resection of the mass in the right face beside the nose was performed, and the adjacent facio-buccal skin flap was advanced for repair (Fig. 10.7). Postoperative pathology: highly differentiated squamous cell carcinoma.

4. The advancement flap of the nasal dorsum. The advancement flap of the nasal dorsum (Rieger method) is suitably used for repair of the defects in the nasal tip and the distal nasal dorsum with a diameter of less than 2 cm. Typically,

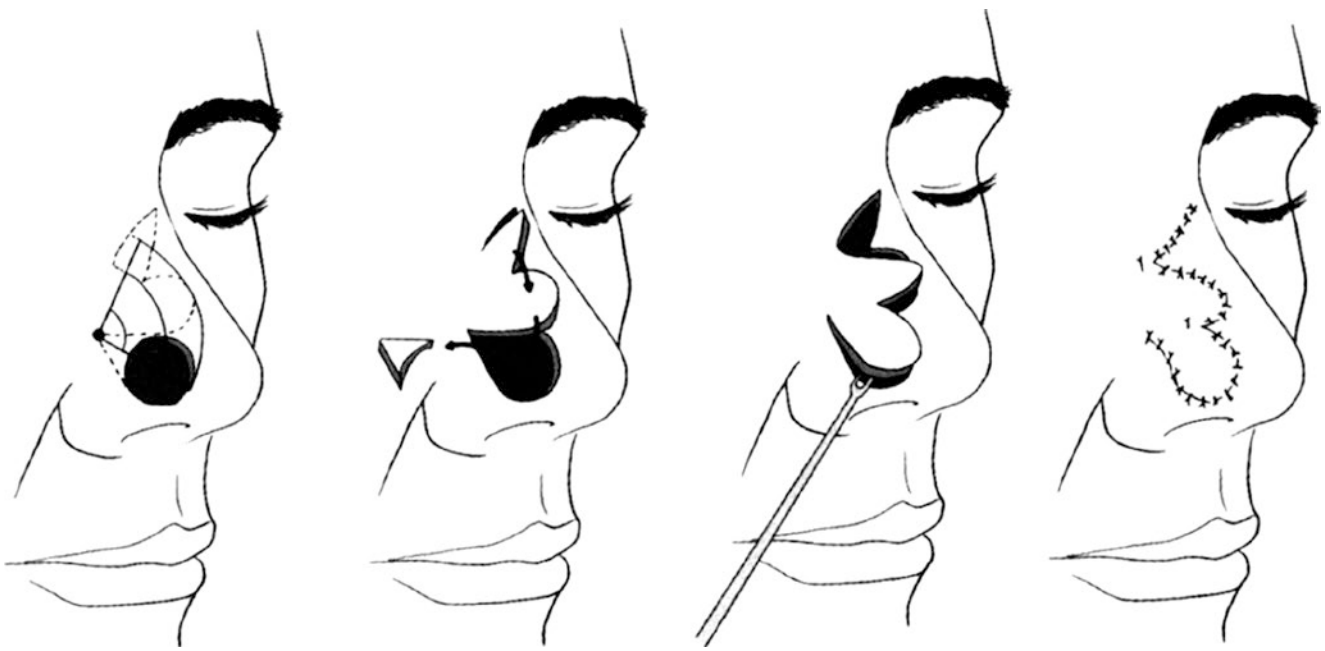

Fig. 10.4 Bilobed skin flap

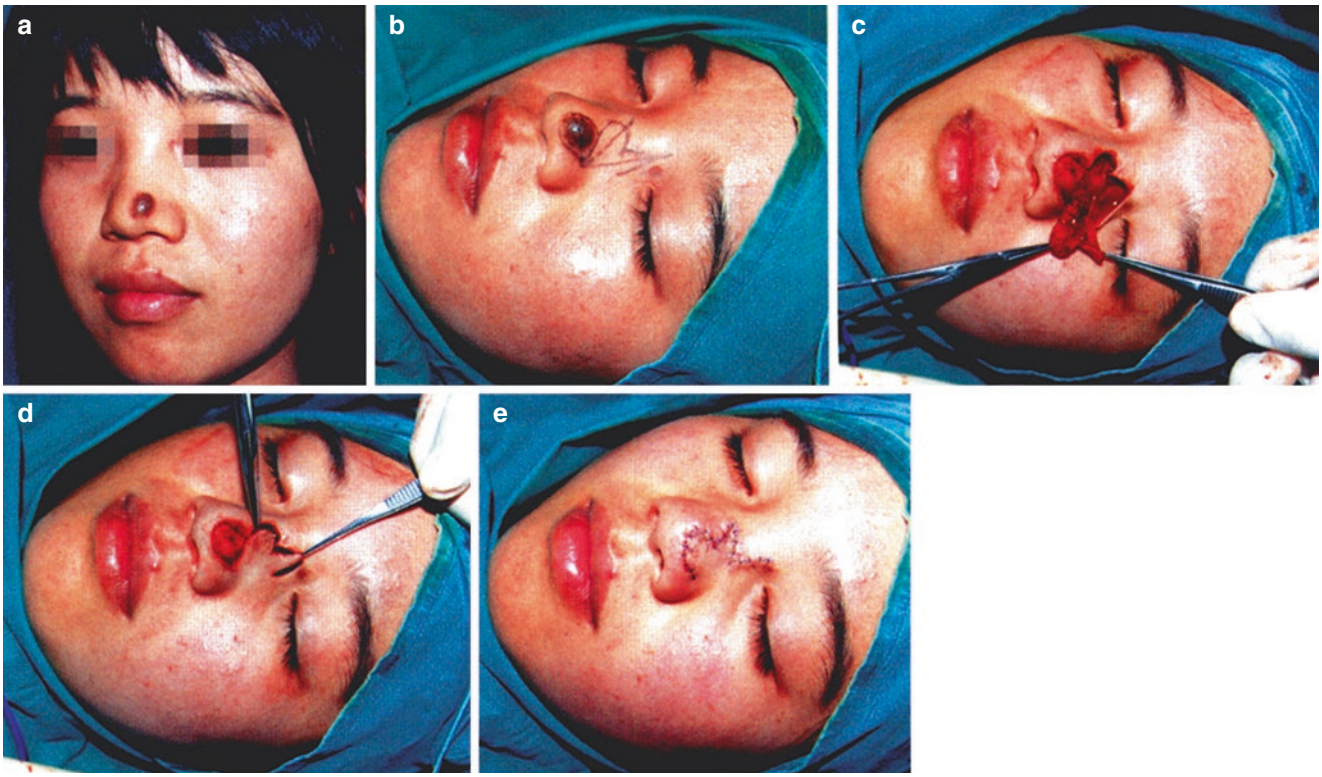

Fig. 10.5 Case I. (**a**) The intradermal nevus at the junction of the nasal tip and nosewing; the size was about 1.5 cm × 1.5 cm. (**b**) Design of bilobed skin flap, the inclined angle was 90–100°, and the second lobe skin flap was designed in the lateral nasal wall with relatively loose tissues, so as to facilitate the direct closure of the wound. (**c**) The bilobed skin flap was prepared after mole removal. (**d**) The bilobed skin flap was separated under the nasal muscles. (**e**) The bilobed skin flap was used to repair the wound in the nosewing

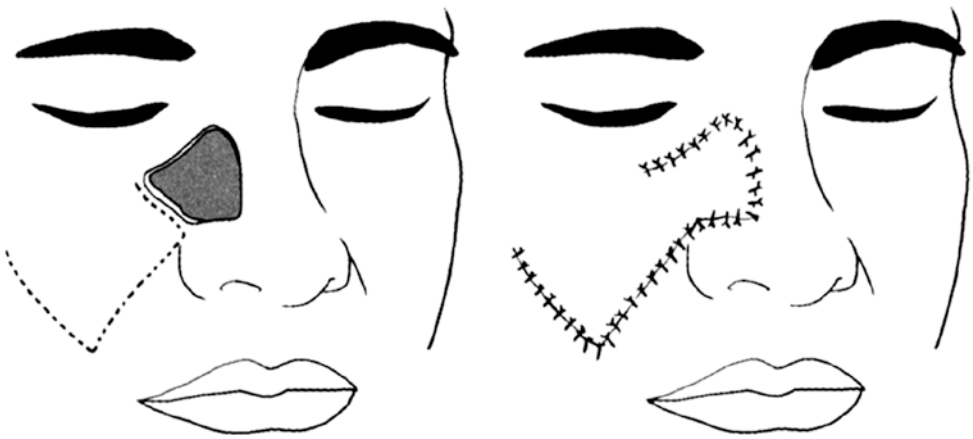

Fig. 10.6 Rhomboid skin flap

the skin flap is used to repair the defect with a distance of at least 1 cm from the nosewing margin which can't be lower than the nasal tip point. If the repair site is too distal, it will lead to postoperative nasal tip rotation or nosewing traction.

Rieger method: The incision line travels from the outside of the defect, extends along the junction of nasal side and buccal area upward to the area between the eyebrows, and stops near the contralateral inner canthus (downward to the inner canthal ligament); after skin flap harvesting, a random rotation skin flap with a long lateral pedicle is formed. The proximal end of the skin flap is lifted up at the subcutaneous level in the areas above bilateral internal canthi, then the separation is performed forward under the muscular layer to the distal end of the skin flap, and then the skin flap is advanced to the appropriate position and is sutured. The defect between the eyebrows after skin flap advancement is closed directly, and the complete dorsum nasal flap is formed into a V-Y advancement flap (Fig. 10.8).

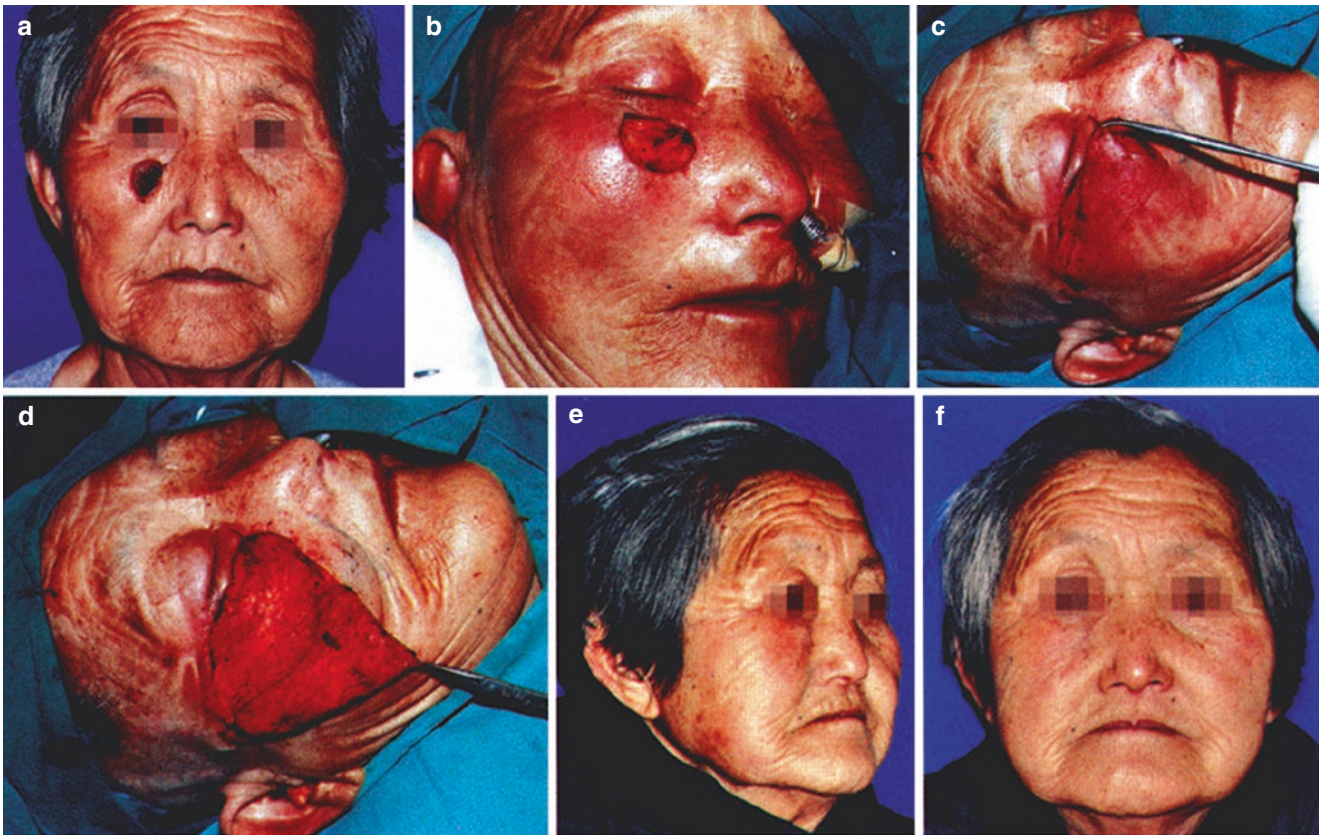

Fig. 10.7 Case II. (**a**) Paranasal squamous cell carcinoma in the right face. (**b**) Intraoperative extensive resection, the pathological examination showed that the periphery and base were negative; the wound was about 2.5 cm × 2 cm. (**c**) Design of the incision of the advancement flap in buccal area. (**d**) The range for subcutaneous dissociation of the skin flap. (**e**, **f**) The lateral and positive profiles at 1 year after surgery

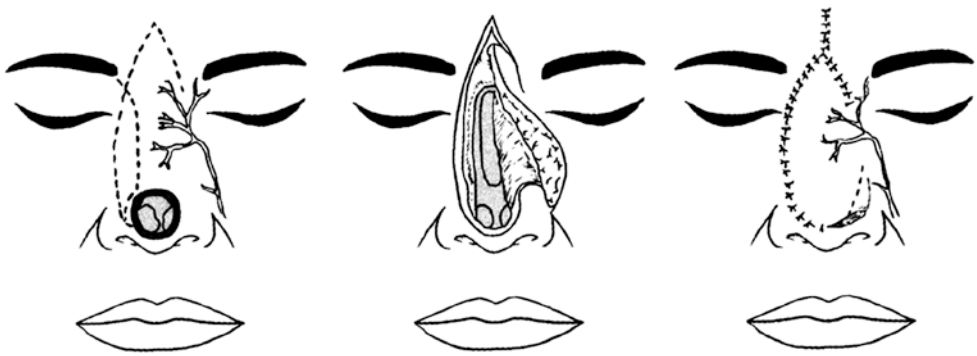

Fig. 10.8 The advancement flap of the nasal dorsum (V-Y advancement flap)

Marchac and Toth improved the random advancement flap of Rieger into an axial pattern skin flap based on the angular artery branch issued near the inner canthus. Such design makes the pedicle become narrow, so that the mobility of the skin flap is greater.

After that, Ercocen designed the complete dorsum nasal island flap based on bilateral angular arteries, and the donor site between the eyebrows is closed with the V-Y method. Such skin flap is easy to be advanced to cover the defects in the nosewing margin, the distal nasal dorsum, nasal tip, and soft triangle and the range of 2–3 cm above the nasal columella.

5. Nasolabial flap. The nasolabial flap is the primary technology used in repair of the nosewing defects with a diameter of less than 2 cm. It can also be used to reconstruct the nasal columella and can be used as the donor site of the nasal lining tissues [4].
   (1) Design methods and transfer modes of the nasolabial flap: There are two design methods for the nasolabial flap: (1) as random flap, its blood supply comes from

the subdermal vascular network; and (2) as axial flap, its blood supply comes from the angular artery and the branch of the facial artery. Its transfer mode also includes two types:

1) Transfer of pedicled island flap: Design the nasolabial island flap or perforator skin flap; design an ellipse which is two times longer than the defect along the nasolabial groove. Taking into account the postoperative scarring and contracture, the size of the skin flap should exceed 1 mm compared with the defect in any direction. The skin flap is harvested from the distal to the proximal end; attentions are paid to avoid damage to the levator labii superioris and the intramuscular perforators. The proximal pedicle skin can be completely retained as a narrow bridge or be completely cut open, and only the subcutaneous pedicle is retained to maintain the blood supply of the skin flap. The skin flap has enough mobility to be able to rotate about 150° to repair the nosewing defect, and the donor site is closed through separation and advancement of adjacent buccal tissues. The pedicle is cut off 3 weeks later; the skin flap after being lifted up is trimmed thin and shaped and is inserted to form the base of the nosewing. If it is a full-thickness defect, it is necessary to harvest cartilage from the nasal septum or auricle for transplantation, and the reconstruction of nosewing support must be included. If the natural junction of the base of the nosewing and the face is not destroyed, it should be protected during surgery, because it is difficult to reconstruct the groove. For the full-thickness defect of the nosewing, the distal end of the skin flap can be folded as the lining and is sewn onto adjacent nasal mucosa.
2) Reversed nasolabial flap: It is used most suitably to repair the full-thickness defect in the lateral nosewing; the defect with a size of three fourths of nosewing can be repaired by this method. The blood supply of the skin flap comes from the facial artery, the infraorbital artery, and the perforating branches of the ophthalmic artery, which converge together near the base of the nosewing. Based on such rich blood supply, when the skin flap is harvested, its base width is 10–15 mm, and its length can reach four times the width. The skin flap is marked at the lateral side of the defect, crossing the nasolabial groove; the position of the base of the skin flap is made as close as possible to the nosewing defect. The skin flap is incised from the distal end and is lifted up toward the proximal end, and the subcutaneous fat layer (2 ~ 3 mm) is retained. It is noted to protect the medial subcutaneous pedicle. After being lifted up, the skin flap is transferred and overturned into the defect area, the inner surface of the skin flap is sutured close to form the lining, and then the distal end of the skin flap is folded on its own surface to form the nosewing margin, which is trimmed and then inserted (Fig. 10.9). The

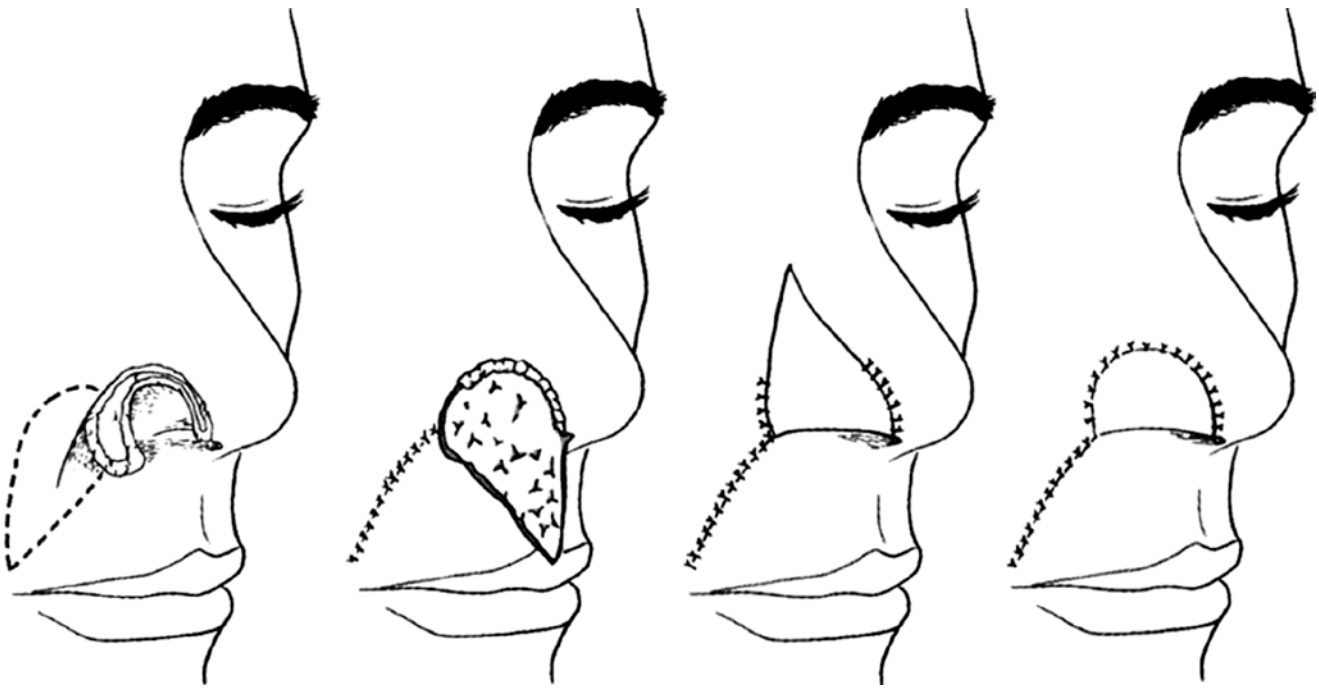

Fig. 10.9 Reversed nasolabial flap

transplanted nasal alar cartilage is inserted between the reverse folded layers. When the second-stage surgery is performed, the base of the nosewing is moved to the medial side with V-Y advancement to create a better contour of the junction of the nose and face. The nasolabial flap has a natural tendency to shrink in the long term, which is useful in the reconstruction of the nosewing, so that the reconstructed nosewing is more natural and realistic.

(2) A typical case:

1) Case III: The patient, male, 45 years old, had had a mass in the left nosewing for 5 years. The patient underwent the extensive resection of the mass and the repair with nasolabial flap (Fig. 10.10).
2) Case IV: The patient, male, 68 years old, had right paranasal basal cell carcinoma. The patient underwent the extensive resection and the repair with nasolabial facial artery perforator flap (Fig. 10.11).

6. Auricular composite tissue flap. The non-pedicled auricular composite tissue flap transplantation is only suitable for repair of the nasal defects less than 1 cm^2. Due to blood supply limitation, with the increase in volume of composite tissue, the transplantation survival rate gradually decreases. The auricular composite tissues can be obtained from the crus of helix, auricular margin, cavum conchae, or earlobe. The crus of helix is the commonly used donor site, because it can provide three-tier structure of the skin, skeleton support, and lining, and remaining scars are not obvious. The transplantation of the auricular composite tissue with a diameter less than or equal to 1 cm is often used for repairs of the nosewing full-thickness defect and the nasal columella defect; the composite tissue including crus of helix and retroauricular skin can be jointly harvested for one-stage repair of the nosewing full-thickness defect and the lateral nasal wall defect involving only soft tissue. Due to lack of blood supply, the area of the transplanted tissue cannot exceed 1.0 cm × 1.5 cm, limiting the further application of donor site of the tissue. In 1993, Julian J. Pribaz firstly reported that the vascularized auricular composite tissue was used to repair the nosewing defect [12]; in the same year, Tanaka Y. reported that the auricular composite tissue flap pedicled with the retrograde superficial temporal blood vessel pedicle was used to repair the nasal full-thickness defect [13]. In 1999, Bakhach Joseph used the communication network between the frontal branches of the superficial temporal blood vessel and the supraorbital vessels as well as the supratrochlear vessels to design the pedicled transfer of retrograde auricular composite tissue flap to repair the nosewing defect [14]. In 2008, Qian Yunliang and Zhang Yixin from Shanghai Ninth People's Hospital reported that the auricular composite tissue flap

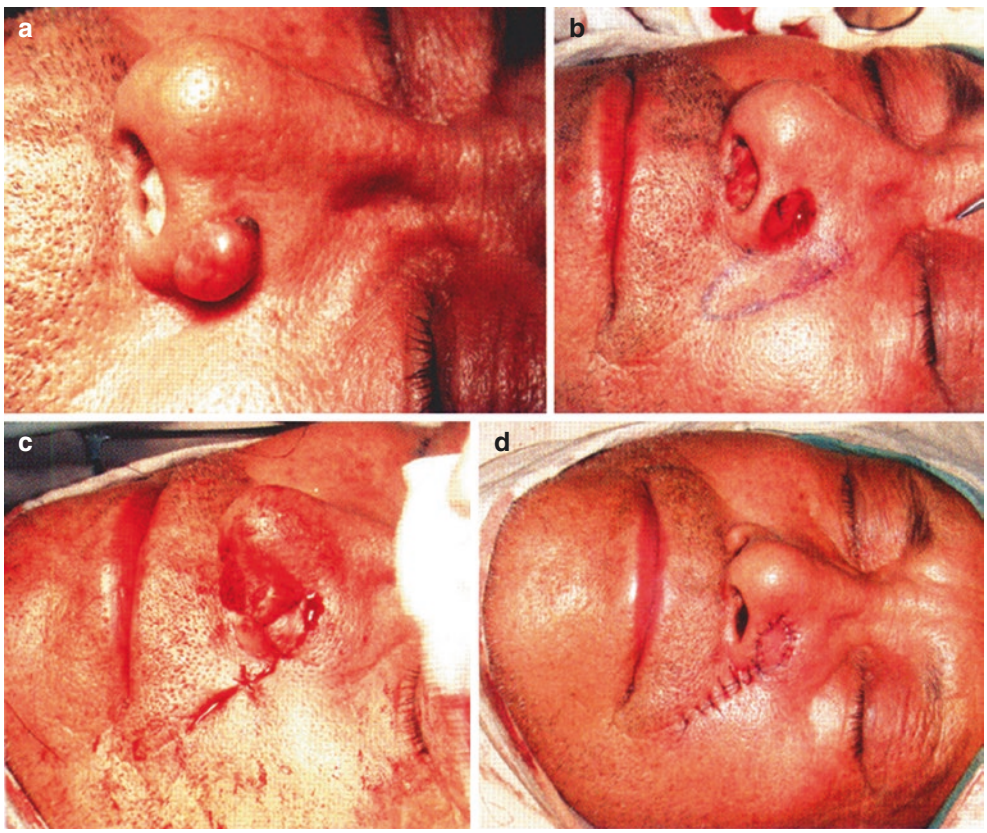

Fig. 10.10 Case III. (**a**) The benign tumor in the lateral nosewing, with a size of about 1 cm × 0.8 cm. (**b**) After tumor resection, the nasolabial flap with a pedicle in the upper part was adopted for repair. (**c**) After harvesting of the nasolabial flap, the donor site after slight dissociation was sutured directly and the scars were located within the nasolabial groove. (**d**) The nasolabial flap was transferred to repair the nosewing defect

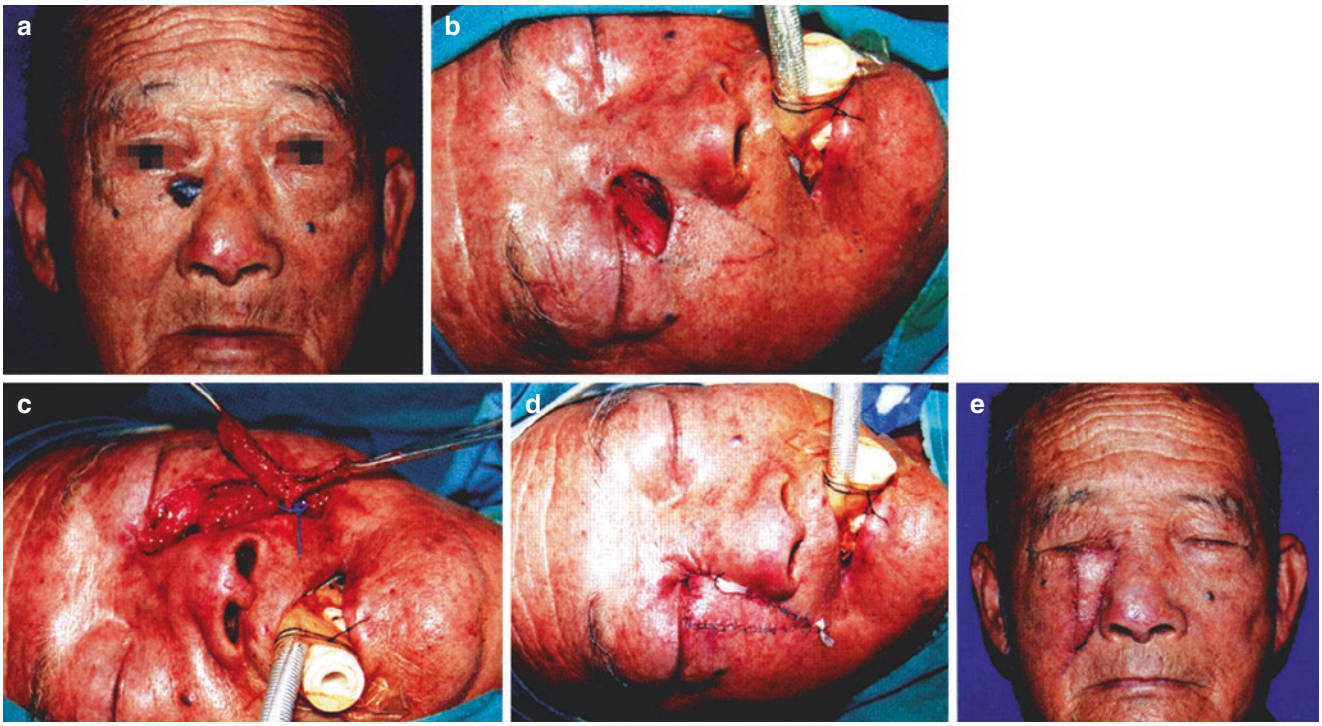

Fig. 10.11 Case IV. (**a**) Right paranasal basal cell carcinoma. (**b**) After tumor extensive resection, the peripheral margins and the base were negative, and the remaining wound was about 2.5 cm × 1.5 cm. (**c**) The defect was repaired with the nasolabial facial artery perforator flap, the perforator vessel issued from the angular artery was observed during surgery, and the perforator vessel was dissociated. (**d**) V-Y advancement of nasolabial perforator flap was performed to repair the wound. (**e**) At 7 days after surgery

including auricular and preauricular tissues which was pedicled with the superficial temporal vessel was used to repair the full-thickness defect in tissues of multiple nasal subunits in 63 patients, expanded the clinical application of surgical techniques, and got a very good therapeutic effect [15]. These research and clinical application break through the limitation on the transplantation area of the traditional nonvascularized auricular tissue, so that it becomes a reality that the auricular composite tissue is taken as the best donor site [16–21].

(1) The anatomical study of the auricular composite tissue flap: Houseman ND and Taylor GI carried out a study on blood vessel perfusion in head and neck area and found that the external ear has two sets of blood supply, the superficial temporal artery and the retroauricular blood vessel system which feed the anterior and dorsal part of the external ear. The superficial temporal artery penetrates out of the deep surface of the superficial lobe of the parotid gland in preauricular area, runs under the facial subcutaneous superficial fascia downward to the temporal region, and gives off several vascular branches at the upper crus of helix to feed the auricle; their blood supply range accounts for about the upper two thirds of the auricle.

We carried out an autopsy study on the superficial temporal artery and Chinese ink vascular perfusion, and the results also reconfirmed that the superficial temporal artery gives off 1–3 small branches to the auricle at the position of crus of helix in preauricular area and the perfusion area concentrates on the upper two thirds of the auricle and the preauricular area without the hair. The feeding layers are based on the subdermal vascular network, and this range can be used as the range for skin flap design in clinics. Since the temporal veins have no venous valves, the skin flap can also be designed as the retrograde skin flap pedicled with the distal superficial temporal artery (Fig. 10.12).

2.2 Surgical Methods

(1) Design of auricular composite tissue flap:
   (1) Anterograde skin flap: Traditionally, the proximal superficial temporal artery is taken as the pedicle to obtain the anterograde auricular composite tissue flap. This design is often used to repair the contralateral nasal defects, which is conducive to the shaping of the skin flap and the placement of the vascular pedicle. The vascular pedicle which can be harvested for the anterograde skin flap is short and is 2 cm or so. It can't be directly anastomosed with the blood vessels beside the nose, and it must be anastomosed with the blood vessels in the receptor site at the side

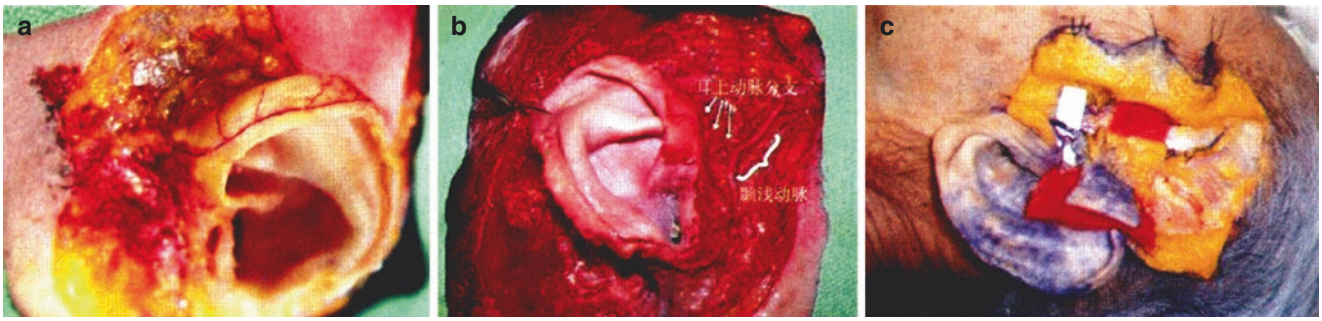

Fig. 10.12 The retrograde skin flap pedicled with the distal superficial temporal artery. (**a**) The distribution of the superficial temporal vessels in the auricular and preauricular area. (**b**) The branches of the superficial temporal artery penetrate out of the deep surface of the superficial lobe of the parotid gland in preauricular area. (**c**) The display of the superficial temporal artery after Chinese ink vascular perfusion in the corpse

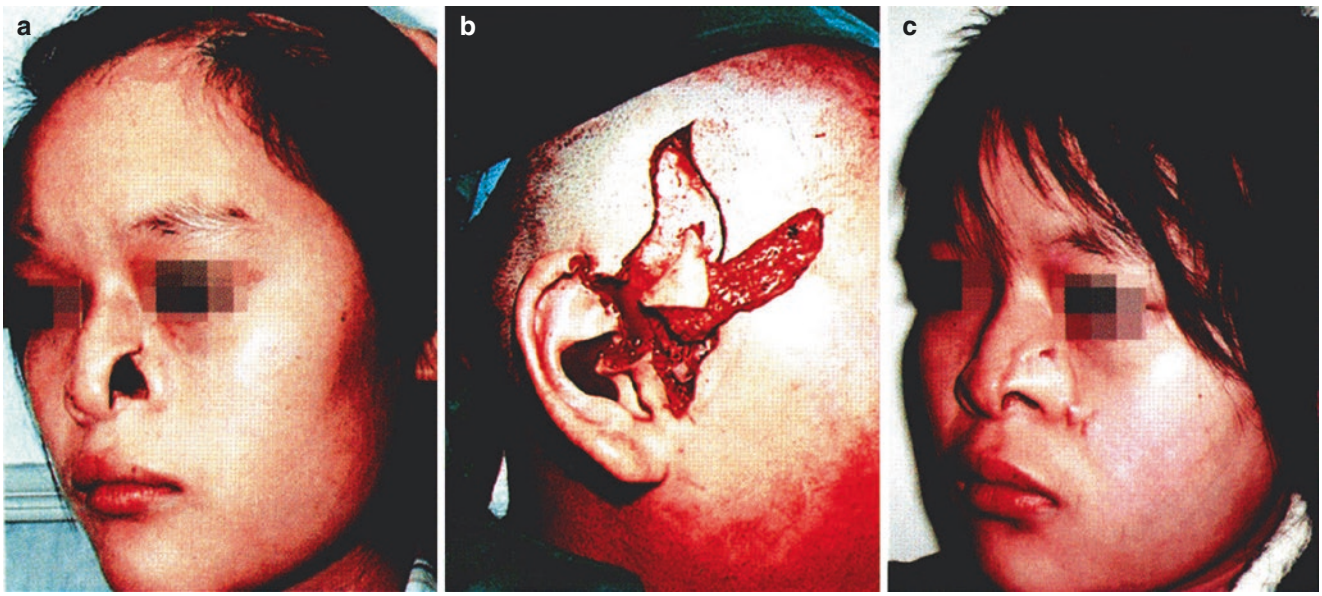

Fig. 10.13 Anterograde skin flap transplantation. (**a**) Before surgery. (**b**) Contralateral anterograde auricular composite tissue flap. (**c**) After surgery

of the defect such as the facial artery and vein and the superficial temporal artery and vein through the vessel bridge (the descending branches of the lateral femoral circumflex vessels are often selected as the vessel bridge) (Fig. 10.13).

(2) Retrograde skin flap: Because the temporal veins have no venous valves, the retrograde composite tissue flap pedicled with the distal superficial temporal artery can also be designed. Similarly, to meet the needs of the shaping of the skin flap and placement of the vascular pedicle, this design is often used to repair the ipsilateral nasal defects (Fig. 10.14). Taking the distal superficial temporal vessels as the pedicle has three advantages compared to taking the proximal superficial temporal vessels as the pedicle: (1) because the diameters of distal blood vessels are smaller than those of the proximal blood vessels, it is possible to obtain the blood vessels with diameters approximate to those of blood vessels beside the nose; (2) it is possible to obtain long enough vascular pedicle; and (3) after harvesting of the skin flap, the proximal superficial temporal vessels can be retained as the blood vessels of the receptor site for bypass anastomosis; in this way, it will be not needed to look for other blood vessels of the receptor site such as facial artery and vein. Because of these advantages, the retrograde tissue flaps at the same side of the defects are more commonly taken as donor sites in clinics.

(2) Surgical procedure and the harvesting of the auricular composite tissue flap: The surgeries are performed simultaneously under general anesthesia through being

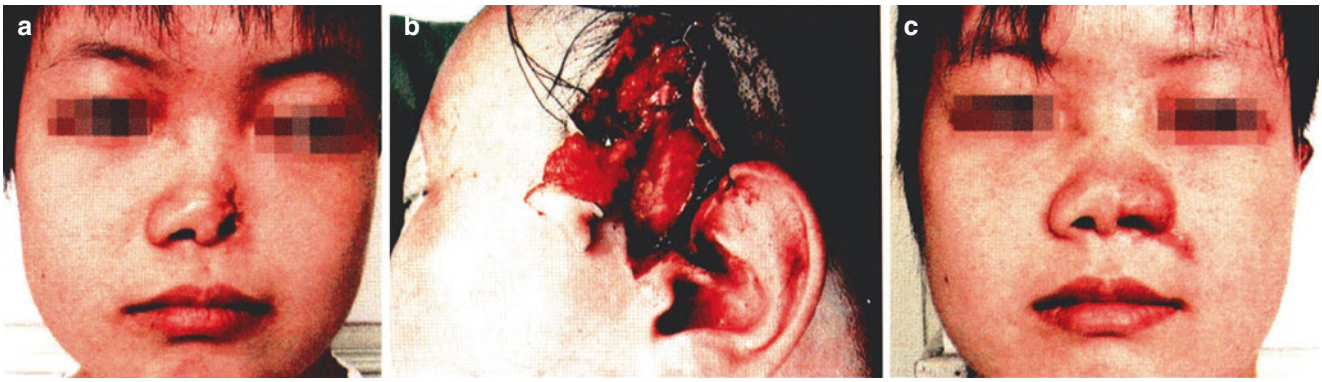

Fig. 10.14 Retrograde skin flap transplantation. (**a**) Before surgery. (**b**) During surgery. (**c**) After surgery

divided into groups, the receptor site is prepared and the preauricular and auricular flap is harvested in one group, and the descending branches of lateral femoral circumflex vessels are harvested in another group. Among the latter groups, the surgery is performed according to the surgical method of the anterolateral thigh flap. An S-shaped skin incision with a length of about 8–10 cm is made at the site in the thigh equivalent to the upper and middle one third of the connecting line between the anterior superior spine and the midpoint of the upper margin of the patella, and the lateral femoral circumflex vessel bundle is dissected and separated in the intermuscular space between the rectus femoris muscle and the vastus lateralis muscle to harvest the blood vessels with required length for standby application. At the same time in the receptor site group, the scar tissue in the periphery of the nasal defect is removed, and the contracture is released, so that the twisted and distorted tissues such as nasal tip or nasal columella are put back to the original place. The actual range and extent of the defect are determined according to the morphology and size of the normal nose, and then the incision of the preauricular and auricular flap is designed in the preauricular area without hairs and the crus of helix according to the actual repair need.

Incise the skin and subcutaneous tissue at the proximal end of the incision line of the composite tissue flap designed in the preauricular area to find out the superficial temporal vascular bundle, and then lift up the preauricular and auricular flap according to the originally designed incision. When the auricle is lifted up, special attentions must be paid to avoid damages to the small blood vessel branches of the superficial temporal vessels entering into the auricular flap; because these branches are very thin, it is difficult to identify them with the naked eyes; therefore, when the auricular flap is lifted up, the dissection depth of the tissue is kept at the deep surface of the superficial temporal vessels. After the dissection of the auricular flap is completed, the blood perfusion status should be carefully examined before the vascular pedicle is cut off, and the vascular pedicle is cut off after confirmation of good blood perfusion. The preauricular and auricular flap is transplanted onto the nasal defect area and is sutured into place after shaping. The facial artery and vein are dissected at the lower margin of the mandible and the anterior margin of the masseter muscle in the ipsilateral side of the nasal defects, or the superficial temporal artery and vein are dissected in the ipsilateral preauricular area; the harvested lateral femoral circumflex vessel bundle is passed through the subcutaneous tunnel to be bridged with the blood vessels of the auricular composite flap; the end-to-end vascular anastomosis is performed under the operating microscope; and the postoperative treatment and observation are carried out according to the routine method in microsurgery.

The skin flap takes the descending branch of the lateral femoral circumflex blood vessels as the vessel bridge, the superficial temporal vessels which are supplying blood are anastomosed with the facial artery and vein and the superficial temporal artery and vein at the side of the receptor site, the maximum length of the vessel bridge is 14 cm, and the minimum length is 10 cm. Due to the variation of the blood vessels and the limitation of the vascular diameter, in a few cases, the angular artery and vein in an area beside the nose can be taken as the blood vessels of receptor site for anastomosis.

(3) Donor site repair: After harvesting of larger preauricular and auricular tissue flap, the tissue defects will occur in the preauricular area and the external auricle of the donor site; the direct closure and suture of the wound will lead to significant auricular defect and deformity. Although they can be covered by hair, when a larger defect exists, the deformity is obvious. Through

the perfusion study on local anatomy, it is found that there are rich anastomosis communicating branches in posterosuperior areas behind the ears between the superficial temporal vessels and the retroauricular blood vessels. Thus, we have designed a large retroauricular flap with the pedicle in the upward side to be transferred for repair and reconstruction of the upper foot of the external auricle. The retroauricular flap should be designed to be longer, in order to facilitate the rotation and shaping of the skin flap; the length-to-width ratio can be up to 4: 1, and the maximum skin flap with a size of 7 cm × 2.5 cm can be harvested. The depth of harvested skin flap reaches the cartilage membrane. When the skin flap is shaped, the tip must be inserted into the cavity of auricular concha. According to the patient's requirements and operating time, the donor site can be repaired by means of one-stage direct repair or second-stage repair. Most of the patients are satisfied with the auricular appearance in donor site after surgery.

(4) The advantages and disadvantages of auricular composite tissue flap: The advantages for the use of the preauricular and auricular composite tissue flap with anastomosed superficial temporal vessels for repair of the defects of nasal subunits mainly include:

1) The preauricular and auricular flap with larger area can be harvested by surgery, the patient with single defect or combined defects and deformities can be treated with one-stage repair (Fig. 10.15a), the area limitation of auricular flap and the problem of survival rate in the traditional surgical method can be overcome, and the scope of repair is expanded.
2) The preauricular skin tissue is thin, with soft texture, the radian and morphology of the crus of helix in auricle are more similar to those of the nosewing, the shaping and the repair location are more flexible, the morphologies of the reconstructed nosewing and nasal tip are vivid and realistic, the tissue thickness is appropriate, and the color is natural.
3) The anatomical positions of the superficial temporal vessels are constant, the vascular diameter is larger, and the blood supply range is stable; therefore, the design and harvesting of the preauricular and auricular flap are simpler; as long as the surgeons are skillful at the microsurgical vascular anastomosis, the surgical successful rate will be high.
4) The patients with severe facial deformities combined with partial nasal defects can be treated with one-stage repair with combined preauricular and auricular flap and other tissue flaps according to the needs of the operation.
5) The method for the use of the descending branch of the lateral femoral circumflex vessels for bypass graft anastomosis can reduce the surgical incision scars in the face, and there is no obvious functional effect in the donor site of blood vessels. Because the conditions of the grafted vessels are good and the step for looking for the paranasal blood vessels is eliminated, the operation time can be shortened.

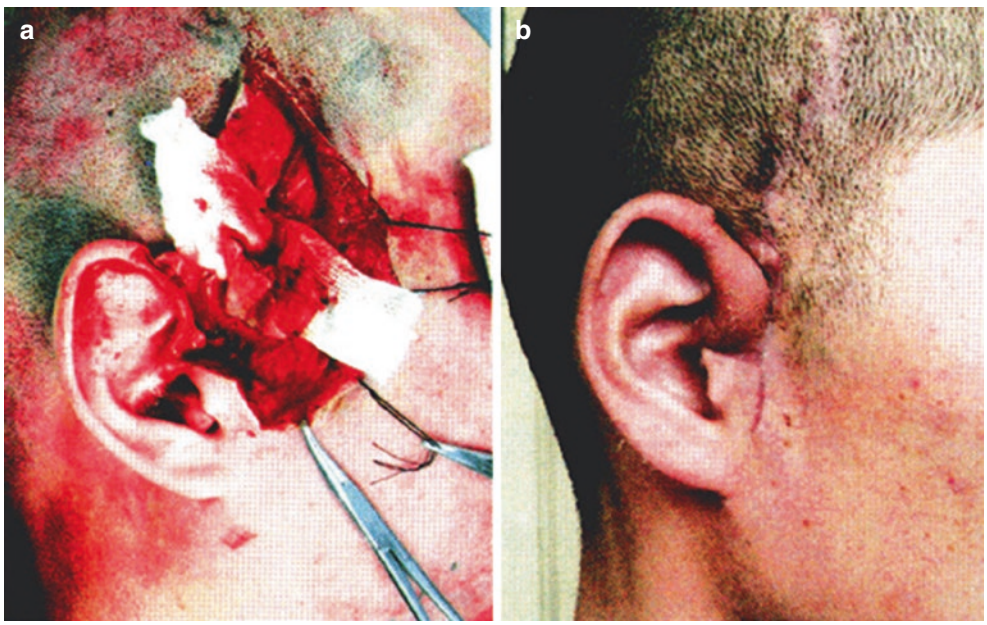

Fig. 10.15 The harvesting and repair of the auricular composite tissue flap. (**a**) Harvesting of the preauricular and auricular flap. (**b**) The auricle in donor site after repair

The disadvantage is that in order to ensure the blood supply of the skin flap, sometimes the pedicle of the skin flap is more bloated, which requires second-stage repair. Although the auricle in donor site has been repaired, the mild partial deformation will still be left (Fig. 10.15b). In addition, compared with the forehead flap, this surgical method will produce three additional surgical scars, but all are more hidden. In addition, the operation time is relatively long and the requirements for surgery are higher (compared with the forehead flap), but it is still worthwhile relative to the effect of nasal reconstruction obtained after surgery, especially in young and healthy patients [8–13].

(5) The typical case:
   1) Case V: The patient, female, 18 years old, had a congenital hemangioma in the left nosewing; the total nosewing defect occurred after radionuclide therapy. The patient underwent repair using the auricular composite tissue flap with superficial temporal artery and vein (Fig. 10.16).
   2) Case VI: The patient, male, 50 years old, underwent incomplete resection of highly and moderately differentiated squamous cell carcinoma in the nosewing and nasal tip within another hospital 10 days ago. The free auricular composite tissue flap was used for repair (Fig. 10.17).

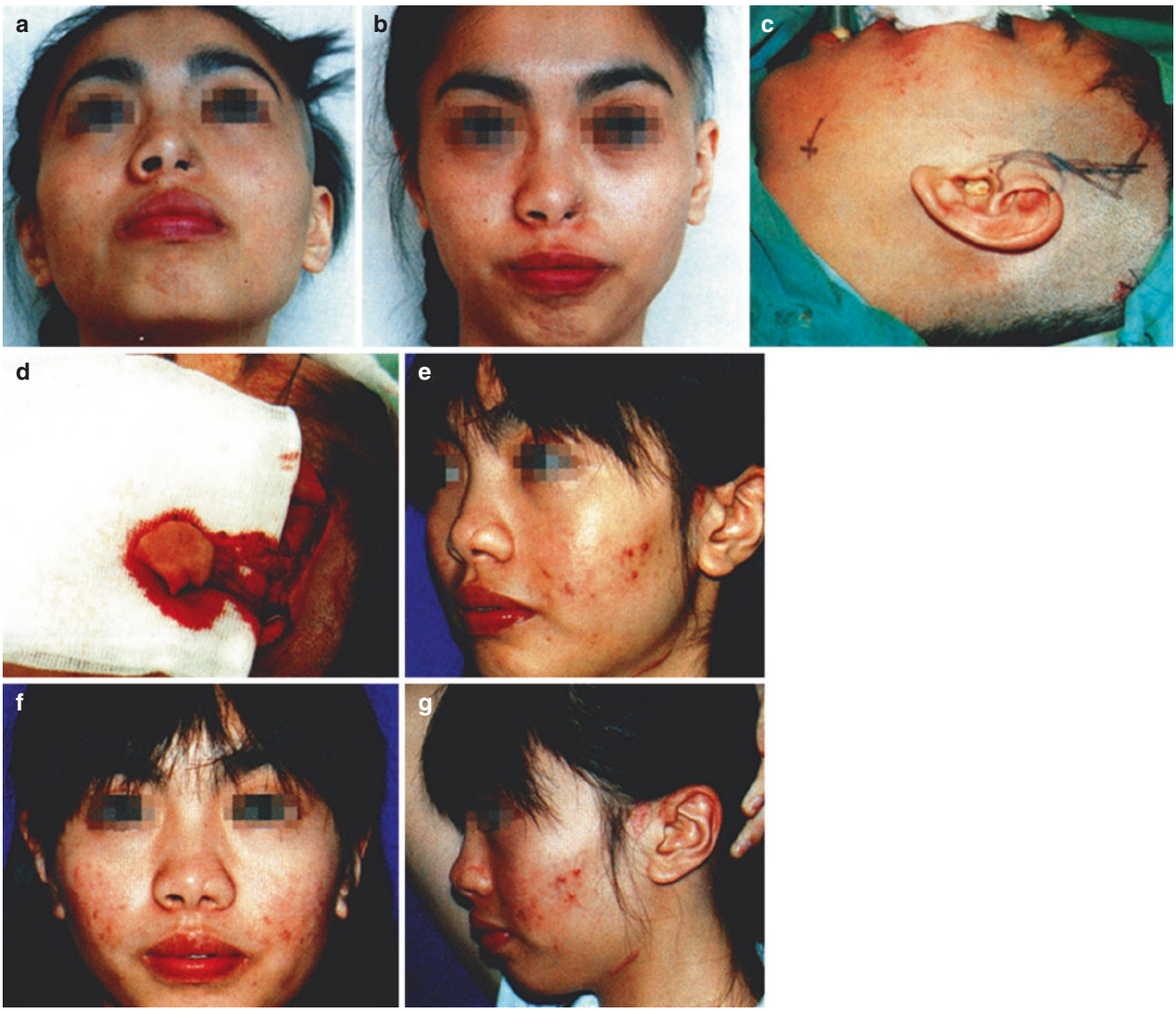

Fig. 10.16 Case V. (**a**) Profile of looking up before surgery. (**b**) Positive profile before surgery. (**c**) Application of the ipsilateral auricular composite tissue with blood vessel transplantation. (**d**) The auricular composite tissue flap of about 2.5 cm × 1.8 cm pedicled with ipsilateral retrograde superficial temporal vessels was harvested during surgery. (**e**) Later profile after surgery. (**f**) Positive profile at 1 year after surgery. (**g**) The donor site was repaired with ipsilateral retroauricular flap

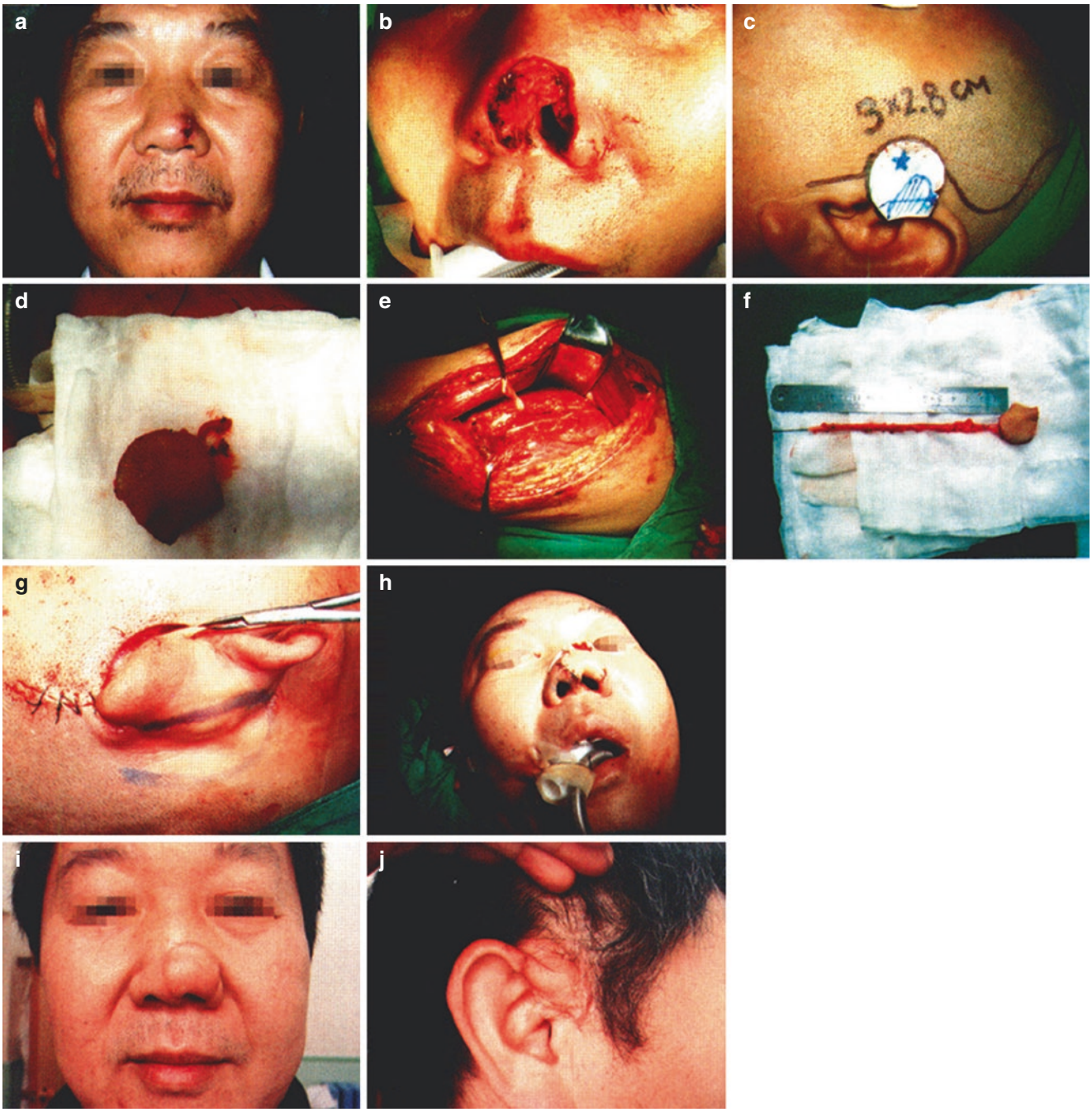

Fig. 10.17 Case VI. (**a**) The skin squamous cell carcinoma in the nosewing and nasal tip. (**b**) The defects in the left nosewing, nasal tip, and soft triangle. (**c**) The auricular composite tissue flap pedicled with the superficial temporal artery and vein was designed. (**d**) The skin flap was harvested. (**e**, **f**) The descending branch of the lateral femoral circumflex vessel bundle was harvested, and the length was about 12 cm. (**g**) The retroauricular flap was designed to repair the preauricular donor site. (**h**) The auricular composite tissue flap was used to repair the nasal defect, and the vascular pedicle was passed through the subcutaneous tunnel to be anastomosed with the facial artery and vein. (**i**) The appearance at 6 months after surgery. (**j**) The auricular donor site of skin flap at 6 months after surgery

2.3 Repair of the Defects of a Large Area

2.3.1 Paramedian Forehead Flap

At present, in the clinical practical application, the forehead flap is the main method for nasal reconstruction. Due to the fact that the skin color and texture of the forehead flap are similar to those of the nose, the blood supply is rich, and the location is adjacent to the donor site; it becomes the most popular method for nasal reconstruction. If necessary, the forehead flap can be harvested safely by multiple times in the same patient.

The median forehead flap of India is initially based on bilateral supratrochlear arteries. Millard confirmed that if

the forehead flap is designed at paramedian position, a single vascular pedicle can maintain the activity of the skin flap. McCarthy and colleagues found through autopsy study that the blood supply of paramedian forehead flap comes from the supratrochlear artery, supraorbital artery, infraorbital artery, the branches of the facial artery such as the external nasal artery and the angular artery, and the branch of the superficial temporal artery, the above blood vessels constitute a vascular plexus with rich anastomosis, and a lot of vascular branches converge around the inner canthus. They concluded that due to the presence of a wide range of collateral blood supply, even if the supratrochlear artery or supraorbital artery is ligated (this kind of situation can be found before cranial and maxillofacial surgery), the forehead flap still be able to survive. The forehead flap can be fed alone by the angular branch artery of the facial artery, but during the separation, attentions should be paid to protecting the supratrochlear vascular pedicle. After separation, the skin flap can be rotated along a point under the supraorbital margin to reach the position of nasal columella. It should be ensured that the base of the skin flap is at least 1.2–1.5 cm wide. If the distal end of the skin flap is folded, it can also be used as the nasal lining.

When the harvested skin flap is 1.25–1.5 cm wide, the forehead donor site can be closed by one-stage repair; however, when the width of the skin flap is up to 3 cm, generally the donor site can only be closed at one stage under the condition that the elderly patients have flabby skin. If the donor site cannot be closed at one stage, the wound can be left to heal by itself in the delayed period. The forehead wound of less than 2 cm can be repaired through the growth of granulation tissue and the crawling of surrounding epithelia, and the ultimate result shows no significant scars. The wound healing and contracture generally take 3–5 weeks.

The nasal reconstruction with the forehead flap can be generally divided into two stages: at the first stage, the forehead flap is lifted up and the distal end is trimmed thin and inserted into the receptor site; and 3 weeks later (at the second stage), the pedicle of skin flap is partially separated and broken off. The disadvantage of this two-stage method is that the thinning of the distal end of the skin flap at one stage may cause damage to blood supply of the site and thus cause skin flap necrosis or fibrosis. To overcome these disadvantages, Millard firstly proposed the three-stage nasal reconstruction with the forehead flap in 1974, and then Menick also described the process. A medium-term surgery is additionally performed between previous two-stage surgeries of the forehead flap, that is, before skin flap pedicle division, the structure of the skin flap is reconstructed, the appearance is sculptured and trimmed thin, and substantially all shapings of the skin flap can be completed at the second stage. The surgery at the second stage can also provide an opportunity to remedy the deficiencies existing in one-stage surgery, such as lack of the lining and insufficient tissue volume of skin flap, and the maximum vascularization of the covering tissue and lining skin flap or skin graft is ensured. Menick treated 90 patients with this three-stage method during 10 years, and only less than 5% of patients needed repair and reconstruction again.

At the first stage, the full-thickness forehead tissue flap including the skin, subcutaneous fat, and the frontalis muscle is lifted up, transferred, and fixed. If the nasal lining is intact or has been repaired through the vascularized nasal mucosal flap, at the moment, the cartilage graft transplantation can be performed at one stage; if the skin graft or the distal end of the forehead flap is folded to reconstruct the lining of the defect, the cartilage graft needs to be transplanted at the second stage. The donor site wound of the forehead flap can be closed by layers.

The second-stage surgery is performed 3 weeks later. The skin and 3–4 mm thick subcutaneous fat of the forehead flap (similar to the thickness of the normal nasal covering soft tissue) are lifted up at the level of the non-scarring subcutaneous tissue, except the pedicle and distal fixation site of the skin flap. At the moment, the forehead flap is seen as double pedicle skin flap. The extent of lifting up the skin flap can be adjusted according to the soft tissue to be removed (frontalis muscle and subcutaneous fat) and the volume of cartilage graft required for transplantation. In this period, the preplaced cartilage graft can also be adjusted in position or sculptured once again to improve the outline of the nasal appearance. If the skin graft or the distal end of forehead flap was folded to repair the nasal lining at earlier stage, the delayed transplantation of cartilage graft can be carried out in this period to reconstruct the nasal bony outline. The skin flap and the receptor site wound are sutured by means of continuous mattress suture.

The third-stage surgery is performed at 3 weeks after completion of second-stage surgery (i.e., at 6 weeks after transfer of the skin flap), the skin flap pedicle division is performed in this period, and the margin is trimmed and fixed. The proximal and distal ends of the skin flap can also be further sculptured in this period.

It is recommended that the smokers quit smoking for 2–4 weeks before nasal reconstruction. For smokers or recent quitters, the delayed skin flap surgery is more favorable. Rohrich et al. also suggested that for smoking patients, the interval time between the skin flap transfer and pedicle division is extended twice to ensure that the skin flap will survive and obtain sufficient blood supply.

The patients with intact forehead skin are usually not recommended to undergo nasal reconstruction through forehead skin expansion; however, for the patients with a narrow forehead or a lower hairline, or lack of normal tissue due to forehead trauma or burns, the forehead skin expansion is necessary (although the skin flap may be extended into the hairline). Mutaf et al. suggested that the forehead skin

expansion is performed in patients who have undergone radiographic exposure of the forehead skin. The purpose of doing so is not only to obtain a skin flap with larger area but also to obtain a more effective delayed skin flap. If there is extensive scarring in forehead, any remaining normal skin after expansion can be used for nasal reconstruction. On the contrary, in the discussion of the article, Burget strongly opposed the use of skin expansion to obtain a lot of donor site tissues required for reconstruction, he believed that the expanded forehead tissues will usually shrink back to the volume before expansion, and in this case, the effect of reconstruction is seriously weakened in either the appearance or the function. Menick also pointed out that the contraction after skin expansion is unpredictable, which will lead to that the best results cannot be achieved at any time after surgery. However, we believe that if the expanded flap can be supported well by its underneath cartilage graft, and the skin flap is designed after the dilator is taken out, it can minimize the contraction of skin flap.

If the skin expansion is performed according to the above indications, a coronal incision can be made at 3–4 cm behind the hairline, and the dilator is placed within the separated spaces under the galea aponeurotica, muscle, or subcutaneous area. Of which, the bleeding is minimum with the method of under the galea aponeurotica; therefore, the risks of occurrences of the hematoma and the injury of pedicle of the skin flap are also reduced, but the thickness of the skin flap is much greater than that of the skin flap after subcutaneous expansion. Adamson emphasized the importance of a thin skin flap. He placed the dilator into subcutaneous layer through the coronal incision and generally placed the water injection valve in a location far away from the dilator to avoid that the rigid expansion valve will exert direct pressure or exert excessive pressure on the thin skin flap. The expansion will begin to be performed at 10–14 days after dilator implantation and will be completed within 5–6 weeks. About 200–250 ml of expansion volume can only provide adequate coverage of the tissues.

1. Case VII: The patient, male, 49 years old, underwent incomplete resection of right nosewing basal cell carcinoma 1 month ago within another hospital. The extensive tumor resection is performed, and the forehead flap is used for repair (Fig. 10.18).
2. Case VIII: The patient, female, 17 years old, had a congenital nasal black hairy nevus and had undergone resection of black hairy nevus plus transplantation of the split-thickness skin graft in young age; after transplantation,

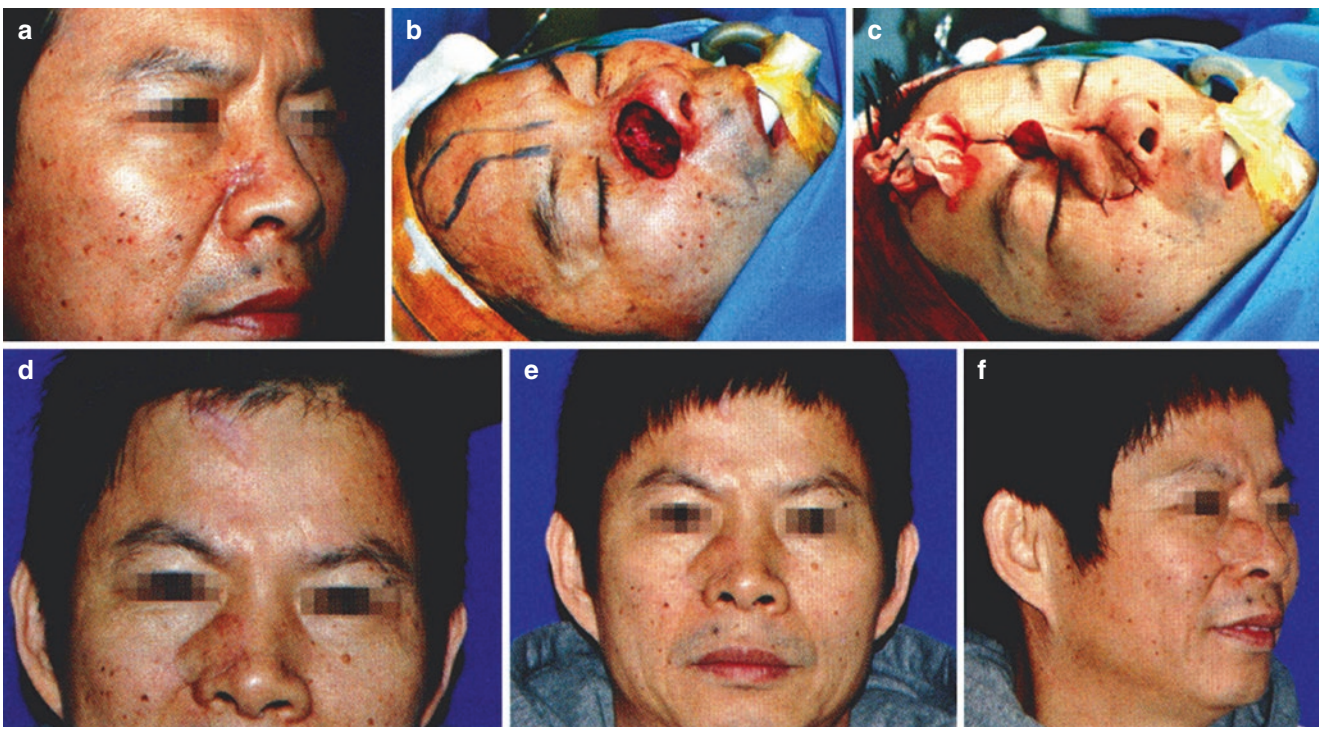

Fig. 10.18 Case VII. (**a**) Right nosewing basal cell carcinoma. (**b**) The extensive resection was performed during surgery until the incisal margin and the base are negative. The wound was about 3 cm × 2.5 cm, involving nasal sidewall, nosewing, and paranasal tissues. The forehead flap with supratrochlear artery was designed for repair. (**c**) After harvesting, the forehead flap was turned over to cover the nasal wound, the forehead wound was not treated with direct skin transplantation and was covered locally by oil gauzes, and the wound was epithelialized by itself. The pedicle was cut off at 3 weeks after surgery. (**d**) At 6 months after surgery, the forehead donor site will heal itself through epithelial crawling. (**e**) Positive profile at 6 months after surgery. (**f**) Lateral profile at 6 months after surgery

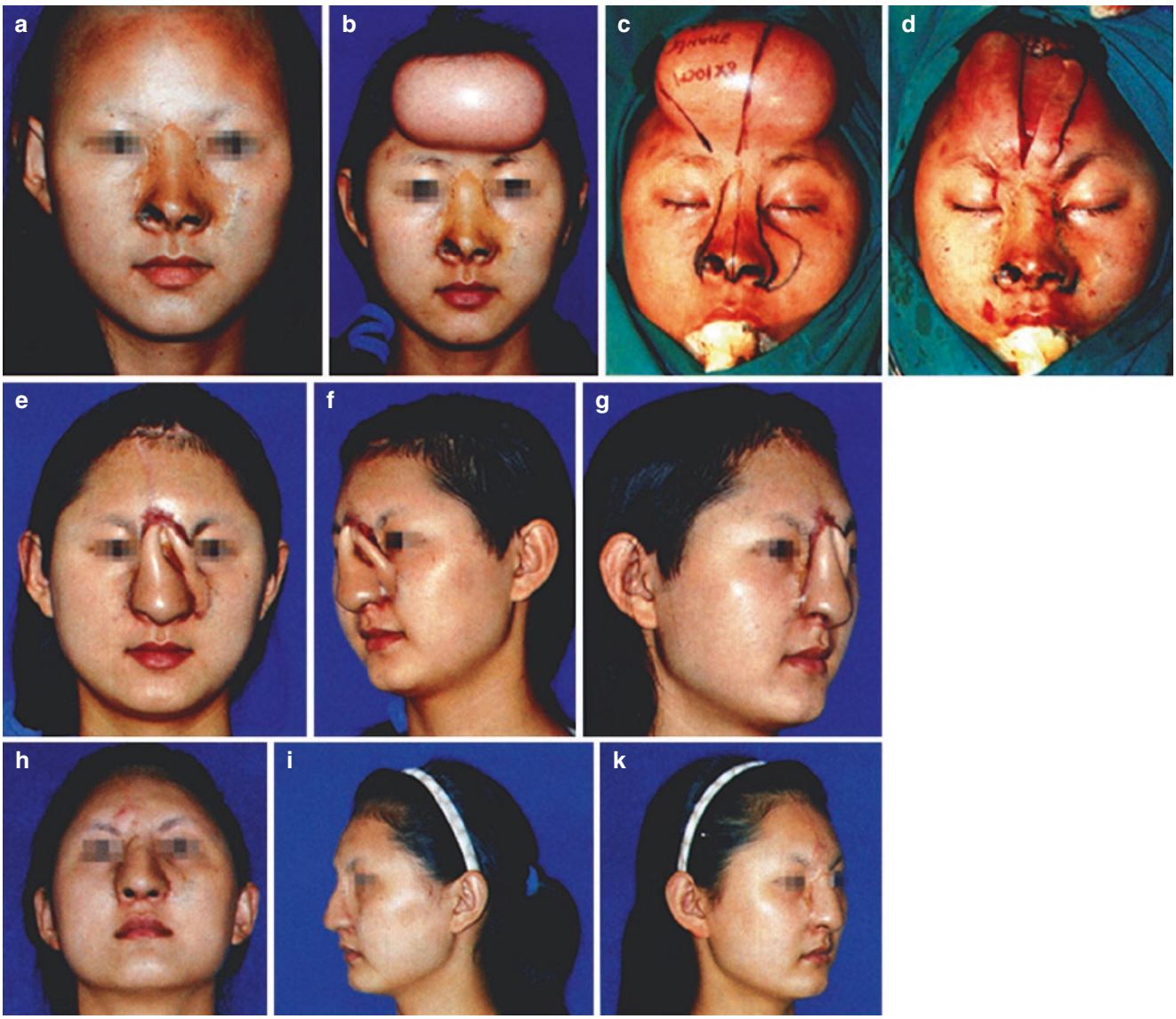

Fig. 10.19 Case VII. (**a**) Positive profile before surgery. (**b**) In one-stage surgery, a 100 ml dilator was placed in the forehead, and after about 250 ml water was injected, second-stage surgery was performed. (**c**) During surgery, the total nasal skin transplantation area was removed, including left paranasal skin transplantation area. (**d**) According to the facial subunit principle, the forehead flap with right supratrochlear artery was used to repair the total nasal defect; the forehead flap with left supratrochlear artery was used to repair the right paranasal defects. The nasal dorsum and the nasal columella were supported using silicone prosthesis. The right nosewing was supported using the cavum conchae cartilage. (**e**) Positive profile at 4 weeks after one-stage surgery. (**f**) Left lateral profile at 4 weeks after one-stage surgery. (**g**) Right lateral profile at 4 weeks after one-stage surgery. (**h**) Profile of looking up at 1 year after second-stage surgery. (**i**) Left lateral profile at 1 year after second-stage surgery. (**j**) Right lateral profile at 1 year after second-stage surgery

the color and texture were poor, and the patient asked for undergoing plastic surgery again. The forehead flap with right supratrochlear artery was used to repair the total nasal defect; the forehead flap with left supratrochlear artery was used to repair the right paranasal defects. The nasal dorsum and the nasal columella were supported using silicone prosthesis. The right nosewing was supported using the cavum conchae cartilage (Fig. 10.19).

2.3.2 Other Methods for Nasal Coverage

Other methods for nasal coverage include the scalp flap with hair, Washio skin flap composed of retroauricular and mastoid skins pedicled with the superficial temporal artery and the posterior auricular artery, sickle-shaped skin flap, or longitudinal forearm free flap which are used for reconstruction through microsurgery. These methods are not commonly used at present.

3 Reconstruction of the Skeletal Structure

The purpose of reconstruction of bone framework is to provide the structure and exclusive airway to maintain the nasal morphology, of which, the key points include the stable dorsal nasal support and nasal structure, shaping of the nasal tip and bilateral sufficient nasal lateral wall tissues, and the internal nasal valve area and external airway which are kept open. The framework of the normal nose is divided into upper one third (nasal bone), middle one third (supported by upper lateral nasal cartilage and nasal septum), and lower one third (i.e., lower lateral nasal cartilage, viz., the nasal alar cartilage).

Over the past, there were a variety of materials which can provide nasal support structure, including autologous transplant and the allogeneic or xenogeneic cartilage and bone after radiation exposure. The use of xenogeneic materials can cause a high risk of infection, ulceration, and rejection; allogeneic materials after radiation exposure are very easy to absorb. In recent years, more surgeons advocate the use of autologous cartilages and bones or combined use of both. The advantage of the cartilage is that it is soft and pliable and similar to the normal tissues. However, the main disadvantage of using a cartilage is that the graft will curl or collapse with the passage of time, and the cartilage tissue will not be integrated with the donor site tissue and is not enough to support the nasal dorsum. The advantage of using bony tissue is that it provides adequate support force, but some have a risk of being absorbed. At present, there are many sources of bones, and the commonly used bones are ribs and the skull.

The most commonly used supporting methods in nasal dorsum midline include L-shaped support of the nasal septal cartilage with mucosal perichondrium and the nasal bone transplantation. L-shaped transplantation was invented by Gillies and was popularized by Millard. They used the autogenous rib bone to reconstruct the nasal dorsum midline. The longitudinal bone or cartilage tissue directly facing the head is fixed to the nasal root and extended to the nasal tip. If the nasal bone is preserved, the newly added tissue will improve the abnormal height of the nasal root. To make the nasal bone adapt to the transplanted cartilage, it is often required to use the bone chisel to modify the nasal bone. The keys to the survival of graft are the initial osseous connection and final osseous union. Appropriate graft fixation can be achieved by using Kirschner wires or microscopic screws.

In addition to the dorsal nasal support, the support of the nasal alar structure is the key to ensure airway patency in patients. Although the first half of the nosewing is supported by the cartilage support and the second half of the nosewing is composed of fibrofatty connective tissue, the transplanted nosewing alternatives need to reconstruct full-thickness nosewing defect and match with the outline of the nosewing on the opposite side, to prevent the deformity or sinking caused by the collapse and scarring of the nosewing. The cartilage transplant should be 1 mm thick, 5–7 mm wide, and 25 mm long. The cartilage can be obtained from the septal cartilage or auricular cartilage.

3.1 Auricular Cartilage Transplantation

The contour shape of the auricular cartilage is similar to those of the nasal tip and nosewing and is the most commonly used cartilage graft and can be obtained through posteromedial or anterolateral approach. The posteromedial approach requires that the incision is performed along the rear surface of the external auricle, the cartilage, and the upper covering soft tissue which are dissociated from the mastoid area, and about 2 cm × 4 cm of cartilage is harvested. The anterolateral approach requires that an incision is made at the medial side of the connecting line between the medial side of the anthelix and the auricle, and this method will cause obvious scars. Preoperative injection of epinephrine can facilitate the separation during the surgery. As long as the adjacent area is intact, the partial harvesting of auricular cartilage does not cause defects in the appearance. After completion of the separation, the cartilage flap is shaped after harvesting and then is transplanted to the receptor site and fixed.

3.2 Composite Nasal Septal Flap

In almost all nasal defects, the nasal septum is generally kept intact and can be used as a good donor site of nasal midline support. The remaining septal cartilage is harvested as L-shaped, and its foot is connected to the mucosa. L-shaped mucosal cartilage flap is cut off at the site of the mucosa, and the septal cartilage is dissociated from the place of vomer. The width of the skin flap must be greater than 1 cm to maintain the blood supply. The skin flap after dissociation is transferred out of the nasal cavity. The exposed cartilage area needs to be trimmed, so that the mucosa can cover the cartilage margin without tension. L-shaped flap is usually sufficient for shaping of the nasal dorsum and nasal tip, but if more tissues are needed, L-shaped flap can be used as the support of other grafts, such as ribs. L-shaped flap can also be used as the support of the surface covering and lining tissues. The reconstruction of nasal framework should be completed before reconstruction of nasal structure with other nasal cartilages and soft tissues, especially the forehead flap.

3.3 The Autogenous Bone Transplantation

The two most commonly used donor sites for autogenous bone transplantation are the ribs and skull.

3.3.1 Ribs

The rib combines the advantages of the bone and cartilage while minimizing the disadvantages of both. The rib flap can be harvested through the incision at 3–4 cm from the inferior margin of the rib. Typically the bone flap is composed of 50% cartilage and 50% bone tissue, so that the blood supply of the bone flap can be reconstructed better and the bone flap can be easily fixed, while the cartilage can be used to reconstruct the nasal tip. Less cartilage may reduce the tendency to bend. The bone cortex is removed to facilitate the integration of the bone tissue with the receptor site, and the Kirschner wire is fixed onto the nasal frontal bone.

Parts of the ninth and tenth ribs are often used, because they are straighter than the fifth and eighth ribs and can reduce the shaping work. Five centimeter osteochondral flap and 4 cm cartilage can be harvested from the ninth rib to be transplanted to the nasal columella. Whether to connect the transplanted nasal columella to the nasal dorsum or not can be selected.

Gurley reported that the pediatric patients underwent nasal reconstruction through autogenous cartilage transplantation and were followed for more than 15 years. The results demonstrated that the use of costal cartilage can get greater nasal tip height and length and the smaller nasolabial angle. Horton et al. followed up two cases of nasal reconstruction patients over 40 years and found that the size and the thickness of the transplanted cartilage were essentially unchanged.

3.3.2 Skull

Some scholars believe that the skull transplantation can provide better results, because the skull in the receptor site with a better blood supply is not easy to be absorbed, and the long-term absorption rate is 15–20%. Another advantage is that the donor site is relatively hidden and the intensity of bone tissue is greater. The skull flap can be used as a nasal bone graft, the disadvantage is that there is no cartilage tissue in the bone flap, the shaping of the nasal tip appears stiff, and there is the risk of invasion.

4 Reconstruction of the Nasal Lining

The reconstruction of nasal lining is critical, if there is not enough lining, the reconstructed nasal structures will have contracture deformities, which lead to the narrowing of the internal and external nasal limen areas. The ideal donor tissue of the lining must maintain good ductility and be thin, and can guarantee the nasal ventilation after covering the cartilage graft. If the nasal mucosa tissue is taken as the lining, and the cartilage graft can be implanted at one stage; if the skin or thin distal forehead flap is taken as the lining, it is needed to implant the cartilage to ensure the blood supply of the receptor site. The tissues which can be used as the nasal linings include skin grafts, the mucosal advancement flap, the septal rotary or pivotal mucosal flap, turning inward type flap and mucoperiosteal composite flap.

4.1 Septal Mucoperiosteal Flap

The nasal mucosa tissue is the first choice for reconstruction of the nasal lining. The septal mucoperiosteal flap may carry or not carry septal cartilage, the pedicle is usually reserved for 1.3 mm wide, and the blood supply is pedicled with the septal branch of superior labial artery. The skin flap travels from the nasal base upward to reach the level of the inner canthus and from the septal branch at the anterior end backward to cross the anterior end (Fig. 10.20).

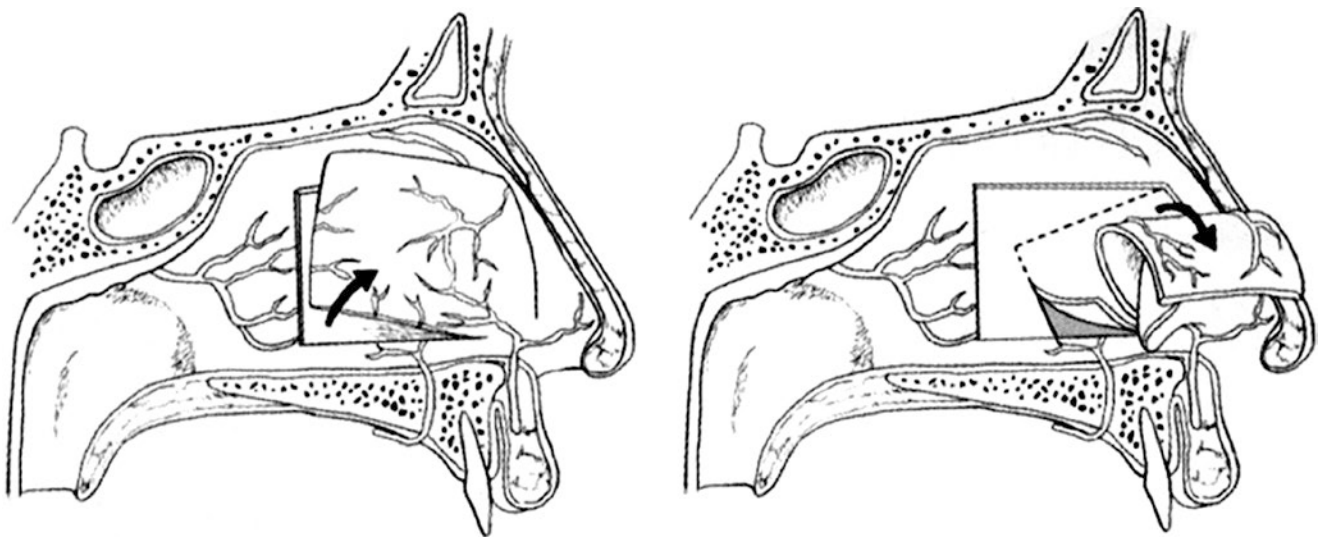

Fig. 10.20 Septal mucoperiosteal flap

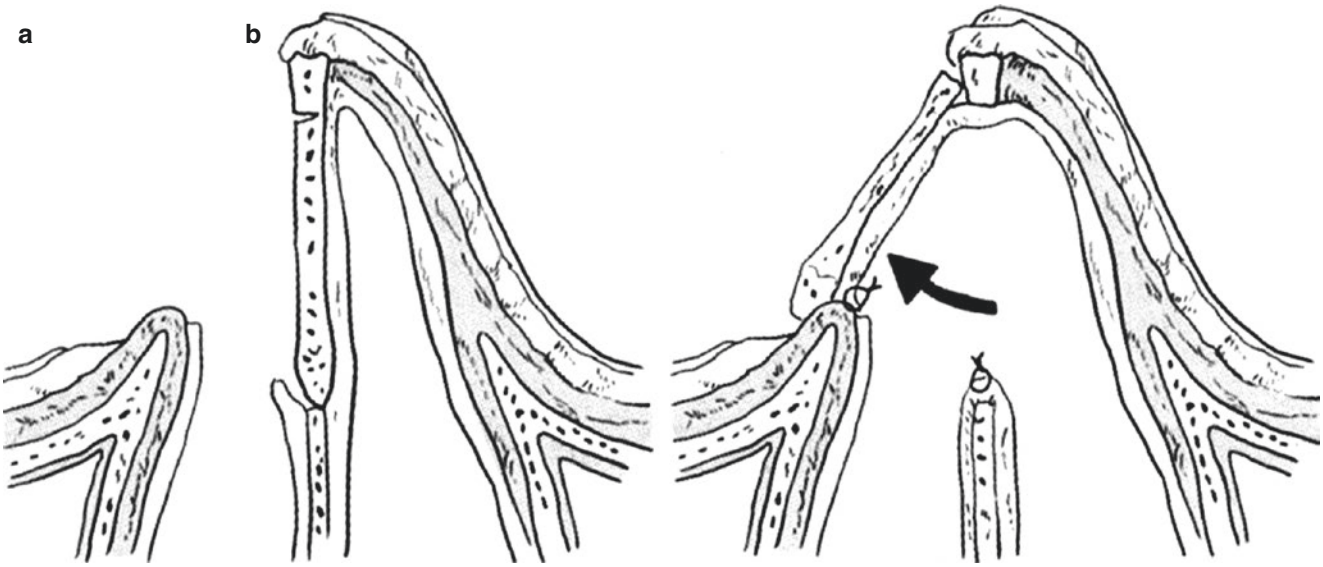

Fig. 10.21 Septal gate-shaped flap (**a**) design the septal gate-shaped flap (**b**) turn over the septal gate-shaped flap (cartilage and mucosa included)

4.2 Septal Gate-Shaped Flap

When the nosewing defect area is too large but involves only one side of the nose, the contralateral mucoperiosteal flap can be combined with the unilateral flap. The contralateral mucoperiosteal flap is separated in the nasal dorsum area, passes through the small window located in the nasal septum, and is turned over to defect area as the lining of the upper or middle part of the top of the nose; the ipsilateral mucoperiosteal flap is used to cover the lower nosewing margin of the defect area. The blood supply of contralateral flap comes from the branch of the anterior ethmoid artery. The septal cartilage and the ethmoid bone can be harvested and used as grafts. If the nasal defect doesn't involve the nasal septum and the nasal septum is intact, it is required to keep at least 1 cm wide L-shaped cartilage framework to support the nasal dorsum.

Millard described that in the gate-shaped flap, the septal cartilage and mucosa are transferred from the midline to the side wall. This particular mucosal flap can also be used either as a support or as the lining of the top of the nose. The square flap is designed on the septum, in addition to that the dorsal side is retained, and the remaining three sides are incised in full thickness. This flap is turned over from the nasal dorsum to the defect area in the side walls, is placed on the margin of maxilla, and is sutured and fixed on the nasal lateral wall after defect reconstruction. The septal flap carries contralateral septal mucosa, which is just used as the new lining of the reconstructed lateral nasal wall (Fig. 10.21).

4.3 Skin Grafts

Full-thickness skin graft can be used to reconstruct the defected nasal lining. Because the poor blood supply of the nasal mucosa tissue is caused by trauma or early rhinoplasty, it can't become a good donor site, and the skin tissue graft is taken as nasal lining. For larger defects, the full-thickness skin graft can be selectively used and simply sutured to defect area and fixed to the internal surface of the forehead nasal flap by mattress suture, and then the framework is selectively used for short-term support. The cartilaginous support graft should be implanted in the delayed period.

The skin graft operation is simple, the procedure is short, and it is especially applicable to the frail elderly patients who cannot tolerate the long, complex, or delayed surgery. Its disadvantages include that the blood supply of tissues and the cartilage grafts cannot be placed simultaneously. If the whole lining of the nasal alar margin is composed by the transplanted skin grafts, the sensation of the outline is not strong and slightly bloated after surgery.

4.4 Turning Inward Type Flap

The turning inward type flap refers that any tissue located around the defect can be turned inward as lining. If the surgery requires reconstructing the appearance of the whole nose, and the paranasal skin is intact, this method will be particularly applicable. The paranasal skin is separated, the subcutaneous tissue pedicle located at the margin of

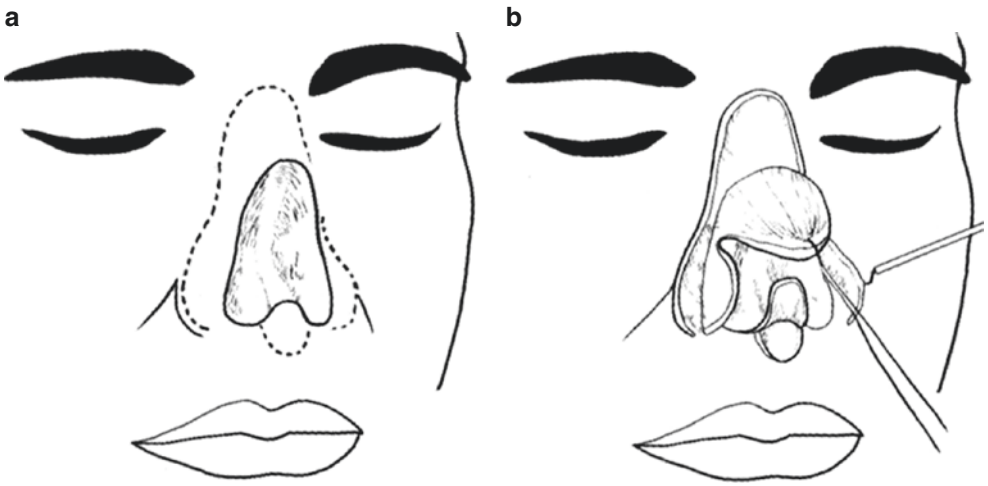

Fig. 10.22 Reconstruction of nasal lining with reversed skin flap in the nasal dorsum. (**a**) design the turning inward type flap (**b**) turn inward the flap as the nasal lining

the defect is retained, and the skin flap is turned inward as the nasal lining (Fig. 10.22). The wound of the skin flap faces outward, and it can be integrated with the wound of the forehead flap or other tissues used as skin coverage. If the paranasal tissues have scar formation due to early-stage operation or trauma, the blood supply of the skin flap will be affected. This skin flap is thick, with hard texture and poor blood supply, and the advantages and disadvantages should be weighed carefully when using the turning inward type flap, especially when designing the small skin flap.

4.5 Improvement of the Forehead Flap

The distal paramedian forehead flap can be folded, and it can be used as the lining and also can be used to reconstruct the appearance. When folded as the lining, the skin flap will seem too thick and ischemic, which will lead to poor nasal ventilation after surgery, and the appearance of the nasal alar rim is poor. When the forehead flap can be used either as the lining or as coverage, it should be extended to span obliquely to the entire forehead or is extended to the hairline.

4.6 Nasolabial Flap

The nasolabial flap can penetrate through the tunnel in the alar groove to repair the nasal defect, and the skin faces the nasal vestibule.

4.7 Microsurgical Skin Flap

The microsurgical reconstruction of the nasal lining is often used as a remedial measure for early surgical failures or insufficient local tissue. Walton et al. recently reported the use of free forearm flap to reconstruct and treat the patients with nasal lining necrosis induced by cocaine, because the nasal cavity has a smaller volume; therefore, the staging debulking procedure of forearm skin flap and delayed operation are performed to obtain thinner lining tissue. Other methods include dorsal skin flap, the first dorsal pedis flap, inferior epigastric arterial skin flap, rib and latissimus dorsi composite tissue flap, or a combination of above flaps. Radial forearm flap is most useful, which requires a further debulking procedure and requires multiple laminated processings before transferring.

5 Problems Related to the Rhinoplasty

5.1 Complications

Typically, when the local skin flap is used to repair the small-scale nasal defect, the skin flap necrosis is rare, and for total nasal reconstruction, due to larger flap preparation or free microsurgical flap transplantation, some distal necrosis is often likely to occur. Common complications of nasal reconstruction include delayed wound healing or poor healing, skin flap necrosis, and nasal ventilation dysfunction; in addition, hypertrophic scar, asymmetry of reconstructed nose, color aberration, and irregular shape are also common complications; therefore, it is often required to perform multiple repairs and reconstructions to achieve the best shape and effect of nasal reconstruction. The patients should be sufficiently informed to have a good understanding before surgery.

5.2 Postoperative Care

The prophylactic antibiotics can be used. After reconstruction of the nasal lining, it is required to carry out suitable nasal packing and support. At the same time, the patients must be told that after nasal reconstruction, the swelling period may take some time; after waiting for wound healing,

it may be necessary to carry out multiple repairs and reconstructions to complete the plastic and reconstructive surgery of the total nose. The scar treatment and maintaining the nasal ventilation should be performed for a long time.

5.3 Shape Righting During Later Period

Six months later, with the wound (scar) matures, if necessary, the shape righting during the later period can be performed. The outline of the nasolabial groove or nasal alar fold can be strengthened through partial resection of soft tissues or V-Y advancement. If the nostril rim is too thick, it can be trimmed thin. The scar on the foreheads or the hypertrophic scar after secondary healing can be repaired. In order to adjust the final effect, it is possible to perform any numbers of late repairs.

The nose is an important facial structure; during nasal reconstruction, the normal structure of the nose should be kept in mind; the status of the defects to be repaired should be analyzed carefully, for example, what tissues are impaired, what tissues are still retained, and what tissues can also be used to reconstruct the defect structure.

A successful nasal reconstruction depends on the precise removal of tumor tissue, the appropriate coverage of nasal defect, and the reconstruction of the framework and the lining tissues. The best reconstruction results depend not only on the optimal surgical options but also the maintaining and recovery of the best ventilation function. Finally, the choice of surgical approach and the evaluation of surgical effect also depend on different requirements and expectations of various patients.

All surgical photographs published in this chapter have been approved by the patients themselves.

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Repair of Facial Nerve Paralysis After Tumor Surgery

11

Chuan Yang and Xiao Zhou

1 Overview

1.1 Causes and Diagnosis

The facial nerve paralysis is called as the facial paralysis in short and is a general term for the syndrome with main characteristics such as the loss of facial voluntary movement and loss of expressive function. Due to failing to control the facial expression muscles, the patients cannot show emotion, and the morphological distortion and functional disorder will also appear. The consequences of facial paralysis are undoubtedly devastating, and the patients often have strange psychological twist and unsociable and eccentric disposition, which severely affect the normal social activities. The repair is particularly important for the facial paralysis patients after tumor surgery, because in addition to the original damage caused by tumor surgery, the subsequent facial paralysis further aggravates the physical and psychological trauma of the patient. And the timely repair of the facial paralysis in patients after tumor surgery cannot only significantly improve the facial condition of the patient and repair the psychological trauma but also enhance their strength and confidence to overcome the disease, because after facial nerve injury, the facial muscles controlled by the facial nerve will have atrophy and degeneration and eventually become the fibrous tissue without systolic function due to fibrosis. To restore the facial activity, it is required to repair the facial nerve as early as possible, and even it is needed to transplant the muscle into the affected face, and the power is reconstructed to repair facial paralysis. Because there are more facial expression muscles, the location and extent of the paralysis may vary; therefore, a detailed and accurate classification of the facial paralysis sequelae must be carried out at first, and then the appropriate repair methods are formulated combining the characteristics of the primary disease and physical condition, psychological quality, and rehabilitation desire in the patients. The individualized repair of facial paralysis and a series of repairs of facial deformities should be the direction of repair of the facial paralysis sequelae after tumor surgery [1, 2].

1.2 Applied Anatomy

1.2.1 The Composition of the Facial Nerve

The facial nerve is the cranial nerve VII. It is a mixed nerve, consisting of three components:

1. Motor fiber: It controls the expression muscle, platysma muscle, stapedius muscle, posterior belly of the digastric muscle, and stylohyoid muscle.
2. Secretory fiber: It controls the lacrimal gland, sublingual gland, submandibular gland, and grands in the palate and nasal mucosa.
3. The sensory fiber: It controls the taste buds in the anterior two thirds of the tongue.

1.2.2 The Extracranial Branch of the Facial Nerve

The facial nerve runs out of the brain to enter into the internal acoustic pore, passes across the bottom of the inner ear, and enters into the facial nerve canal in the petrous bone. Within the facial canal, it runs toward the anterior lateral side at first but then runs toward the posterior lateral side, the trunk after turning runs downward again, passes out of the stylomastoid foramen, and runs forward into the parotid gland (Fig. 11.1):

1. The posterior auricular nerve: It is given off at the site near the stylomastoid foramen and runs backward to control the occipitalis muscle and the muscles around the ear.

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Fig. 11.1 Facial nerve anatomy

2. The digastric branch and the stylohyoid branch: They are parallel to the posterior auricular nerve and control the muscle of the same name.

Above these are three small branches. The trunk of the facial nerve runs forward from the deep surface of the mastoid process and enters into the gland essence from the deep lobe of the parotid gland; in most cases, it is divided into two branches such as upper and lower branches and then are woven into a single bundle within the parotid gland, which runs between the deep and superficial lobes of the parotid gland and then gives off the following branches radially at the anterior margin of the parotid gland:

1. Temporal branch: It controls the frontal muscle and orbicularis oculi muscle.
2. Zygomatic branch: It controls the orbicularis oculi muscle and zygomatic muscle.
3. Buccal branch: It controls the cheek muscle, orbicularis oris muscle, and other muscles around the mouth.
4. Marginal mandibular branch: It runs downward along the lower margin of the mandible and controls the quadrate muscle and deltoid muscle of the lower lip.
5. Cervical branch: It controls the platysma muscle.

Since the anatomies of the terminal branches of the facial nerve are highly variable, this brings many difficulties to the surgical exploration of the facial nerve. However, as long as the possible variation is fully considered during surgery, and each patient is regarded as a new variant case, serious and careful operations are performed to safely and quickly expose the facial nerve anatomy and prevent the occurrence of accidental injury of the facial nerve due to surgical operation. The local anatomies of the facial nerve branches and the surgical considerations will be described in detail in the relevant chapters.

1.3 Clinical Classification

The facial paralysis can be classified according to the course of the disease, location, scope, extent, and etiology. According to the etiology alone, it can be classified into congenital, traumatic, neurogenic, infectious, metabolic, neoplastic, toxic, iatrogenic, and spontaneous classes, but given the range of topics in this chapter, only the facial paralyses related to tumor and caused by tumor surgery are discussed herein.

The common tumor-associated facial paralysis includes the following categories:

1. The facial paralysis which is caused by direct tumor invasion of the facial nerve, such as facial nerve neuromas.
2. The facial paralysis which is caused by the tumor growth compression on the adjacent facial nerve, such as acoustic neuroma of the brain, the squamous cell carcinoma of the middle ear, meningioma, schwannoma, or other malignant tumors [3, 4].
3. The facial paralysis which is caused by removal of the facial nerve and facial muscles during tumor resection, such as facial malignant tumor resection, external ear tumor resection, radical mastoidectomy, acoustic neuroma resection, parotid gland tumor resection, facial hemangioma resection, and neurofibroma resection.
4. The facial paralysis which is caused by the injury of the facial nerve, it is commonly seen in the buccal surgery, parotid surgery, and mastoid surgery.

However, no matter the facial paralysis is caused by what kind of tumor surgery, what problems faced in the clinical work are actually the repair of injury of the facial nerve and/or facial expression muscle which has occurred, as well as the repair of partial loss or complete loss of facial muscle function.

1.4 Classification of Functional Statuses of Facial Nerves and Muscles

The functional statuses of the facial muscles are directly related to the presentation of facial expressions, and the

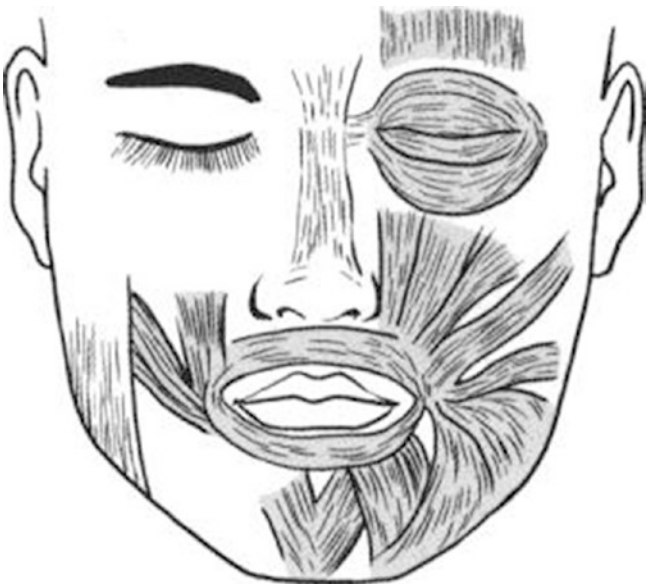

Fig. 11.2 The anatomies of the facial expression muscle

contraction of the facial muscle is controlled by the facial nerve. Therefore, the treatment of facial paralysis is repair of functions of facial nerves and muscles. The functional statuses of facial nerves and muscles are classified to directly reflect the functional statuses of the facial nerves and muscles. Therefore, the classification is performed according to the anatomy of the expression muscle (Fig. 11.2), anatomy of the facial nerve (see Fig. 11.1), and their functional statuses, which has significant clinical implications for guiding the treatment and repair of facial paralysis. Summarizing the experiences in repair of facial paralysis in the clinic, the authors have proposed the following classification:

1.4.1 Classification of Facial Nerve Functional Statuses

1. Complete transection of the facial nerve: It is the complete injury of the facial nerve which is caused by the surgery or trauma.
2. Incomplete transection of the facial nerve: It is the partial injury of the facial nerve which is caused by the surgery or trauma.
3. Complete degeneration of the facial nerve: It is injury and degeneration of the facial nerve after resection of the intracranial tumors (the acoustic neuroma is more common).
4. Absence of the facial nerve: It is congenital and trauma-induced complete or partial facial nerve defect.
5. The getting lost of the nerve axons: After the nerve is broken, the surgical suture causes the dislocation anastomosis of the nerve bundle branch or the regenerated nerve axons get lost. Due to the dislocation growth of the neural axons, the error will occur in the transmission of action potentials, which causes the corresponding facial muscle movement disorders or the occurrence of the synkinetic movement, false movement of different facial muscles, and abnormal facial expressions.

1.4.2 Classification of Functional Statuses of the Facial Muscles

1. Absence of facial muscles: Congenital complete absence or partial absence of facial muscles and partial absence of facial muscles caused by surgery and trauma. The facial muscles after denervation gradually degenerate and thus result in fibrosis and loss of contractile function.
2. Complete paralysis of facial muscles: At the early stage of the facial nerve injury, the facial muscles have no muscle strength, but the facial muscles are not yet completely denatured. After regeneration of the nerve, the paralyzed facial muscles can be innervated again to restore contractile function.
3. Partial paralysis of facial muscles: Parts of the facial muscles are denervated.
4. Insufficient muscle strength of facial muscles: Part of facial muscles has muscle strength, and the muscle strength of bilateral facial muscles is out of balance, which causes the asymmetric facial expressions.
5. Facial muscle spasm: The facial muscles show involuntary spasm-like contraction.
6. Synkinetic movement and false movement of facial muscles: The facial muscles can contract, but the movements are out of control; there is no coordinated movement or there is only platelike synkinetic movement and false movement. The synkinetic movement of the affected orbicularis oculi muscle, zygomatic muscle, and risorius muscle is most commonly seen; when the patient closes his eyes, the contractions of the affected zygomatic muscle and risorius muscle will be triggered, which makes the mouth skewed to the affected side; and when the patient smiles, the affected corner of the mouth cannot contract, which makes the mouth skewed to the healthy side.
7. Abnormal attachment points of the facial muscles: In congenital or trauma-induced abnormal attachment points of the facial muscles, because the attachment points on bilateral facial muscles are asymmetric, which leads to distortion of commissure and grotesque expression.

It can be seen from the clinical classification of facial paralysis that the facial muscles and facial nerves in various parts are likely to be injured, respectively, and different combinations of injuries will exhibit a variety of forms of facial paralysis. Therefore, it is required to understand the medical history as detailed as possible and perform scrupulous physical examinations before treatment, including the determination of the cause, onset time, injured location, and assessment of injured degree, and then the appropriate method is selected

according to the rehabilitation requirements and physical conditions of the patient, characteristics of the original disease, recurrence rate, and the prognosis of the disease.

1.5 Treatment Protocols

There are various surgical methods for the repair of facial paralysis, but they are basically divided into two types, namely, static and dynamic repairs. The static repair can only maintain bilateral symmetry of the face at the static state; once the facial activities appear, for example, when the patient talks, smiles, and shows expression on the corner of the mouth, the facial deformity will still occur. Therefore, currently, the static repair is only used as supplementary means for dynamic repair in clinics and is not used alone. The dynamic repair can also be divided into two types such as physiological dynamic repair and nonphysiological dynamic repair [5, 6].

1.5.1 Physiological Dynamic Repair

1. The broken ends of the injured facial nerve are sutured directly, or the broken ends are sutured after nerve transplantation. The original innervation of the facial nerve may be restored at the affected side, and the original facial muscle function may be recovered. The method is suitable for patients in the early stages with good proximal and distal ends of the facial nerve.
2. The cross-face nerve transplantation: According to the principle that most facial movements are bilateral synchronous movements, the nervous impulses at the healthy side are transferred to the affected side through nerve transplantation to control the affected facial muscles to move synchronously with that at the healthy side. Such repair method is only suitable for patients with early facial paralysis, that is, no atrophy or degeneration has been detected in facial nerve branches and facial muscles.
3. Replacement of the paralyzed facial muscle through transplantation of the muscle flap carrying blood vessels and nerves to the affected side. The control nerve of the muscle flap crossing the face is anastomosed with the branches of the facial nerve at the healthy side, and the facial nerves at the healthy side are used to control the contraction of the transplanted muscle. Consequently, the corner of the mouth is pulled, and the affected side can move synchronously with the healthy side to restore a symmetrical smile and thus achieve the purpose of being similar to the normal physiological activities of the facial expressions. The surgical method is suitable for patients with late facial paralysis, that is, atrophy or degeneration has been detected in facial nerve branches and the facial muscles [7–10].
4. The existing surgical method still cannot obtain a natural and casual smile for the reasons below:
   (1) There are as many as ten facial muscles controlling the fine activities of the corner of the mouth at one side, and thus it is not possible to recover all delicate facial expressions only through transplanting a muscle.
   (2) In the facial muscles, the ratio of the nerve axons to the muscle fibers dominated by them is 1:25, and the ratio of the nerve axons to the transplanted bone and muscle is 1:200 to 1:150. The fewer muscle fibers each muscle fiber controls, the more sophisticated the controlled activity is; therefore, the delicate expressions exhibited by the facial expression muscles cannot be manifested by the contraction of the skeletal muscles. Nonetheless, it is still possible to recover a particular facial expression (e.g., smile) through single muscle transplantation to meet the need of the patient for social activities.
   (3) If the nerve at the healthy side is used to control the muscle activity at the affected side, it is necessary to carry out the nerve transplantation. Since the transplanted nerve during surgery is longer and the passing rate of nerve regeneration is low (only 20–50% of axons pass through), the effect of the transplanted nerve would be difficult to predict. At present, the regulatory mechanism of nerve regeneration has not been fully deciphered. It is not guaranteed that the nerve regeneration can be achieved and the harvested nerve can control the transplanted muscle accurately, so the surgical effect is still unstable.
   (4) The existing surgical method has high technical requirements, and it needs to be completed together by two to three groups of surgeons with skilled microscopically techniques. Thus, although the physiological dynamic repair is the direction of the repair of facial paralysis, due to great surgical trauma, slow postoperative recovery, uncertain effect, and high technical requirements, the drawbacks such as the synkinetic movement and false movement of facial muscles may occur. The doubts of the surgeons and patients on the surgical effect affect the popularization and application.

1.5.2 Nonphysiological Dynamic Repair

1. Local muscle flap transposition: The facial muscle flap at the affected side is translocated and is sutured and fixed with the corner of the mouth at the same side. When the muscle flap contracts, the corner of the mouth is pulled to restore smiling facial expression at the affected side. At present, the temporal muscle and masseter muscle are mostly taken as the dynamic muscles. After this kind of prosthetics is completed, the contraction of the dynamic

muscle is not synchronized with the facial muscle activity at the healthy side, and thus it must be practiced to coordinate with the healthy side. The nonphysiological dynamic repair takes the temporal muscle and masseter muscle as the dynamic muscles. Because its muscle flap is transferred with pedicle and the nerve regeneration process is avoided, the postoperative recovery is quick and the effect is stable. But the patient should go through certain practicing for this kind of smile, and that this kind of smile can only be made when gritting one's teeth and mastication, while this will make the patient's smile looks like grinding his or her teeth. When the patient eats and chews, there will be involuntary strange spasm in the corner of the mouth, and this is difficult to be accepted by the patient. Therefore, it is now rarely used. Nevertheless, the nonphysiological dynamic repair has characteristics such as quick recovery, stable effect, easy operation, and low risk; thus, there is an urgent need to further improve the existing surgical method in the clinic.

2. Transposition of sternocleidomastoid: In 1999, the author designed the use of the sternocleidomastoid as a power source to repair the late facial paralysis, avoiding the disadvantage of the original surgical method, which has achieved a very good clinical effect.

1.5.3 Personalized Repair Methods

Since there are numerous and diverse surgical methods for repair of facial paralysis, how to select the appropriate surgical methods for repair of various facial paralyses is the primary issue every clinician must address. According to the classification of the functional statuses of facial muscles and facial nerves, the appropriate individualized repair surgery programs can be designed based on the damage situation. Based on years of clinical experience, the authors summarize the designing scheme for repair of facial paralysis to provide some reference for the performers, in order to obtain good repair effect.

1. The repair method for the facial paralysis due to facial nerve trunk injury:
   (1) The main reasons of facial nerve trunk injury: The most common facial nerve trunk injury occurs mostly within the range from the facial canal within the petrous portion of the temporal bone to the portion of the parotid gland, and it is caused mostly by tumor resection or accidentally injured due to surgical operation. Once the facial nerve trunk injury is observed, the immediate completion of connection between nerve stumps is the simplest method among all repair surgeries, and it can also be expected to get the best recovery effect. The direct apposition suture cannot be performed often due to scar formation and contracture in the nerve stumps during the delayed nerve stump surgery, and it is often required to carry out nerve transplantation in the space between nerve stamps. The cross sections for the nerve to pass by are increased (about 30% of regenerated nerve axon bundles will be reduced for each additional cross section passed through by the nerve). As a result, the number of regenerated nerve axon bundles that are allowed to pass is reduced, which directly affects the surgical effect.
   (2) Common surgical methods and their effects:
      1) Apposition suture of nerves: It is suitable for patients with neurotmesis and intact proximal and distal nerve ends. The effect is most ideal due to direct apposition suture of nerves.
      2) Nerve transplantation: The nerve transplantation can be performed for patients with defects in neural stumps. Due to increase of cross sections for the nerve to pass by, the effect is greatly affected.
      3) Cross-face nerve transplantation: If the proximal nerve is damaged, and the distal nerve and the facial muscle are intact, the nervous impulses of the proximal end of the branch of the facial nerve at the healthy side are transmitted to the distal end of the branch of the facial nerve at the affected side to restore the muscular tension and expression activities of the affected facial muscles through cross-face nerve transplantation. For the success of cross-face nerve transplantation, the transplantation should be carried out in the early stage of the facial paralysis. To confirm that the distal end of the nerve and the facial muscles at the affected side are intact, the transplanting cultivation of the nerves is performed before the regenerated nerve axons reach to ensure that the facial muscles will not shrink. In this way, the regenerated nerves can be connected with the motor end plates. The hypoglossal nerve can be transposed to the facial nerve for parasitic culture; after the cross-face transplanted nerves grow long enough, the distal facial nerve will be separated with the hypoglossal nerve. Since the regenerated axons of the nerve need to pass through two cross sections, and the nerve regeneration still needs to pass through a distance of more than 15 cm, the recovery time is longer, which will take about more than 1 year. Once the operation is successful, the affected facial muscles can move synchronously with the facial muscles at the healthy side, but the effect is not ideal in most cases.
      4) Neuronal replacement with accessory nerve and hypoglossal nerve transpositions: The proximal end of the hypoglossal nerve or accessory nerve is used to replace the facial nerve and is connected

with the distal end of the facial nerve, which is also suitable for the patients with intact distal facial nerve. The surgical method has been widely used for these reasons: the operation is easy and the nerve regeneration passes through only one cross section, and therefore it takes about 4–6 months to restore the activities of the affected side; the disadvantage is that due to damage to the donor site of the hypoglossal nerve or accessory nerve, most of the facial movements at the affected side are the plate-shaped synkinetic movements; in the early postoperative period, when the patient shrugs (accessory nerve transposition) or moves the tongue when chewing (hypoglossal nerve transposition), the affected face will be distorted. The ultimate effect will be determined by the result of long-term training of the patient.

(3) Case I: The patient, female, had facial paralysis after parotid gland tumor resection and underwent the facial nerve repair surgery (Fig. 11.3).

2. Repair method for facial paralysis due to facial nerve branch injury:
   (1) The common causes of facial nerve branch injury: In clinical practice, the facial nerve branches are wrapped within the tumor body mostly due to the growth of the parotid gland tumor and cheek tumor; the facial nerve branches can only be removed together when the tumor resection is performed. In addition, if the tumor body is too close to the facial nerve within the surgical field, there are more bleedings in the surgical field, and the surgical field is unclear; all these factors can also easily lead to accidental injury of the facial nerve branches.
   (2) Common surgical methods and their effects:
      1) Neural anastomosis: The immediate direct apposition suture of the broken ends of the nerve branch is the repair method with best effect.
      2) Nerve transplantation: When the space between the broken ends of the nerve branch is too large to perform direct suture, the free autologous nerve transplantation can be performed. The great auricular nerve, the cutaneous branch of the cervical plexus, the cutaneous branch of the radial nerve, and the sural nerve are selectively used as the donors for nerve transplantation. Compared with the direct neural anastomosis, the effect is a bit poor.
      3) Cross-face nerve transplantation: The nervous impulses at the healthy side are transmitted to the affected side through nerve transplantation to restore the synchronous movements of bilateral facial muscles; of course, the affected facial muscles must be intact, if the facial muscles have been injured, and it is needed to select other surgical method.
3. The repair method for the facial paralysis due to the facial muscle injury:
   (1) Common causes of facial muscle injury: Mostly due to the tumor growth, the facial muscles will be wrapped within the tumor body; when the tumor resection is performed, the facial muscles can only be removed at the same time. In addition, the denervated facial muscles are degenerated into the fibrous tissue and lose their contractile functions in the later period of injury in the proximal end or the branch of the facial nerve.
   (2) Common surgical methods and their effects:
      1) Free muscle transplantation during neurovascular anastomosis: It belongs to the physiological dynamic repairs. The donors of muscles for the

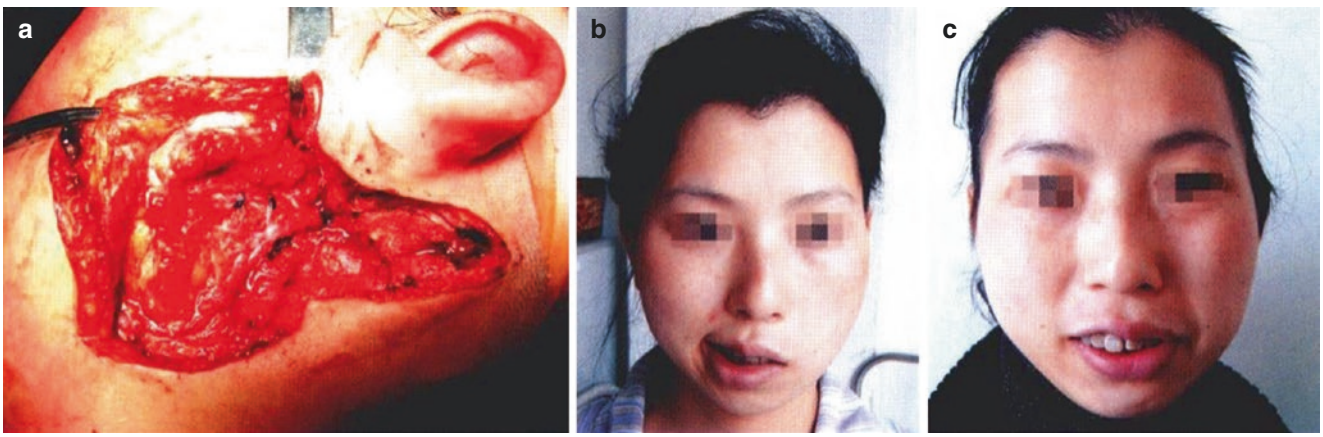

Fig. 11.3 Case I. (**a**) The facial nerve trunk and branches were separated off after parotid gland tumor resection. (**b**) Before facial nerve repair for left facial paralysis. (**c**) The left facial paralysis had been repaired 4 months after facial nerve repair

first-stage transplantation with relatively positive effects include the latissimus dorsi muscle, gracilis muscle, and rectus femoris muscle, of which, it is more commonly seen that the latissimus dorsi muscle is transplanted to repair the facial paralysis. The surgical method has the advantages that the nerve has only one anastomotic stoma, and the facial recovery is quicker compared to the second-stage muscle transplantation; the disadvantages are that the surgical trauma is big, and the requirements for surgical techniques are demanding; when the nerve localization result is inaccurate, the transplanted muscles may produce false movements. If the nerve branches of the transplanted muscle are dissected mistakenly or the blood vessels are improperly sutured during the operation, the surgical failure will easily occur [11] .

2) Pedicled sternocleidomastoid muscle transposition: It belongs to the nonphysiological dynamic repair. The pedicled sternocleidomastoid muscle at the affected side is transposed to the corner of the mouth at the affected side, and the movements of the corner of the mouth at the affected side are reconstructed. The surgical method has the advantages of positive effect and less trauma and quicker recovery; the disadvantages are that there is a cervical incision scar after surgery, and the smiling face can be recovered only after simple training [12, 13].
3) Pedicled temporalis muscle transposition: It belongs to the nonphysiological dynamic repair. The temporal muscle attachment points at the affected side are stripped off from the temporoparietal area, and this muscle is turned over downward together with the aponeurosis and periosteum at the top and then passes through the subcutaneous tunnel to be sutured with the corner of the mouth, and the activities of the corner of the mouth are mobilized when the temporal muscles contract. The advantages include positive effect and rapid recovery; the disadvantages are that the temporal depression is obvious, and the smile can only be presented when the patient grinds his or her teeth to mobilize the activities of the corner of the mouth, and the smile is less natural.
4) Direct suture of facial muscles: For the patients with ruptured facial muscles, the direct suture of facial muscles can receive good results. Especially the ruptured facial muscles at the medial side of the connecting line from the outer canthus to the corner of the mouth may be accompanied by ruptured facial nerve branch. The local nerve branch has been very small, and its exposure is quite difficult, while the suture of the muscle is conducive to the regeneration of nerve branches in the near side of the broken ends of the muscle, and thereby the denervated distal muscle can be innervated to restore the function of the facial muscles.

4. The repair method for facial paralysis with facial soft tissue defects: The facial soft tissue defects mostly refer to skin defects in the parotid area. The facial soft tissue defects are more commonly seen in patients with hemangioma, neurofibroma, and malignant tumor in the face and cheek which have invaded the skins; at the same time, for tumor resection, the skin tissues which have been invaded must be resected. The local skin defect may be repaired with local skin flap transfer, pedicled local myocutaneous flap, or free myocutaneous flap with vascular anastomosis. Commonly used surgical methods are as follows:
   (1) Cervical local skin flap transfer: It is suitable for patients only with skin defects in the parotid area but without defects in the facial muscles and the facial nerve. The retroauricular and cervical skin flap is harvested by surgery and is rotated forward to cover the wound; if the cervical donor site cannot be sutured directly, it can be repaired with transplantation of skin grafts.
   (2) Transplantation of free latissimus dorsi myocutaneous flap: It is suitable for patients who have facial paralysis and larger buccal skin defects after tumor resection:
      1) Surgical design and skin flap harvesting: A skin flap slightly larger than the size and shape of cheek skin defect is harvested, and the latissimus dorsi myocutaneous flap attached under the flap is harvested according to repair needs, and then it is sutured and fixed between the temporal fascia and corner of the mouth for repair of the facial paralysis. The thoracodorsal artery and vein of the skin flap can be anastomosed with the facial artery and vein, and the control nerve can be anastomosed with the ipsilateral facial nerve to restore some activities of the affected face.
      2) The repairing principle and surgical method for the huge facial defect after tumor resection: For patients with huge facial soft tissue defects, the repair of facial paralysis is not the key point, while the latissimus dorsi myocutaneous flap can be used to cover the wound. The huge facial tumors often involve the frontoparietal area to the ipsilateral mandible, and the wound left after debridement can reach up to 25 cm × 15 cm. For such a huge wound, the primary problem is to use the tissue with good blood supply to cover the wound. Because there are exposures of bones and

cavities in the wound, the vascularized free myocutaneous flap transplantation is the only option. At present, the myocutaneous flaps in the human body available for selection only include the latissimus dorsi myocutaneous flap. The latissimus dorsi myocutaneous flap has large area, rich blood supply, strong resistance to infection, easy operation, and hidden position, and thus it is most commonly used in the clinic. It is not necessary to consider the repair of the facial paralysis during surgery, and it is feasible to mainly perform the simple covering. Because the myocutaneous flap has a considerable thickness, it is required to properly enlarge the sections around the area covered by the skin flap when the area of the skin flap is designed. The blood vessels of the donor site can use the facial artery and vein and can also use the superior thyroid artery and the lateral superficial cervical vein. The thoracodorsal nerve can be anastomosed with the facial nerve. Since the latissimus dorsi myocutaneous flap is too thick and heavy, the postoperative skin flap is prone to sagging deformation, which requires multiple repair and construction to improve the appearance as far as possible.

3) Case II: The patient, female, had left facial hemangioma, and the wound had been festering. The left facial defects occurred after extensive resection of the tumor. The latissimus dorsi myocutaneous flap was used to repair the left face, and the wound healed well after surgery (Fig. 11.4). However, because the latissimus dorsi myocutaneous flap is too hypertrophic and heavy, the skin flap is prone to sagging deformation after surgery, which requires multiple repair and construction to improve the appearance.

(3) The first-stage repair with pedicled sternocleidomastoid muscle flap: It is suitable for patients with defects in the facial nerve trunk, and it branches after tumor resection which cannot be repaired with nerve transplantation:

1) Surgical design: According to the need to repair the facial paralysis, the sternocleidomastoid muscle flap of appropriate length is prepared and was rotated to the face, and the ends of the muscle flap are fixed to the sites such as the orbicularis oculi muscle and orbicularis oris muscle, respectively, to correct facial paralysis. The innervation depends on the isolated sternocleidomastoid muscle branch of the accessory nerve, or the remaining facial nerve trunk is anastomosed with the sternocleidomastoid muscle branch of the accessory nerve. When the facial skin defects exist, the pedicled sternocleidomastoid muscle flap is used for the first-stage repair of the facial paralysis and facial skin defects.
2) Case III: The patient, female, had recurrence after resection of parotid carcinoma with right facial paralysis. It was observed during surgery that the facial nerve was invaded and destructed, the tumor was extensively resected, the sternocleidomastoid muscle flap with an appropriate length was prepared according to the repair need and

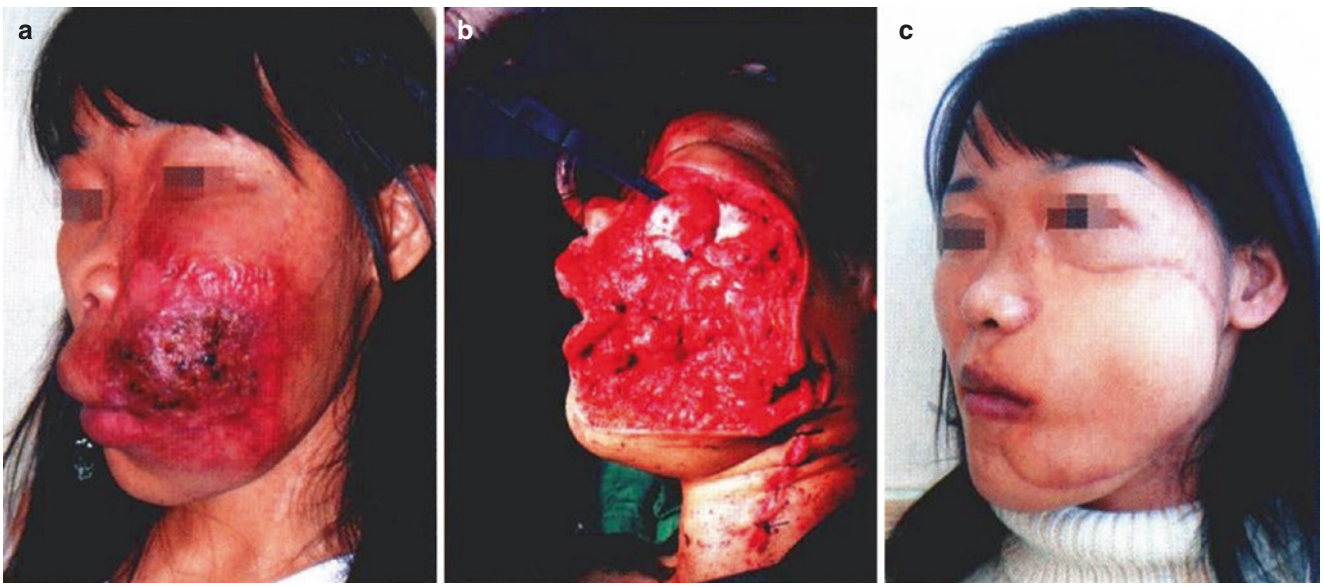

Fig. 11.4 Case II. (**a**) Preoperative appearance of left facial hemangioma. (**b**) Left facial tissue defect after tumor resection. (**c**) After repair of left facial defect with latissimus dorsi myocutaneous flap

was rotated to the face, and the ends of the muscle flap were fixed to the sites such as the orbicularis oculi muscle and orbicularis oris muscle, respectively. The remaining facial nerve trunk was anastomosed with the sternocleidomastoid muscle branch of the accessory nerve. After completion of radical surgery of parotid carcinoma, the sternocleidomastoid muscle flap with the sternocleidomastoid muscle branch of the accessory nerve was used for the first-stage repair of the facial paralysis (Fig. 11.5).

(4) Transfer of pedicled sternocleidomastoid muscle flap: It is suitable for patients with facial paralysis and smaller cheek skin defect after tumor resection:

1) Surgical design: An appropriate skin flap is designed and harvested according to the size and shape of cheek skin defect and the length of the muscle belly of the sternocleidomastoid muscle, so as to prevent that due to a too close distance of the skin flap from the mastoid process, the radius of the muscle flap after rotation is too small, so that the skin flap cannot cover the cheek wound.
2) Case IV: The patient, female, had right cheek tissue defects after tumor resection. The sternocleidomastoid myocutaneous flap was designed and harvested, and the sternocleidomastoid myocutaneous flap was used to repair the tissue defects, and the wound healed well after surgery (Fig. 11.6).

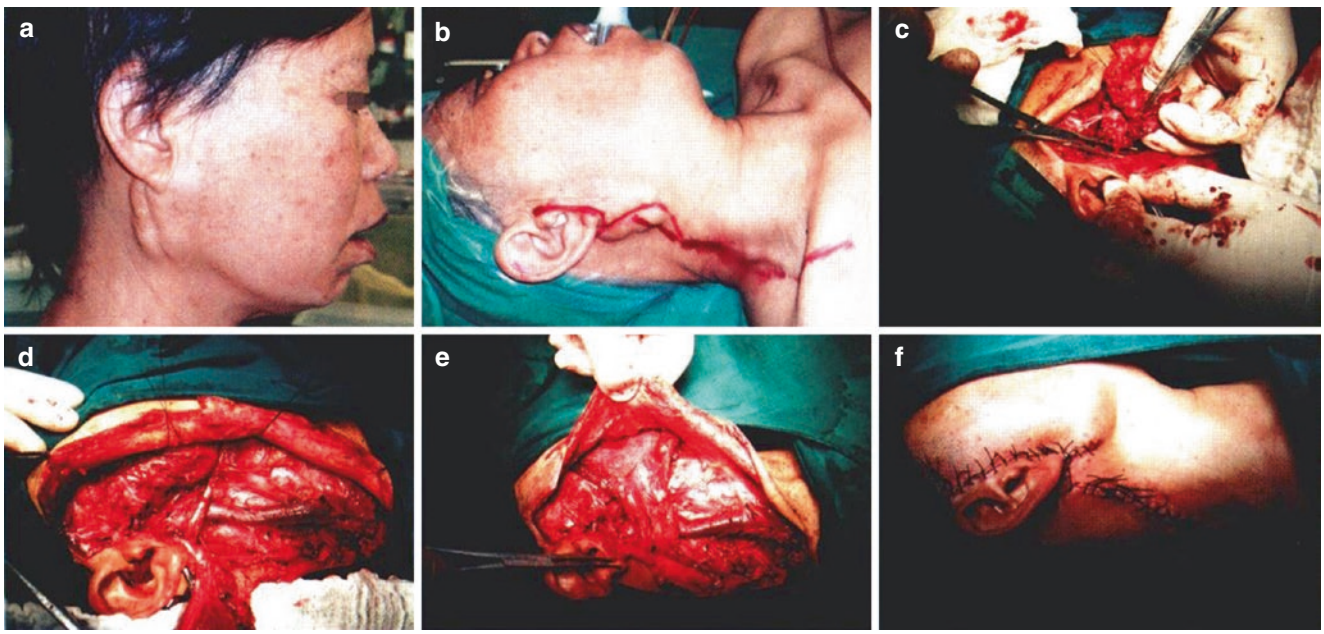

Fig. 11.5 Case III. (**a**) Preoperative appearance. (**b**) Surgical incision design. (**c**) The invaded and destructed facial nerve observed in the operation. (**d**) Result of radical surgery of parotid carcinoma. (**e**) The sternocleidomastoid muscle flap with the sternocleidomastoid muscle branch of the accessory nerve was used for the first-stage repair of the facial paralysis. (**f**) After surgery

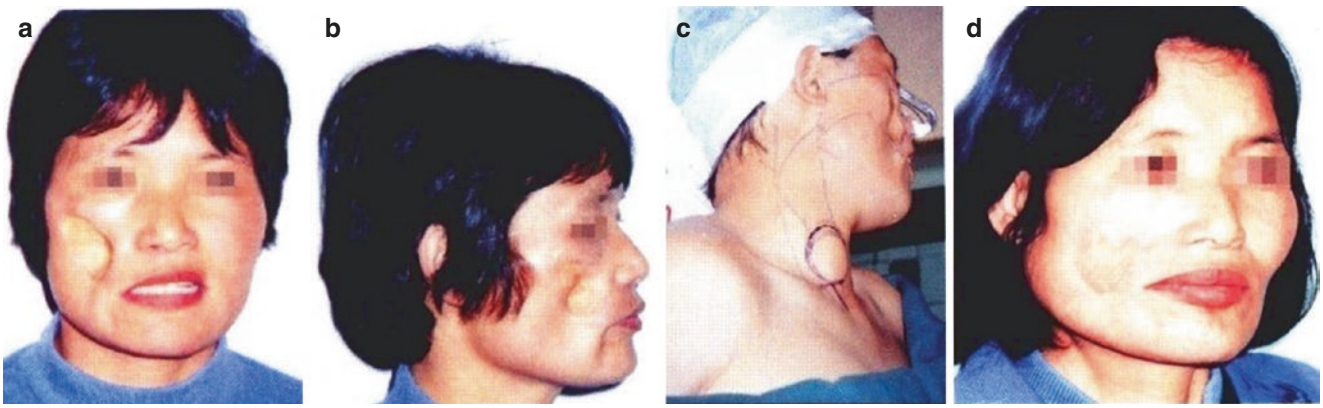

Fig. 11.6 Case IV. (**a**) Postoperative frontal view. (**b**) Postoperative lateral view. (**c**) Design of the sternocleidomastoid myocutaneous flap. (**d**) After repair with the sternocleidomastoid myocutaneous flap

2 Commonly Used Methods of Surgical Repair of Facial Nerve Paralysis

The repair of facial paralysis is a very challenging problem for plastic surgeons. In order to repair the complex disease, it is very necessary to be familiar with all kinds of surgeries which can improve the functions and repair the appearances. Through careful examination, comprehensive analysis, serious consideration, and carefully formulated repairing plan, each patient can undergo individualized repair, in order to achieve the desired restoration of the function and appearance [14].

2.1 Anastomosis and Repair of the Facial Nerves

2.1.1 Indications

The anastomosis and repair of the facial nerves are suitable for patients with the early facial nerve injury and rupture. The broken ends of the facial nerve after rupture should be sutured as soon as possible, but the patients often delay the best repairing time due to various circumstances and the fluke mind. The surgical suture is generally performed within 6–12 months after injury, which is still likely to get better results.

2.1.2 Surgical Methods

1. Facial nerve exposure: Since the anatomic variation of the facial nerves is greater, especially the various branches of the facial nerve constantly give off subbranches and then are fused into each other, it is difficult to find the cases with identical anatomies in the clinic. According to many years of clinical experiences of the authors, if the facial nerve needs to be exposed during surgery, it is recommended to perform the surgery with the following basic methods:
   (1) Exposure of the first-grade branch of the facial nerve: The first-grade branch of the facial nerve (trunk) penetrates out from the stylomastoid foramen at the deep surface in front of the mastoid process, runs forward and downward at the superficial surface of the posterior belly of digastric muscle, and enters into the deep surface of the parotid gland at the deep surface of the sternocleidomastoid muscle. In order to facilitate the exposure, some attachment points of the sternocleidomastoid muscle are stripped off from the mastoid process, and a 1.5 cm bone at the lower anterior end of the mastoid process is carefully resected, and then it can be exposed in its deep surface.
   (2) Exposure of the second-grade branches of the facial nerve: The second-grade branches of the facial nerve (temporal trunk and cervical trunk) present as a plexiform shape and pass through the parotid gland between the deep and superficial lobes of the parotid gland.
   (3) Exposure of the third-grade branches of the facial nerve: The third-grade branches of the facial nerve (temporal branch, zygomatic branch, buccal branch, mandibular marginal branch, and cervical branch) penetrate out slightly radially from the anterior margin of the parotid gland.
   (4) Exposure of the fourth-grade branch of the facial nerve: Of the fourth-grade branches of the facial nerve (terminal branches), in addition to that the branch controlling the cheek muscle enters into the muscle from the superficial surface, most branches enter into the muscle belly from the deep surface of facial expression muscles under their control. When the surgical exposure is performed, the proximal end of the facial nerve may be sought out among the normal tissues, and then the search is performed carefully toward the distal end.
2. Suture of the broken ends: The broken ends of the nerve can be exposed according to the anatomical layers of different positions of the facial nerves. After the defects in the broken ends of the nerve or the generated neuroma are removed, as long as there is no large section of defect between the broken ends of the nerve, and the suture tension is not too large, most broken ends of the nerves can be closed and sutured directly. When the suture is performed, it is recommended that the orientations of the neural axons should be correctly aligned under the surgical microscope and thus avoiding the twisting and malposed suture of the broken ends of the nerve. A 9-0 minimally invasive monofilament suture needle thread is used; when the suture is performed, only the nerve sheath should be sutured. If the diameter of the nerve is larger, it can be sutured through passing through the membrane between nerve axons to assure the accurate apposition suture. The facial nerve trunk can be sutured with four to six stitches, and the branch can be sutured with two to four stitches, and the thinner peripheral branch can be sutured with only one stitch. The main points of the operation include the thorough local hemostasis, the accurate apposition of the broken ends of the nerve, no excessive suture tension, and soft and delicate operation.
3. Postoperative treatment: The local drainage is performed to prevent hematocele and effusion, and the antibiotics are used to prevent infection. It is recommended that the neurotrophic drugs are used for more than 3 months.
4. Precautions: The facial nerve of the child is thinner, so the exposure of the nerve is very difficult. Once it is damaged, the difficulty of repair is doubled. In addition, the mastoid process in children has not yet been fully developed, thus the positioning during exposure of the facial nerve trunk is slightly different with that of the adult. Because the facial nerve is not covered by the mastoid process, it is easily damaged, which should be paid full attention during surgery.

The patients in whom the facial nerve is accidentally cut off during parotid gland tumor resection should undergo immediate neural anastomosis. Because the parotid gland has been removed, the broken ends of the nerve can be anastomosed without tension, and so the good recovery can often be obtained. If the suture cannot be performed immediately during surgery, the repair should be carried out as soon as possible within 2 weeks. If the repair is delayed too long, the local scar adhesion is obvious, which can lead to difficulty in nerve exposure, not only increasing the surgical difficulty, but also affecting the effect of repair. The nerve regeneration is rather slow; the postoperative effect to children is significantly better than that to adults, while the elderly have a weak regenerative capacity, and so the surgical effect is relatively poor. Therefore, the patients should be informed of the effect of related nerve surgery before surgery.

2.1.3 Typical Case

Case V The patient, female, had facial paralysis due to facial nerve rupture after left parotid gland tumor resection. Because the parotid gland had been removed, the broken ends of the nerve could be anastomosed without tension, and the good recovery could often be obtained. At 6 months after surgery, the left paralyzed facial nerve was repaired, and the recovery condition was good (Fig. 11.7).

2.2 The Repair with Facial Nerve Transplantation

2.2.1 Indications

The facial nerve is damaged and ruptured in the early stage, and the proximal and distal ends of the facial nerve are intact. But when a large segment of nerve defect between the broken ends cannot be closed and sutured directly, the repair with facial nerve transplantation can be performed. The repair of facial nerve defect after parotid gland tumor resection is the most commonly seen repair in the clinic.

2.2.2 Surgical Methods

The selection of the donor nerve should be determined according to the nerve length required for transplantation. The great auricular nerve can be used when the length of the transplanted nerve is less than 10 cm. It is suggested that the sural nerve is used when the length of the transplanted nerve is more than 10 cm:

1. The harvesting of the great auricular nerve: The great auricular nerve penetrates out from the Erb's point at the mid-upper one third of the posterior margin of the sternocleidomastoid muscle and then runs toward the direction of the external auditory canal and parotid grand, which can be used as the marker for confirmation (Fig. 11.8).The local hypesthesia in the periauricular area may occur after the harvesting of the great auricular nerve.
2. The harvesting of the sural nerve: The sural nerve is located at the posterior side of the lateral malleolus and the anterolateral side of the Achilles's tendon and is accompanied by the small saphenous vein (Fig. 11.9). When the harvesting is performed, a transverse incision is made at the lateral malleolus of the lower leg at first. After being exposed and confirmed, the sural nerve is dissected toward the proximal end and then is gently lifted, and a small transverse incision at about 5 cm in its proximal end is made according to its running direction exposing the nerve. After the sural nerve is dissected out, a small transverse incision is made at its proximal end, which is performed upward segment by segment until a sufficient length is obtained.

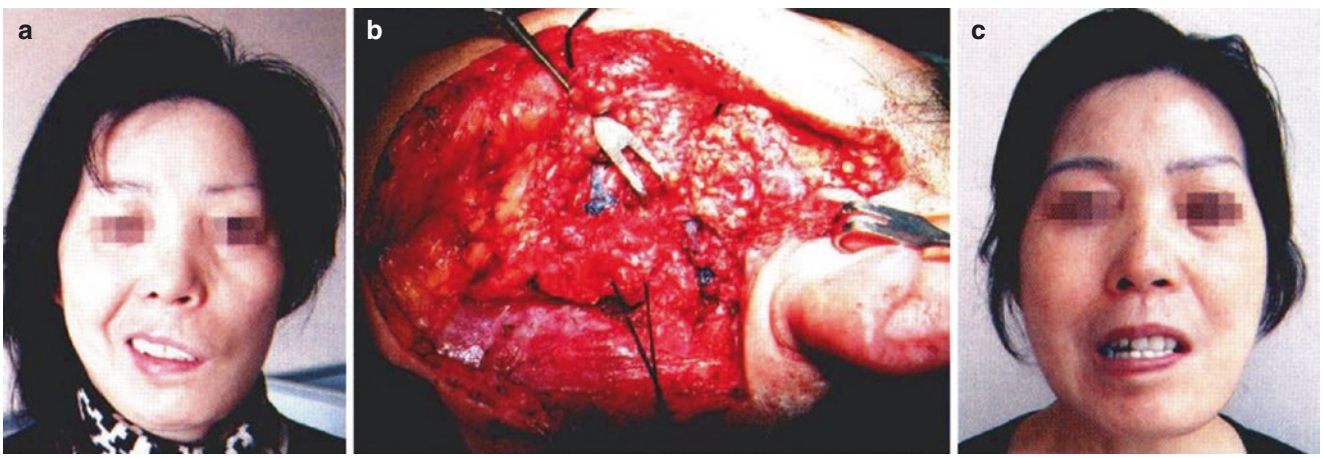

Fig. 11.7 Case V. (**a**) Postoperative frontal view. (**b**) Intraoperative exploration of the facial nerve situation. (**c**) At the sixth month after facial nerve repair for the patient with left facial paralysis

Fig. 11.8 The anatomy of the great auricular nerve

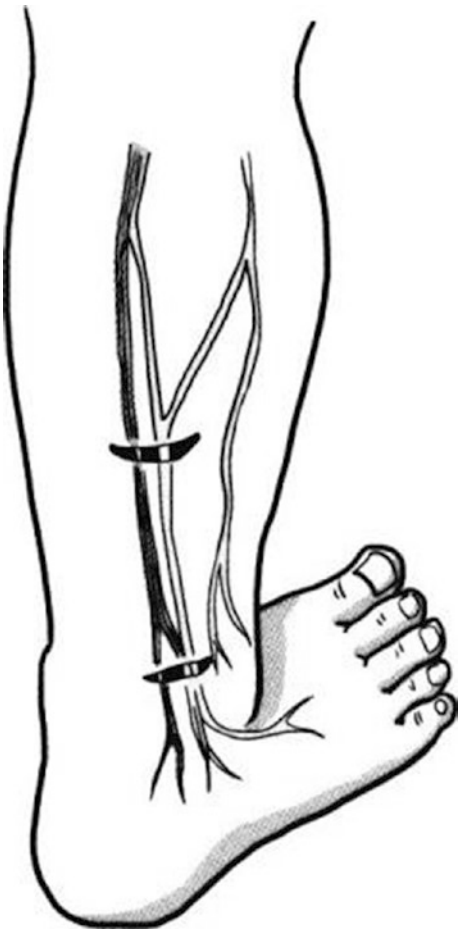

Fig. 11.9 The anatomy of the sural nerve

2.2.3 Postoperative Treatment

It is the same with that of the repair and anastomosis of the facial nerve.

2.2.4 Precautions

The length of the transplanted nerve should be appropriate, and the suture should be performed without tension, but it should not be too long, so as not to prolong the recovery time. It is recommended that the distal end of the transplanted nerve is sutured with the proximal end of the nerve in the receptor site, and the proximal end of the transplanted nerve is sutured with the distal end of the nerve in the receptor site. This conforms to the potential conduction laws of the nerve and may help in reducing the occurrence possibility of getting lost of the regenerated nerve axons. Since the transplanted nerve has no blood supply, it is required that the transplant bed has a good blood supply; at the same time, it needs to be covered by the local tissue flap with good blood supply, which is likely to lead to revascularization of the transplanted nerve to restore the blood supply and make it survive. After nerve transplantation, the local negative pressure drainage is performed in the receptor site to reduce the occurrence of hematocele and effusion. Since the nerve tissue is thin and delicate, the local compression should be avoided after surgery to prevent the occurrence of the anastomotic rupture. After nerve transplantation, the magnitude of local activities in the cheek should be reduced, and the activities such as laughing out loud, eating with a big mouth, and forcibly rubbing cheeks should be avoided.

2.3 Modified End-to-Side Anastomosis Between the Hypoglossal Nerve and the Facial Nerve

2.3.1 Indications

The modified end-to-side anastomosis between the hypoglossal nerve and the facial nerve is suitably used for repair of early facial nerve injury, especially for patients in whom the damage in the proximal end of the facial nerve cannot be

found, while the distal branches of the facial nerve and facial muscles are intact.

2.3.2 Surgical Methods

The hypoglossal nerve transposition can be performed through the incision used in parotidectomy. The distal end of the facial nerve is exposed at first, and the length of the hypoglossal nerve for transposition is predicted on this basis. The hypoglossal nerve is exposed at the outer side of the vagus nerve and between the internal jugular vein and internal carotid artery, and the dissection is performed downward to a sufficient length. The hypoglossal nerve is anastomosed with the facial nerve through the nerve transplantation, and the specific method is as follows: after the hypoglossal nerve is exposed, the epineurium and nerve sheath at the site of anastomosis are removed, and one third of its cross section is incised at first, and then the nerve stimulator is used to detect whether the motor axon bundles of the hypoglossal nerve are intact. If there is no obvious damage, the incision can be continued to reach up to 1 s of the cross section to expose more motor axon bundles (Fig. 11.10).

The great auricular nerve can be used as the graft between the hypoglossal nerve and the facial nerve. The graft and the exposed axon bundle of the hypoglossal nerve are sutured by two stitches (end-to-side anastomosis), and the other end is anastomosed with the distal end of the facial nerve (Fig. 11.11), so as to not only make the paralyzed facial muscles to regain innervation but also to minimize the hypoglossal nerve injury as far as possible. The clinical curative effect of the operation and the operation procedure need further researches.

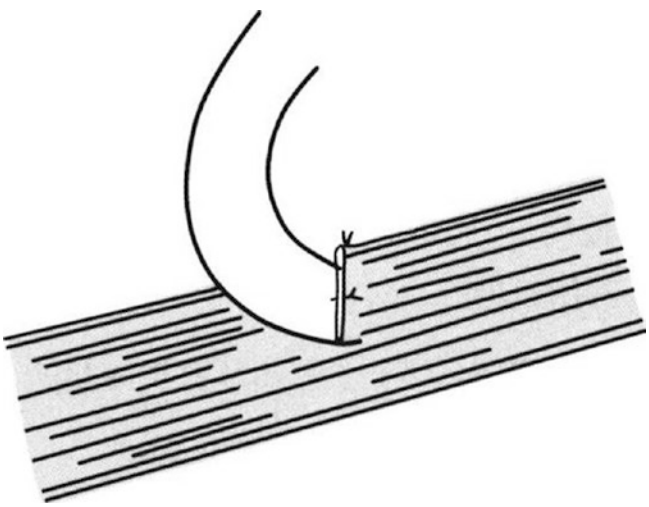

Fig. 11.10 Schematic diagram of the end-to-side anastomosis between the hypoglossal nerve and the facial nerve

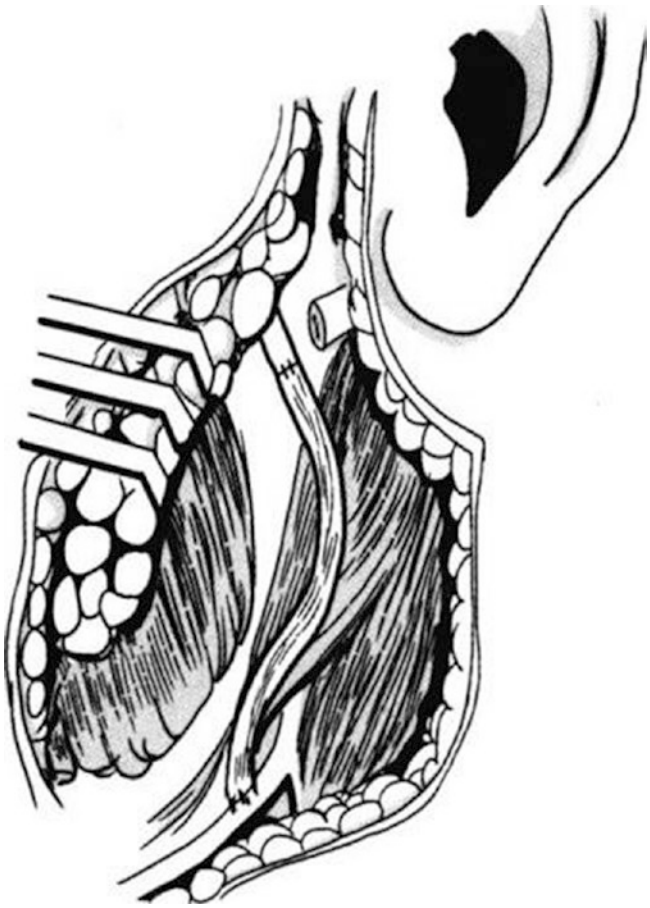

Fig. 11.11 The nerve transplantation is connected with the hypoglossal nerve (end-to-side anastomosis) and the facial nerve (end-to-end anastomosis)

2.4 The Repair with Cross-Face Nerve Transplantation

2.4.1 Indications

This method is physiological dynamic repair; it is suitable for patients with early damage and rupture of the facial nerve in whom the damage in the proximal end of facial nerve cannot be repaired or is hard to find, while the distal branches of facial nerve and the facial muscles are intact.

2.4.2 Surgical Methods

The surgery is divided into two stages which are carried out, respectively:

1. The first-stage surgery: A preauricular incision is made at the healthy side. In order to expose well, the upper end of the incision can bend toward the anterior hairline to extend the incision. The separation is carried out forwardly at the superficial layer of the parotid fascia, and the third-grade branches of the facial nerve such as the zygomatic branch, the upper buccal branch, and the lower

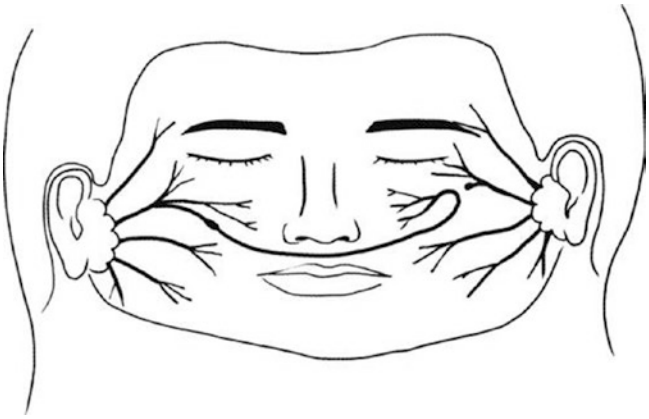

Fig. 11.12 Schematic diagram of the repair with cross-face nerve transplantation (the donor site is on the right side and the receptor site is on the left side)

buccal branch are exposed at the anterior margin of the parotid gland. The appropriate branch is selected, and then the nerve stimulator is used to detect whether its control range meets the requirements, and the branches with important function at the healthy side are retained. Meanwhile, the other 50% branches without obvious damages in the original control range are retained for standby application. In addition, a 15–20 cm long sural nerve is harvested from the lower leg and is split into two bundles for standby application. The transplanted nerve is anastomosed with the proximal end of the selected nerve branch from the preauricular incision at the healthy side. The small incisions in bilateral nasolabial grooves are taken as the interim transitions, and the transplanted nerve conduit is carefully guided to the affected preauricular subcutaneous area through the cross-face subcutaneous tunnel (Fig. 11.12). The electrophysiological detection is carried out 6 and 12 months after surgery. When the regenerated nerve axon bundle has grown to the affected side, the second-stage surgery can be performed.

2. The second-stage surgery: The preauricular incision is still used; the method for nerve exposure is the same as that at the healthy side. After exposing the corresponding branches of facial nerve at the affected side, the overlong transplanted nerve is resected depending on the anastomosis location. The epineurium in the suture site is incised, and the neural axon bundle is clearly exposed and is sutured carefully without tension.

2.4.3 Postoperative Management

It is the same as that in the repair with the facial nerve anastomosis.

2.4.4 Precautions

The repair with cross-face nerve transplantation is a kind of physiological repair. Since the nerves provided by the healthy side are extremely limited, it is impossible to transplant the nerve according to the ratio of 1:1. It is suggested that the cross-face nerve transplantation is carried out in accordance with the following principles:

1. One-to-many anastomosis: One of the third-grade branches in the donor site can be anastomosed with the third-grade nerve branches in the receptor site.
2. The upper and lower parts are separated: The nerve branches of the zygomatic branch and the upper buccal branch in the donor site are anastomosed with the upper facial nerves in the receptor site, and the nerve branches of the lower buccal branch in the donor site are anastomosed with the lower facial nerves in the receptor site.
3. Functional recovery: The functional recovery of the upper facial nerves mainly includes closing the eyes, while the functional recovery of the lower facial nerves mainly includes smiling.

After some of the third-grade branches of the nerve at the healthy side are cut off, the effect on corresponding muscles at the healthy side demonstrates as the slight weakening of the muscle strength, but the facial symmetry on both sides can be improved, that is, to use a small amount of nerve transplantation to get the neural functional recovery in key parts as much as possible. However, since the regeneration regularity of the nerves has not yet fully mastered by the humans, the synkinetic movement of different facial muscles may occur during the postoperative neurological recovery.

2.4.5 Typical Case

Case VI The patient, male, had right facial paralysis after right acoustic neuroma resection, and the patient underwent the repair with cross-face nerve transplantation (Fig. 11.13).

2.5 Regulation of the Facial Nerve on the Synkinetic Movement of the Eye and the Corner of the Mouth

In the sequelae of facial paralysis, facial synkinesis is most common, of which the synkinetic movement of the eye and the corner of the mouth is more common. The synkinetic movement of the eye and the corner of the mouth has the biggest influence on the facial expressions of the patients; when the patient closes the eyelids every time, the accompanying convulsion and lifting of the corner of the mouth at the affected side will occur, but when the patient smiles, the corner of the mouth at the affected side cannot be lifted up normally, and this leads to drooping of the angle of the mouth. Such grotesque expressions often cause social difficulties for the patient, which is also the most common reason for the patient to see a doctor. In the past, there was no repair method

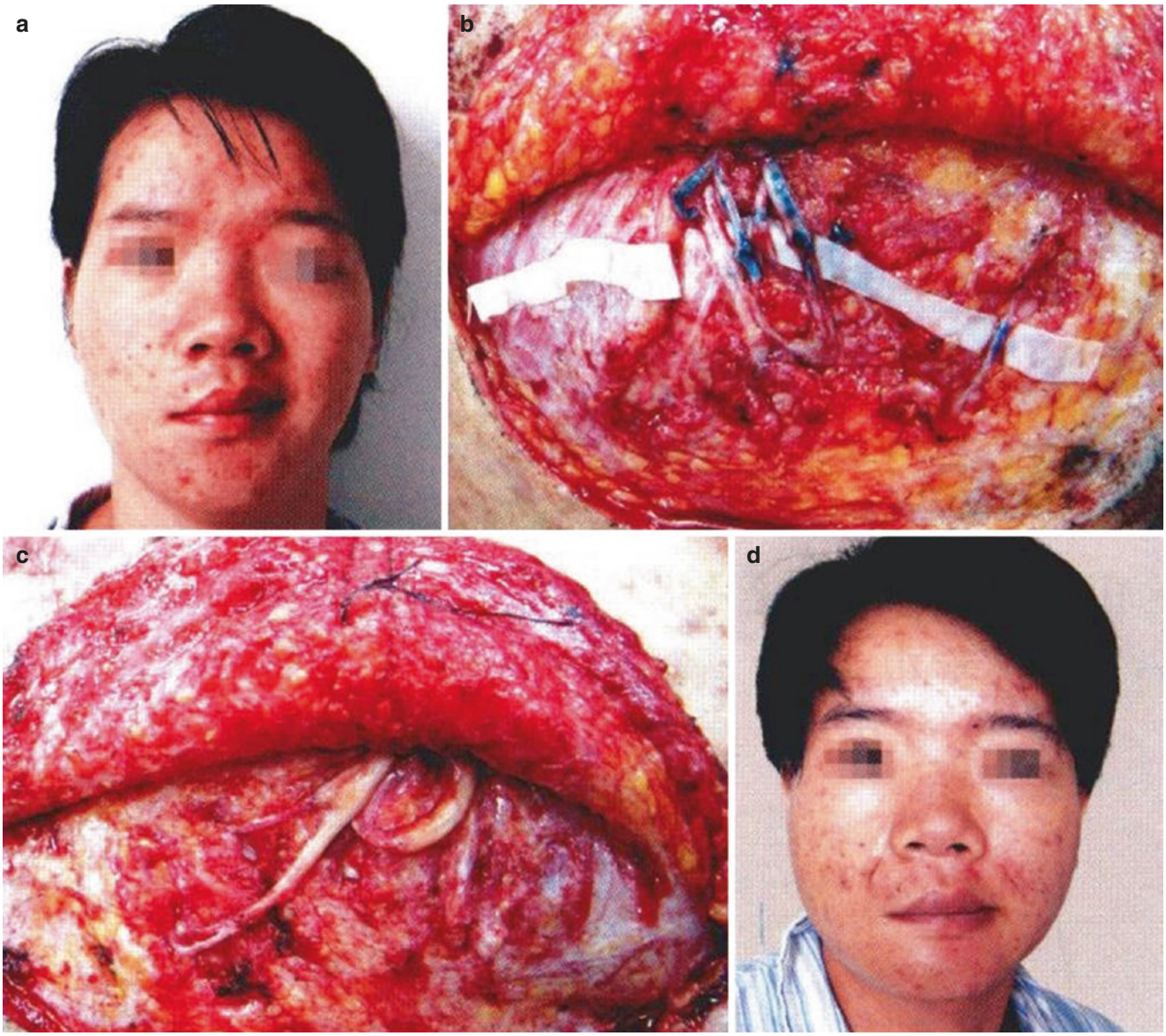

Fig. 11.13 Case VI. (**a**) Postoperative frontal view. (**b**) Cross-face nerve transplantation in the left face (donor site). (**c**) Cross-face nerve transplantation in the right face (receptor site). (**d**) After repair with cross-face nerve transplantation

for the facial synkinesis. In 2003, the authors designed the regulation of the facial nerve to be applied in the clinic, which has already achieved success [15].

2.5.1 Indications

After facial paralysis, there is some facial muscle function recovery, but there are synkinetic movements and false movements of the facial expression muscles. The facial muscle strength at the healthy side is stronger; when the patient smiles, the corner of the mouth skews to the healthy side; when the patient closes the eyelids, the facial muscles at the affected side contract, the corner of the mouth skews to the affected side, and the facial expression is weird and looks like a wry smile. Because this surgical method is designed to restore the smile of the affected face, there are only surgical indications for the younger patients whose zygomaticus and risorius at the affected side have enough muscle strength to lift the corner of the mouth when closing the eyelids and who have a strong desire for repair; for the patients with synkinetic movements of facial muscles which look like twitching, the effect is limited due to insufficient muscle strength.

2.5.2 Surgical Methods

1. The first-stage surgery:
   (1) The selection of branches of the facial nerve at the healthy side: A preauricular incision is made at the healthy side, and the separation is performed at the superficial layer of the parotid fascia. The

zygomatic branch and the upper buccal branch of the facial nerves are dissected out in front of the parotid fascia (it is determined depending on the variation of the facial nerve branches) (Fig. 11.14a). To reduce the muscle strength at the healthy side, the nerve stimulator positioning is performed at first, some tertiary branches of the facial nerves at the healthy side corresponding to the muscles with false movements at the affected side are high selectively cut off for standby application, and most of them are the control nerves of the zygomatic major muscle and risorius muscle.

(2) Cross-face autologous nerve transplantation: The autologous sural nerve of about 15–200 m is harvested as the nerve transplantation, and the distal end of the nerve transplantation is anastomosed with the proximal end of the branch of the facial nerve; through the subcutaneous tunnel, the neural dynamics of the proximal end at the healthy side is transmitted to the affected side through cross-face nerve transplantation, and it is marked with the black silk sutures and then is placed under the skin before the tragus (Fig. 11.14b). Ten to twelve months later, when it is confirmed that the transplanted nerve has regenerated into the affected side, the second-stage surgery can be carried out.

2. The second-stage surgery:

(1) The separation of the nerves controlling the synkinetic movement at the affected side: The purpose is to restore the expression activities of the corner of the mouth at the affected side which are synchronized with those at the healthy side. The preauricular incision is still used in the surgery, and the method for exposing the cross-face transplanted nerve and the branches of facial nerve is the same as that for the healthy side. The nerve stimulator positioning is performed at first, and then the fourth-grade branches of the facial nerves at the affected side (most of them are the branches of the zygomatic branch) are high selectively cut off and separated, so that the facial muscles with synkinetic movements can be separated from the nerves controlling the synkinetic movement (Fig. 11.14c). At the moment, the nerve stimulator is used to stimulate the trunk of the zygomatic branch; thus, it can be found that the movement of closing the eyes is completely separated with the uplift movement of the corner of the mouth.

(2) The anastomosis of the facial nerve branch at the affected side with the transplanted nerve: The separated and broken distal end of the nerve branch at the affected side is anastomosed with the transplanted

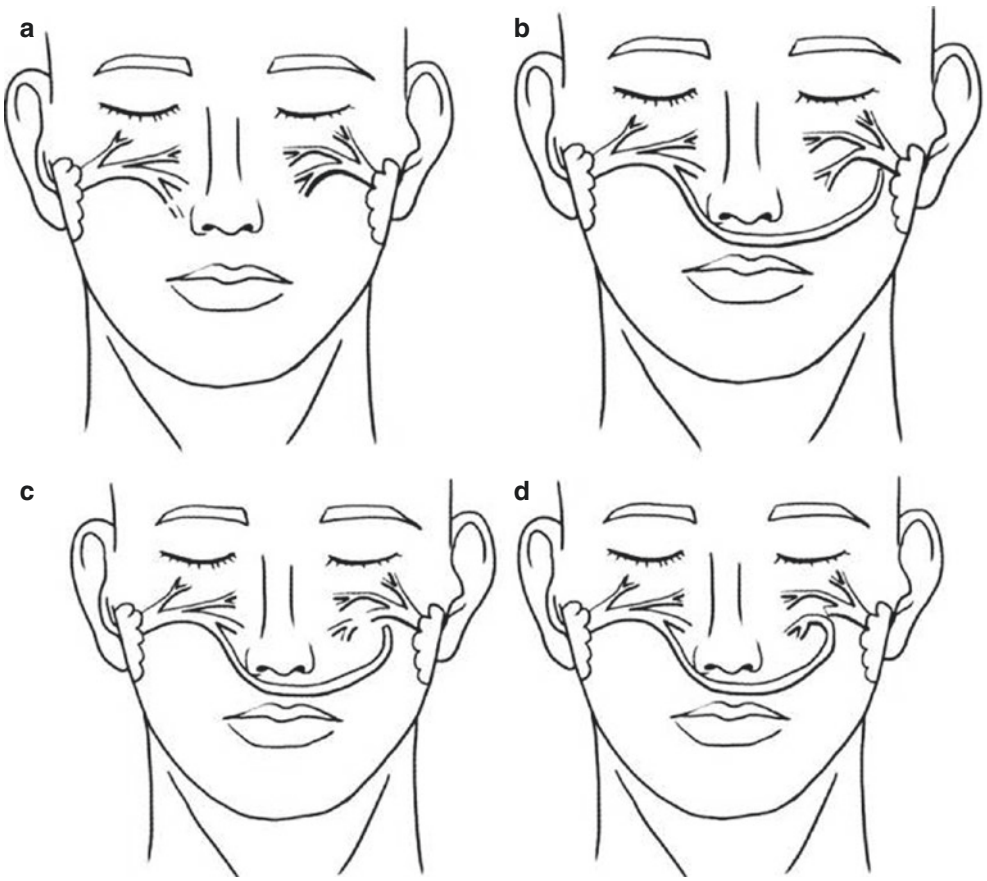

Fig. 11.14 Regulation of the facial nerve on the synkinetic movement of the eye and the corner of the mouth. (**a**) Exposure of the selected branch of the facial nerve at the healthy side (right). (**b**) Cross-face nerve transplantation at the affected side (left). (**c**) The cross-face transplanted nerve has regenerated and grown to the affected side, and the left nerve controlling the synkinetic movement is transected. (**d**) The cross-face transplanted nerve is anastomosed with the distal end of the transected nerve controlling the synkinetic movement

nerve which is transferred across the face from the healthy side. After nerve regeneration, the power provided by the nerve at the healthy side can control part of the facial muscle at the affected side, so that the facial muscle can obtain the movement synchronous with that of the healthy side, that is, to control the muscle strength at the healthy side through cross-face nerve transplantation and separate the movements of the facial muscles with synkinetic movements at the affected side, so that the contractile activities of the zygomatic major muscle and risorius muscle at the affected side are synchronous with those at the healthy side (Fig. 11.14d); thereby, it is expected to resume symmetrical facial movements and natural smiling expressions [16].

2.5.3 Postoperative Treatment

It is the same as that in the repair with facial nerve anastomosis.

2.5.4 Some Explanations for the Regulation of the Facial Nerve

1. It is very difficult to locate the incorrectly connected (get lost) facial nerve. In clinics, the facial synkinesis often has different symptoms: the left and right corners of the mouth of the patient is still symmetrical at the static state, but when the patient smiles, the corner of the mouth at the affected side cannot be lifted up normally and thus skews to the healthy side; when the patient closes the eyes, the corner of the mouth skews to the affected side, the more strength is used for closing the eyes, the more severely the corner of the mouth skews, and even every time when the patient blinks, there is concomitant unconscious twitch of the corner of the mouth at the affected side. Its pathogenesis is nothing more than a result of the incorrect connection of the branch of the facial nerve. After the facial nerve is ruptured by the trauma or the axon bundle is injured, part of the regenerated axon bundle of the original nerve branch controlling the orbicularis oculi muscle (zygomatic branch) restores the innervation of the orbicularis oculi muscle, and another part of the axon bundle gets lost during regeneration, strays into the control nerves of the zygomatic muscle and risorius muscle, and is incorrectly connected with the zygomatic muscle and risorius muscle at the affected side. Therefore, whenever the patient closes the eyes (the orbicularis oculi muscle contracts), the zygomatic muscle and risorius muscle also shrink at the same time (the severe convulsions can occur throughout the affected side of the face) and thus causing the synkinetic movement of the eye and the corner of the mouth. Due to the complexity of the cause, it is very difficult to locate the nerve which gets lost during nerve regeneration. Therefore, the repair of the synkinetic movement of the eye and the corner of the mouth is very difficult and challenging.
2. The ultimate effect of regulation of the facial nerve depends on the condition of the patient and the nerve regeneration condition. The purpose of the regulation of the facial nerve is to separate the synkinetic movement of the eye and the corner of the mouth, so that the corner of the mouth at the affected side can restore smile synchronized with that in the healthy side. Therefore, the selection of surgical cases has a decisive impact on the final effect of surgery. If the facial muscles at the affected side have a wide range of synkinetic movements and weak muscle strength, the surgery can only separate the synkinetic movements and improve the smile, while the improvement of the facial symmetry is still not satisfactory. Only in the patients in whom more facial muscles are retained after recovery of facial paralysis and the muscle strength at the affected side is stronger, the synkinetic movements are separated after surgery, but the larger muscle strength can still be maintained, and an ideal symmetrical smile can be achieved. The ultimate effect depends on the condition of the patient and the nerve regeneration condition, and the patients must be well informed before surgery. Since it is difficult to determine the location where the nerve gets lost, in the surgical method, the facial nerve trunk and the second- and third-grade branches are kept off, and the fourth-grade branches are cut off and separated in front of the site where the nerve enters into the muscle, so that not only is the nerve completely separated but also the damage to the normal nerve is reduced.
3. The operative process is longer and the recovery is slow. During the operative process, because it is required to perform nerve transplantation and pass through two anastomotic stomas, even with the best passing rate of the regenerated nerve axon bundle, only less than 50% of the axon bundle can reach the facial muscles. Both doctors and patients must have a definite cognition about the surgical effect. After the first-stage surgery, the nerve regeneration may take 12 months to recover. Four to six months later, the growth of the regenerated nerve axon bundle can be estimated by Tinel test. The method is that along the running direction of the transplanted nerve in the subcutaneous tunnel, gently tap from the distal end to the proximal end, until a feeling of numbness and needling appears in the tapping site, and the location of this place is the site where the regenerated nerve axon bundle has grown up to, the general error is within 2–3 cm. If the regenerated nerve axon bundle has grown up to the required site, it is generally believed that it is still required to delay 3 months to carry out the second-stage surgery.

It is assessed that the patient must go through a waiting period of about 1 year from the beginning of the first-stage surgery to the end of the second-stage surgery. It requires a recovery period of 4–6 months after the second-stage surgery. During this period, since the facial muscles with synkinetic movements are paralyzed due to the fact that the original incorrectly connected control nerve is severed, it is required to wait until the nerve after cross-face transplantation has regenerated into the facial muscles; the paralyzed facial muscles can only have functional contraction. Therefore, the recovery period may take up to 24 months, and the patient must understand that the postoperative facial nerve regeneration is slow and difficult.

4. The importance of accurate nerve positioning: Due to delicate and colorful facial expressions and extremely complex nerve axon bundle, it is necessary to carry out accurate positioning and operation seriously and carefully on the controlling statuses of the nerves; otherwise, it is impossible to obtain the desired effect, and once a mistake occurs, it could cause irreparable consequences.
5. The importance of postoperative facial muscle function exercise: After the success of the surgery, due to the changes in the control nerves of the facial muscles with synkinetic movements, to restore coordinated and natural smile, it is still required that the patient faces the mirror to carry out training of smiling facial expressions with the facial muscles regaining innervation after repair, making the successful surgical effect become better.

2.5.5 Typical Case

1. Case VII: The patient, female, had facial synkinesis; when she closed her eyes, the corner of her mouth would skew to the right side, and the facial nerve regulation was performed (Fig. 11.15).

2.6 Repair of Facial Paralysis with Pedicled Sternocleidomastoid Muscle Transposition

The authors designed the surgical method of using the pedicled sternocleidomastoid muscle transposition to repair the late facial paralysis on the basis of anatomical studies, and the surgical method has been used in the clinic since 1999.

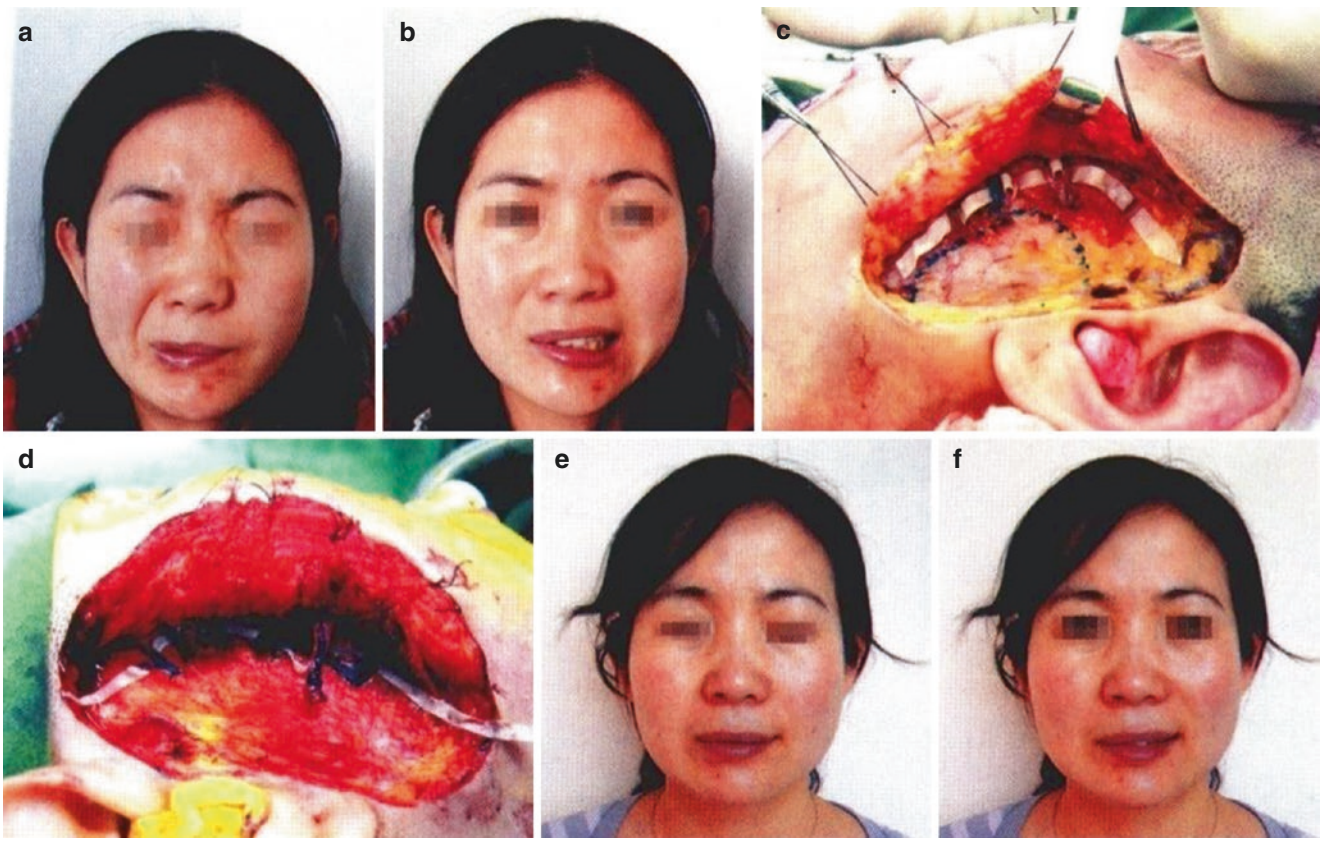

Fig. 11.15 Case VII. (**a**) Preoperative appearance (when closing the eyes, the corner of the mouth skewed to the right). (**b**) Preoperative appearance (when smiling, the corner of the mouth skewed to the left). (**c**) The left donor site of the facial nerves. (**d**) The nerve controlling the synkinetic movement was separated and then was sutured with the cross-face transplanted nerve. (**e**) One year and 6 months after facial nerve regulation (when the eyes are closed, the corner of the mouth did not skew). (**f**) One year and 6 months after facial nerve regulation (when smiling, the bilateral corners of the mouth were symmetrical)

The surgical method is suitable for late facial paralysis patients whose facial nerves and facial muscles have been completely denatured. During surgery, the pedicled sternocleidomastoid muscle at the affected side is transferred to the affected face to replace the paralyzed facial muscles and reconstruct the facial expression activities. This method is proposed herein for uncomplicated operation, high success rate, and satisfying results.

2.6.1 Indications

In the patients with advanced complete facial paralysis, as long as the function of the sternocleidomastoid muscle is normal, this surgical method can be applied for repair of the facial paralysis.

2.6.2 Applied Anatomy

The sternocleidomastoid muscle starts from the sternum and the internal extremity of clavicle, travels toward the upper posterior side obliquely across the whole cervical length, and ends at the mastoid process of the temporal bone (Fig. 11.16). Its starting site is mostly tendinous. In the specific person, the tendinous portion accounts for one third of the full length.

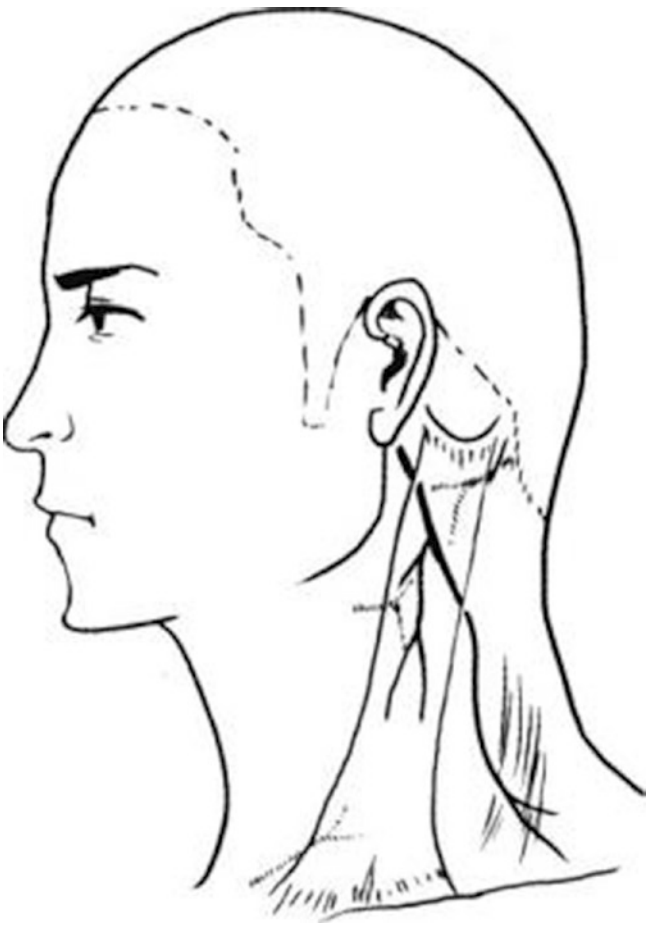

Fig. 11.16 The local anatomy of the sternocleidomastoid muscle

The muscle is covered by the platysma, and the cervical plexus cutaneous nerve and the supraclavicular cutaneous nerve penetrate out from the midpoint of its posterior margin and are distributed to skins in the lower anterior cervical area and the anterior chest wall. The external jugular vein crosses over its surface, and there is jugular vein in its deep side. The blood supply of the sternocleidomastoid muscle comes from multiple and segmental sources. The main source of the upper part comes from the branch given off from the occipital artery; the main source of the middle part comes from the branches of superior thyroid artery and the external carotid artery; the lower part is fed by the branches given off from the thyrocervical trunk and the transverse cervical artery. There are rich anastomoses between the abovementioned various blood vessels, when the pedicled transfer is performed; as long as the sternocleidomastoid branch of the occipital artery is retained, the blood supply to the muscle can be maintained. The innervation of the sternocleidomastoid muscle mainly comes from the accessory nerve and also comes from a small branch of the cervical plexus. The accessory nerve runs downward mostly accompanied with the sternocleidomastoid branch of the occipital artery. The accessory nerve runs downward to be divided into two branches, and it can be divided into two types such as the branching type outside the muscle (59%) and the branching type inside the muscle (41%) according to the sites of the branches.

1. The branching type outside the muscle: Before entering into the muscle, the accessory nerve is divided into two branches. The sternocleidomastoid muscle branch enters into the muscular porta at the upper one third of the muscle and then gives off branches, and the trapezius muscle branch continuously runs downward to the trapezius muscle. Two branches are easily separated, and a cleavage of 1–2 cm is often made proximally at the bifurcation point to facilitate muscle transposition.
2. The branching type inside the muscle: After entering into the muscular porta of the muscle, the accessory nerve is divided into two branches. The sternocleidomastoid muscle branch gives off multiple branches to control the muscle, and the trapezius muscle branch penetrates out from the deep surface of the sternocleidomastoid muscle and then continuously runs downward to the trapezius muscle. Because the trapezius muscle branch passes through the muscle bundle at the deep surface portion of sternocleidomastoid muscle and is hampered to affect the muscle transposition, this portion of the muscle bundle may be cut off during surgery to release the trapezius muscle branch, so that the muscle transposition can be carried out smoothly.

After carrying out studies on two aspects such as the anatomy and clinical application of the sternocleidomastoid

muscle, it is considered that according to the anatomical features of the sternocleidomastoid muscle, the application of the muscle flap as the dynamic muscle to repair the late facial paralysis is still feasible; especially when the sternocleidomastoid muscle contracts, no movements such as biting and chewing are needed, so that the patient can smile more naturally and coordinately, and it has obvious advantages compared to other dynamic muscles. The repeated studies on surgical methods are performed, and corresponding changes in the surgical method are made targeting the causes of previous surgery failures: (1) the attachment points at the mastoid process are retained, and the sternocleidomastoid muscle branch of the occipital artery is used to maintain the blood supply to the muscle; (2) the sternal head and clavicular head of the muscle are cut off to increase the extent of the muscle transposition; (3) the bifurcation area between the sternocleidomastoid muscle branch and the trapezius muscle branch of the accessory nerve is appropriately split to increase the degree of freeness of the nerve to facilitate muscle transposition; (4) when being transposed, the muscle passes through the curved tunnel in the cheek to change the direction of contraction, so that the direction of the activity of the corner of the mouth can meet the requirements; and (5) the muscle belly is appropriately trimmed thinly to reduce excessive swelling. At present, a new surgical method has been designed and successfully used in clinics.

2.6.3 Surgical Methods

1. Surgical incision design: The incision is made from the anterior crus of the helix, travels downward along the antilobium and earlobe, and travels downward from the posterior margin of the mandible to the mandibular angle, and then the incision is made from the lower pole of the earlobe toward the retroauricular area and turns arc-shapedly from the site near the hairline toward the lateral side of the neck, passes through the posterior margin of the sternocleidomastoid muscle and then continuously travels downward, then travels inward along the upper margin of the clavicle, and terminates at the ipsilateral sternoclavicular joint (Fig. 11.17a). The incision can fully expose the full length of the sternocleidomastoid muscle and simultaneously make the cervical incision deviated to the posterior side of the neck incision, thereby the scar is more hidden. The lower end of the incision is consistent with the cervical dermatoglyph, and the scar is not obvious. However, a segment of incision at the mandibular angle is still vertical to the dermatoglyph. In order to reduce the scar, this segment of incision can be made at the posterior area as far as possible. In order to facilitate suturing the sternocleidomastoid muscle with the orbicularis oris muscle, an additional incision is made along the nasolabial groove at the affected side; thus, the corner of the mouth at the affected side can be lifted through this incision, and the nasolabial groove can be reconstructed.
2. Surgical operation: The skin is incised according to the design, and the undermining dissection is performed along the deep surface of the platysma muscle, and then the skin flap is lifted up to expose the full length of the sternocleidomastoid muscle. During surgery, it is noted to avoid the external jugular superficial veins and preserve the cervical plexus nerves as far as possible. When cutting off the attachment points of the sternocleidomastoid muscle at the sternum and clavicle, complete hemostasis is performed. The sternocleidomastoid muscle is raised, then the separation is performed along the deep surface of the muscle toward the proximal end, and attentions should be paid to protecting the deep jugular veins. The small nourishing blood vessels encountered in the lower-middle part can be ligated, but the nourishing blood vessels encountered in the upper part should be retained as much as possible. The accessory nerve is dissected out carefully at the posterior margin of the middle part of the muscle, and the separation is performed proximally along the nerve, and then the sternocleidomastoid muscle branch of the accessory nerve and its concomitant nourishing artery of the sternocleidomastoid muscle given off from the occipital artery can be exposed at the deep surface of the upper part of the sternocleidomastoid muscle; meanwhile, they should be protected and cannot be injured. When the muscle transposition is performed, in order to reduce the

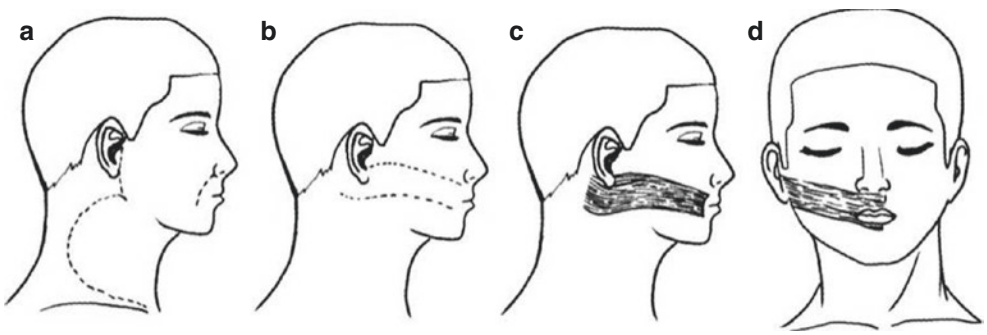

Fig. 11.17 Surgical incision, surgical tunnel, and muscle displacement

constraint of the accessory nerve, the sternocleidomastoid muscle branch may be cleaved off carefully by 1–2 cm from the accessory nerve trunk to increase the extent of muscle transposition. Among the existing surgical patients, there are nearly 40% patients in whom the accessory nerve enters into the sternocleidomastoid muscle and then bifurcates and gives off the sternocleidomastoid muscle branch inside the muscle, and such anatomical structure will no doubt increase the difficulty of the operation. At the moment, the sites where the accessory nerve enters into the muscle and penetrates out of the muscle should be exposed, and careful observation is performed, and then part of the muscle bundle at the deep surface of the nerve is carefully cut off to fully expose the nerve bifurcation and cleave proximally by 1–2 cm to facilitate the muscle belly transposition. The undermining dissection of a curved tunnel is carried out from the preauricular incision and diagonally downward along the superficial surface of the parotid fascia to the incision at the nasolabial groove (Fig. 11.17b). The sternocleidomastoid muscle is passed out of the tunnel and is sutured carefully with the orbicularis oris muscle at the corner of the mouth after its muscle tone is properly regulated (Fig. 11.17c, d).

If due to the fact that the course of disease is too long, and there is no orbicularis oris muscle at the affected side, a stitch of mattress pattern suture is performed, respectively, at the sternal head and clavicular head of the sternocleidomastoid muscle, which is passed through the subcutaneous tunnel of the upper lip and lower lip to exceed the midline to contact with the orbicularis oris muscle at the affected side, and the suture lines are tightened, and then the percutaneous suture and fixation are performed through tying the knot with oil gauze nail. Several stitches are performed between the submucosal residual orbicularis oris muscle at the corner of the mouth and the deep surface of the sternal head of the sternocleidomastoid muscle, so that the corners of the mouth can be presented as a smiling appearance. At the preauricular area, after the muscle belly is tightened, it should be sutured and fixed with the deep temporal fascia and the periosteum of the zygomatic process with several stitches, so that the direction of contraction of the muscle belly can be more ideal and can prevent downward shift of the muscle belly. At the moment, the symmetry of left and right corners of the mouth should be maintained, or the affected side slightly exceeds. Since the corner of the mouth at the affected side is raised, the excessive skin in the nasolabial groove should be removed, and the corner of the mouth can be further lifted. The subcutaneous area at the incision can be sutured with the deep muscle membrane with several stitches to reconstruct the nasolabial groove. For the patients with longer facial paralysis and obvious flabby face at the affected side, a horizontal incision can be made at the hairline in front of the ear, and the unnecessary wedge flap is removed after the facial flap is tightened upward, and finally the incision is sutured, and the negative pressure drainage tube is placed, which can be removed 48 h later.

3. Typical case – Case VII: The cervical skin flap was led through the tunnel to correct the asymmetry of corners of the mouth (Fig. 11.18).

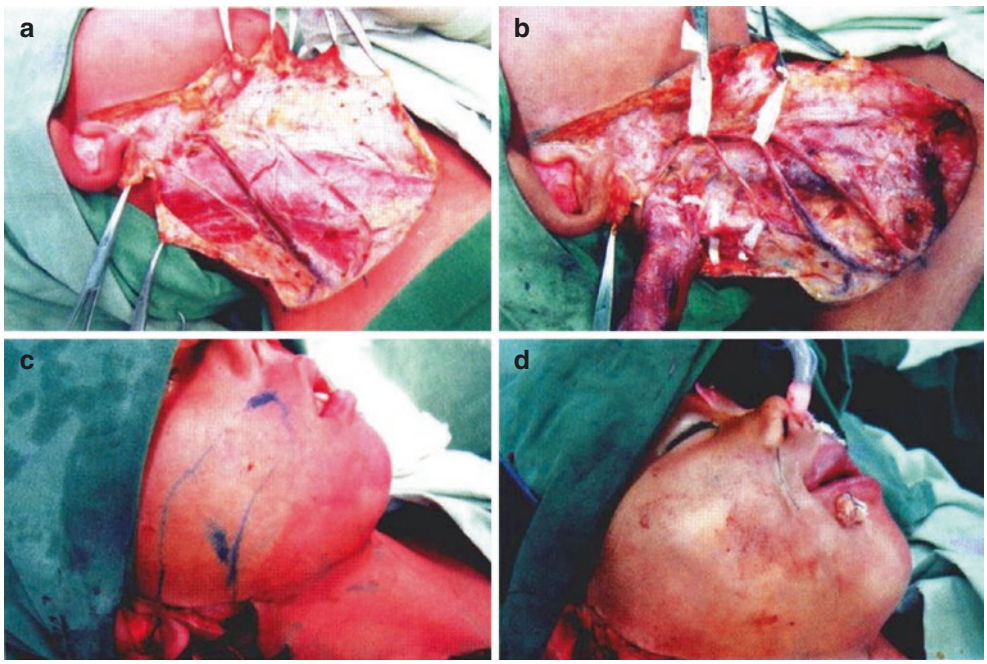

Fig. 11.18 Case VII. (**a**) The cervical skin flap was lift up to expose cervical blood vessels and nerves. (**b**) Exposure of the sternocleidomastoid muscle. (**c**) Buccal subcutaneous tunnel. (**d**) The corner of the mouth was corrected into a smiling appearance after surgery

2.6.4 Postoperative Treatment

The conventional anti-infection treatment is carried out after surgery, and the stitches are taken out discontinuously 7 days later. If the muscle belly is sutured and fixed with the orbicularis oris muscle at the healthy side, the stitches should be taken out 12–14 days later. At the early stage, it should be avoided too early and forcefully activate the corner of the mouth, raise the head, and rotate the neck. The reexamination is performed a month later, and the functional exercises of the transposed muscle start to be carried out.

2.6.5 Some Explanations for Pedicled Sternocleidomastoid Muscle Transposition

1. Nonphysiological dynamic repair: The repair of facial paralysis with pedicled sternocleidomastoid muscle transposition is a nonphysiological dynamic repair. This surgical method is to use the contraction of the transposed sternocleidomastoid muscle to replace the contraction of some facial muscles, since the transposition of the sternocleidomastoid muscle with nerve requires no nerve anastomosis, and therefore the surgical effect is confirmed. As long as the function of the sternocleidomastoid muscle at the affected side is normal, there is surgical indication. Because its surgical indications are wide, and the technique is not complicated, the surgical method has been used and popularized in a number of grassroots hospitals.
2. The sternocleidomastoid muscle transposition is the anatomical basis to restore the activities of the corner of the mouth: Since the muscle belly of the sternocleidomastoid muscle is longer, the nourishing blood vessels come from multiple and segmental sources. The control nerve issued by the accessory nerve enters into the muscle at the junction of upper and middle one third of the muscle belly; therefore, after cutting off the attachment points at the sternum and clavicle, it is easy to transpose upward to the corner of the mouth. When the muscle contracts, it can affect the activities of the corner of the mouth and maintain the symmetry of the corner of the mouth at static state with that at the healthy side. After carrying out anatomical studies, it is found that ① the direction of muscle transposition can be changed by the direction of the tunnel during transposition to make it conform to the moving direction of corner of the mouth during smiling; ② due to the fact that the volume of the sternocleidomastoid muscle in Chinese people is significantly thinner than that in the white people, the distal end of the muscle can be properly trimmed thinly, and therefore the postoperative appearance does not look bloated; ③ under the support of microsurgical techniques, after the control nerve is appropriately cleaved from the trunk, the muscle transposition cannot be affected. Since the abovementioned three operational problems have been settled, the surgical method can be implemented and has already achieved success.
3. Design of transposition direction of the sternocleidomastoid muscle: The characteristics of mouth shape of the patient with a smile should be examined in detail before surgery. When the corner of the mouth at the affected side is pulled to the normal position, the patient is asked to smile, so as to determine the direction and distance of the transposition of the corner of the mouth at the normal side. Generally, when the person smiles, the corner of the mouth moves to the outer upper side, has an angle of 25–30° to the horizontal line, and moves about 1.5–2.0 cm; in some person, the corner of the mouth moves mainly to the lateral side during smiling. Therefore, the characteristics of the smiling when the patient smiles should be understood before surgery in order to adjust the contraction direction and tension size of the transposed muscle during surgery, which will help obtain a more natural smiling effect.
4. The importance of retraining of the transposed sternocleidomastoid muscle: When the neck turns to the healthy side, the sternocleidomastoid muscle shows contraction, which is the basis for the activities of the corner of the mouth after surgery. Because the patients do not understand this, therefore, it is necessary to teach the patient how to make the donor muscles at the affected side flexibly contract before surgery; otherwise, it will be more difficult to teach the patient how to control the transposed donor muscles after surgery. In the early postoperative period, when the patient rotates the neck combined with a smile in the corner of the mouth at the healthy side, this may exhibit an effect of turning back and smiling, but always makes people feel unnatural. After guidance, the patient carries out repeated training in front of the mirror, so that the patient can make the muscle contract only through slightly lowering the head with subjective ideas instead of rotating the neck, so as to make the smile on the face of the patient more natural, and give the patient an unexpected surprise. As long as it adheres to the training, after the patient is used to smiling actions, the smile will be more natural.
5. Reinnervation of perioral muscles: The sternocleidomastoid muscle with nerves and blood vessels plays a role in reinnervation of paralyzed perioral muscles. Previous studies have confirmed that, after the muscle bundle with nerves and blood vessels is implanted into the paralyzed muscle, the paralyzed muscle will be made to restore innervation. Among the patients who have been followed up, it is found by electrophysiological examination that, when the sternocleidomastoid muscle is transposed, the close contact between the muscle belly and the perioral muscles can make the paralyzed perioral muscles gradually restore innervation. In the existing cases, the corners of the mouth are more symmetrical in patients with a

short course of disease due to innervation of multiple perioral muscles, and the better surgical effects are obtained, while in patients with long course of disease and completely disappeared perioral muscles, who have only the contraction of single piece of the transposed muscle, the surgical effects and the symmetry of the corners of the mouth are not as good as the former. Especially in patients who have facial paralysis since childhood, because the affected side is pulled by the healthy side and is affected by the unilateral chewing for a long time, bilateral facial growths are quite different. After surgery, the corner of the mouth is improved, but the overall facial symmetry still needs to be repaired with local surgery.

6. Impact of sternocleidomastoid muscle transposition on original functions: Although the sternocleidomastoid muscle at the affected side is transposed in this surgical method, the movements of the neck can be compensated by other neck muscles; therefore, the patient has no cervical movement disorders and no obvious appearance deformities after surgery. Only when the patient rotates the neck to the healthy side, or when the patient in supine position raises the head, the corner of the mouth will contract, which is the normal performance of the transposed sternocleidomastoid muscle during contraction, and can be explained to the patient before surgery. In addition to this, the negative consequences have not been found yet. But for children, whether the transposed sternocleidomastoid muscle will affect their cervical functions and development is not yet clear, it is recommended that this surgical method is not applied in pediatric patients temporarily. The main impact on cervical appearance is the incision scar; sometimes due to concerns about the scar, the patient refuses the surgery. For this reason, now the surgeons have considered the application of endoscopic minimally invasive harvesting of the donor muscle, and the incision suture can be replaced with biological tissue adhesive glue to minimize the incision scar. The unilateral sternocleidomastoid muscle transposition has no great impact on neck rotation function, but the individual patient feels strenuously when the patient in supine position raises the head in the early postoperative period, and the patient can adapt to it a few months later.
7. Characteristics of sternocleidomastoid muscle transposition: The surgery of physiological dynamic repair of late facial paralysis is more complex, with high technical requirements; therefore, the surgical indications are fairly strict and subject to the limitations of age and physical constitution; there are not many patients suitable for the surgery. Since the surgical effect cannot be confirmed, the patients have doubts about the surgical effect and thus the surgery cannot be extensively carried out. The sternocleidomastoid muscle transposition is to use the contraction of the transposed sternocleidomastoid muscle to replace the contraction of some facial muscles. It belongs to the nonphysiological dynamic repair, but since it avoids the instability of nerve regeneration, the short-term effect of the surgery is satisfactory. Currently, we are still following up the patients; what kind of effect will be eventually achieved remains to be assessed by time. But generally speaking, the surgical operation has wide indications, and the operating techniques are not complex; all well-trained plastic surgeon can master it. At the same time, the surgical method has small damage to the patient, obvious and reliable effects, rapid postoperative recovery, shorter hospital stay, less costs, and other characteristics, which are easily accepted by patients, and thus it is believed that the surgical method is easy to be popularized and used.
8. The repair of late facial paralysis is a systematic project: The late facial paralysis leads to the loss of expressive functions and the appearance of various secondary deformities in the forehead, eyebrows, nose, mouth, and cheeks. Since the scopes and degrees of paralysis of the facial muscles are diverse from each other, and the performances of facial deformities are also varied, it is clearly wrong to expect to only use a surgical method to repair all deformities of the late facial paralysis, and it is also a desire which is impossible to achieve. The surgical treatment of facial paralysis is individualized and the repair of facial paralysis deformity is serialized, whose purpose is to hope that the appropriate surgical method is selected on the basis of careful examination, and the multiple deformities in the affected face can be repaired gradually and sequentially on the basis of repair of perioral deformities, so that the repair of late facial paralysis can be carried out better.

2.6.6 Typical Case

Case IX The patient, female, 28 years old, had complete right facial paralysis after resection of intracranial schwannoma in February 1999. The patient underwent the repair with right sternocleidomastoid muscle transposition in November 2005. The reexamination was performed in June 2006, and the activities of the corner of the mouth in the right face were restored (Fig. 11.19).

2.7 The Repair of Facial Paralysis with Pedicled Temporal Muscle Transposition

2.7.1 Indications

The repair of facial paralysis with pedicled temporal muscle transposition is nonphysiological dynamic repair, and it is suitable for patients with damaged facial nerves and facial muscles. However, this surgical method has a good effect

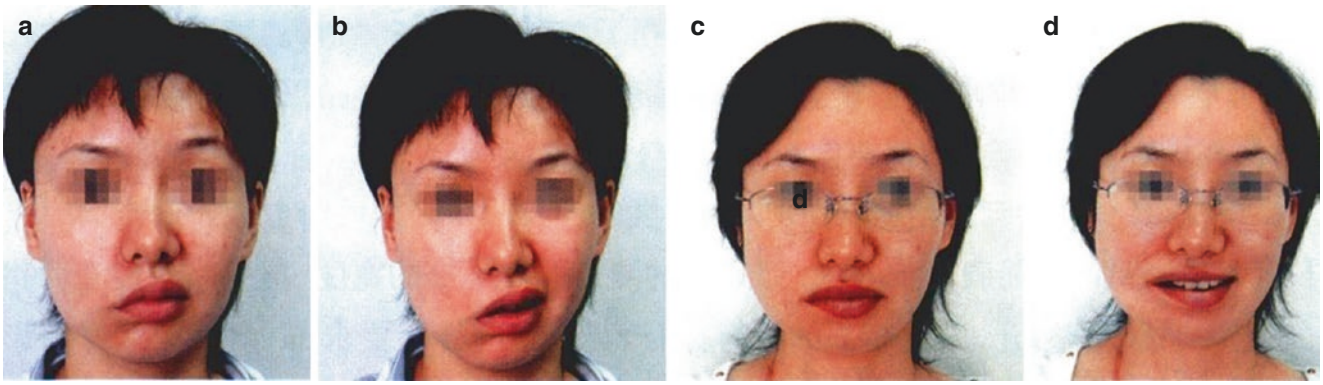

Fig. 11.19 Case IX. (**a**) Before surgery (the corner of the mouth at the static state was askew). (**b**) Before surgery (the corner of the mouth was obviously askew when the patient smiles). (**c**) After right sternocleidomastoid muscle transposition (the corner of the mouth at the static state was symmetrical). (**d**) After right sternocleidomastoid muscle transposition (the facial expression was natural expression when the patient smiled)

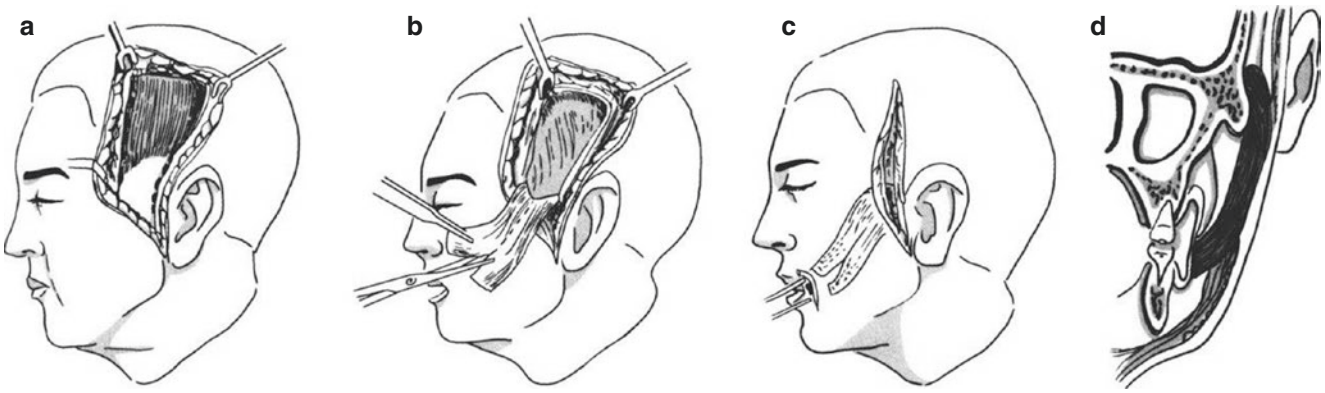

Fig. 11.20 Repair of facial paralysis with pedicled temporal muscle transposition. (**a**) The temporoparietal incision is made at the affected side to expose the temporal muscle, temporal fascia, and periosteum. (**b**) The middle one third of the muscle belly of the temporal muscle is harvested and turned over downward. (**c**) The temporal muscle composite tissue flap is passed through the subcutaneous tunnel to the corner of the mouth. (**d**) The temporal muscle composite tissue flap is passed through the subcutaneous tunnel to the deep surface of the mucosa in the corner of the mouth

only in maintaining the static symmetry of the lower part of the face, while the recovery of facial movements is not ideal.

2.7.2 Surgical Methods

A preauricular incision is made at first, which travels upward approximately 10 cm from the crus of helix to the parietal area; a curved incision of about 8 cm perpendicular to the preauricular incision is made further, which is incised layer by layer. The scalp flap is turned over to expose the deep temporal fascia and temporoparietal periosteum (Fig. 11.20a). The skull periosteum is incised open by about 2–3 cm upward from the starting point of the temporal muscle, and the electric scalpel is used to directly reach and incise the periosteum, and then the muscle is lifted up from the temporal region to the upper margin of the zygomatic bone to make the composite tissue flap consisting of the periosteum with the middle one third of the muscle belly of the temporal muscle, temporal fascia, and temporal muscle; subsequently, it is turned over downward from the zygomatic arch (Fig. 11.20b). The distal end of this composite tissue flap is incised by 2 cm to make it split into two parts, and the normal saline is injected into the SMAS fascia and subcutaneous area along the zygomatic arch, the corner of the mouth, and the nasolabial groove, and then the blunt dissection is carried out to make a wide tunnel; subsequently, the composite tissue flap is passed out of the incision in the nasolabial groove (Fig. 11.20c). Both upper and lower flaps are sutured, respectively, with the orbicularis oris muscles of the upper and lower lips of the corner of the mouth, so that bilateral corners of the mouth at the static state have appropriate hypercorrection, and it is appropriate

to expose the second molar. The submucosal area at the corner of the mouth is sutured and fixed with the deep surface of the center seam between two flaps with several stitches (Fig. 11.20d), so that the corner of the mouth is presented slightly as smiling appearance. The subcutaneous tissue of the incision in the nasolabial groove is sutured with the myolemma of the composite tissue flap with several stitches to reconstruct the nasolabial groove. The sunken defect after the turning over of the temporal muscle can be filled with the silicone prosthesis. The scalp is sutured by means of full-thickness suture, and the wedge resection of the excessive slack skin in the preauricular hairline area is carried out to tighten the affected side. The negative pressure drainage tube is placed in the incision, and the moderate compression bandage is carried out.

2.7.3 Postoperative Treatment

The patient can take soft diet within 3 weeks and should avoid forceful chewing. The functional training is carried out a month later.

2.7.4 Precautions

Since the composite tissue flap is directly sutured with the corner of the mouth, it is required to harvest the pericranium of sufficient length. It should be fully estimated during surgery. Once the length is insufficient, it can only be compensated through transplanting the iliac fascia. The tunnel from the temporal area to the corner of the mouth should have sufficient width. Generally, it is required that the width is more than two fingers; thus, the muscle flap can be spread smoothly to avoid facial asymmetry. It is required that the muscle flap is sutured reliably with the corner of the mouth, and the loose stitches will certainly affect the surgical effect. In the early postoperative period, there may be hypercorrection in the corner of the mouth at the affected side, but there can be a better long-term result. In the surgical method, the corner of the mouth is driven to move while the temporal muscle contracts, and therefore, the twitch of the corner of the mouth will inevitably occur when the patient is eating and chewing, while showing a smile is also realized by different biting strengths, and the patient must have a full understanding of this, which is conducive to independent functional exercise to achieve the desired results.

2.7.5 Typical Case

Case X The patient, male, 59 years old, had complete facial paralysis after resection of right parotid gland tumor in 2004. In May 2006, the pedicled temporal muscle transposition was performed to repair the facial paralysis. At subsequent visit in April 2007, bilateral corners of the mouth were symmetrical, and the patient could show a smiling face (Fig. 11.21).

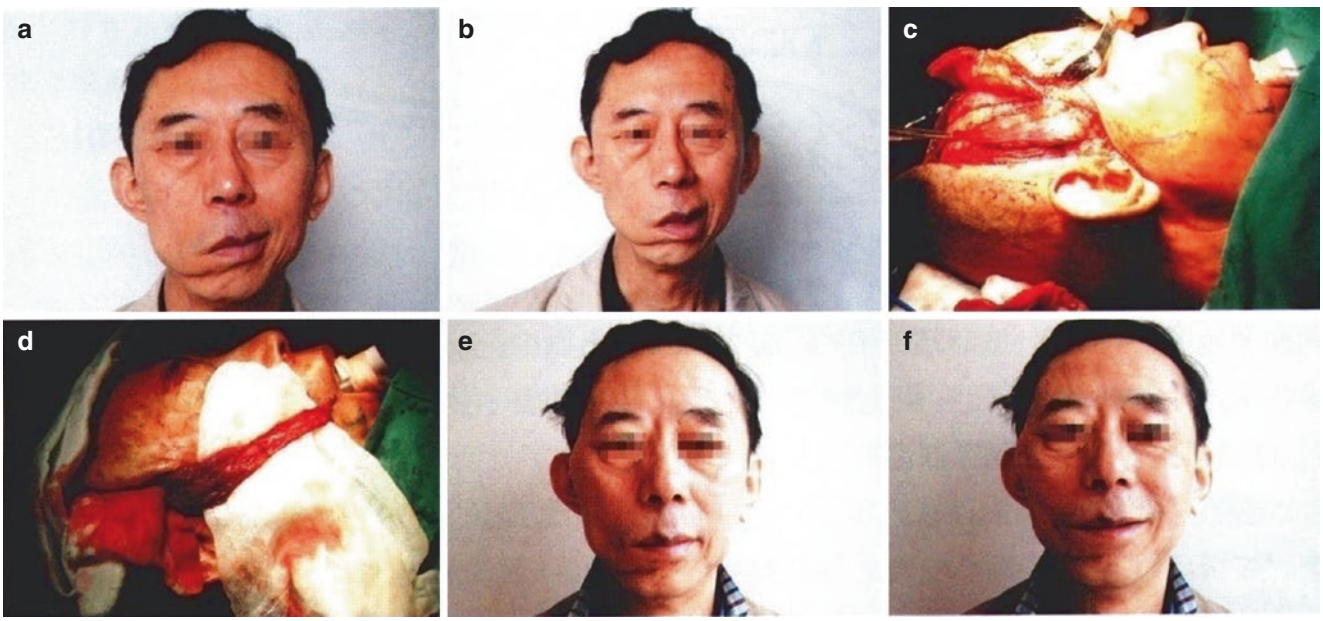

Fig. 11.21 Case X. (**a**) Before surgery (the corner of the mouth at the static state was askew). (**b**) Before surgery (the corner of the mouth was obviously askew when the patient smiles). (**c**) Harvesting of the temporal muscle, fascia, and periosteum composite tissue flap. (**d**) The temporal muscle composite tissue flap was turned over to the corner of the mouth. (**e**) After surgery (the corners of the mouth at the static state were symmetrical). (**f**) After surgery (the corners of the mouth were basically symmetrical when the patient smiles)

2.8 Repair of Facial Paralysis Through Transplantation of the Muscle Bundle of Free Latissimus Dorsi Muscle with Blood Vessels and Nerves

2.8.1 Indications

The surgical method is the physiological dynamic repair, and it is suitable for unrecoverable late facial paralysis patients who have facial nerve injury for more than 1 year with fibrosis and degeneration of facial muscles. During surgery, the free latissimus dorsi muscle with blood vessels and nerves is harvested and transplanted into the affected side to replace the paralyzed facial muscle, then the neurovascular bundle is led through the cross-face tunnel to be anastomosed with the facial artery and vein and the proximal end of the buccal branch of the corresponding facial nerve at the health side, and the facial nerve at the health side is used to control the transplanted muscle bundle to restore its activities synchronized with that at the health side. According to many years of clinical experience of the authors, the design uses a muscle bundle of the latissimus dorsi muscle with special morphology for transplantation, which not only can be taken as dynamic reconstruction but also can be taken as the surgical method to make the multiple denervated muscles at the affected site which contact with the muscle bundle reinnervated and restore certain functions, and it has received good results.

2.8.2 Surgical Methods

The surgery is carried out through dividing it into two groups such as the receptor site group and donor site group:

1. Exposure of the donor muscle: The harvesting of the left latissimus dorsi muscle for repair of left facial paralysis is taken as an example. Under the tracheal intubation anesthesia, the patient is in right side-lying position. The anterior margin of the latissimus dorsi muscle is taken as vertical axis to make S-shaped incision, and the skin and subcutaneous tissue are incised to expose the anterior margin of the latissimus dorsi muscle of about 25 cm. The anterior margin of the latissimus dorsi muscle is turned over backward to expose the subscapular artery issued by the axillary artery at its deep surface of the muscle, the downward continued thoracic dorsal artery, and the accompanying veins and thoracodorsal nerves.
2. Preparation of the latissimus dorsi muscle bundle with blood vessels and nerves: After the subscapular artery and vein and the thoracodorsal nerves are exposed, the branches of the blood vessel are ligated and cut off segment by segment. After the circumflex scapular artery is ligated and cut off, the running direction of the thoracodosal artery and vein and their accompanying thoracodorsal nerves are carefully identified, and subsequently various branches are gradually ligated and cut off. When the nerve branches are cut off, it is necessary to use the electrical nerve stimulator to locate the muscle bundle to confirm that the harvested muscle bundle has good innervation and blood supply. The neurovascular pedicle is designed according to the distance from the left corner of the mouth of the patient to the facial artery at the inferior border of the right (healthy side) mandible, and the length is about 14–15 cm, and then the muscle bundle of the latissimus dorsi muscle with the main body of the muscle bundle and the proximal and distal ends of muscle bundles is harvested according to the design (Fig. 11.22). It is noted to gradually separate the whole layers of the muscle along the muscle fibril gap during harvesting, so that the nerve branches can be retained within the muscle bundle as much as possible. The cone-shaped muscle fibers are retained around the site where the distal end of the neurovascular pedicle enters into the muscle bundle to protect the delicate blood vessels and nerves from accidental injuries. At the moment, once again the electrical nerve stimulator is used to test the innervation status of the muscle bundle. When stimulating the proximal end of the nerve, the muscle bundle will contract rhythmically, confirming that the innervation is intact, and the preparation of the muscle bundle of the latissimus dorsi muscle is completed for standby application.

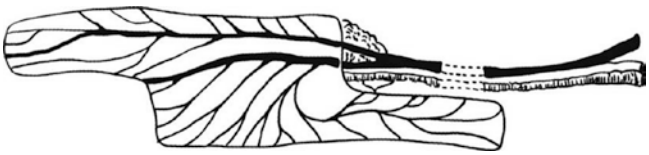

Fig. 11.22 Schematic diagram for the preparation of the muscle bundle of the latissimus dorsi muscle

3. Exposure of the facial nerve and facial artery and vein at the healthy side (right): A curved incision is made along the preauricular area and the mandibular margin, then the underneath separation is performed toward the midline at the superficial surface of the platysma muscle (facial area), and the buccal flap is lifted up. The layer is easily separated with less bleeding, and it is impossible to accidentally injure the facial nerve branches. Various branches of the buccal branch of the facial nerve are exposed at the anterior margin of the parotid gland. The electrical nerve stimulator is used to select a buccal branch which can be stimulated to make the right corner of the mouth move toward the upper outer side for standby application. The facial artery and vein at the lower side of the anterior margin of the masseter muscle are exposed for anastomosis.
4. Preparation of transplant bed at the affected side (left): The incision is the same as that at the healthy side, and the separation is made along the deep surface of the platysma muscle. In addition, an additional incision of about 3 cm is made at the medial side of the left nasolabial groove.

The buccal flap is lifted up to be connected with the incision in the nasolabial groove, and extensive dissection is performed from the superficial temporal fascia to the left corner of the mouth to form a wide transplant bed of the muscle bundle. Then a space is separated from the left corner of the mouth along the orbicularis oris muscle downward between the orbicularis oris muscles of the lower lip for transplantation of the proximal end of the muscle bundle. Another space between the orbicularis oculi muscles of the lower eyelid at the left lateral canthus is separated toward the direction of the inner canthus for transplantation of the distal end of the muscle bundle

5. Transplantation of the muscle bundle of the latissimus dorsi muscle: A subcutaneous tunnel is made under the upper lip at the healthy side, which passes through the orbicularis oris muscle of the upper lip to be connected with the transplant bed of the muscle bundle at the affected side. After the pedicle of the muscle bundle of the latissimus dorsi muscle is cut off, under the guidance of a silicon catheter with a diameter of 8 mm, the neurovascular pedicle is imported from the affected side, which passes noninvasively through the tunnel of the upper lip and penetrates out of the buccal flap at the healthy side; meanwhile, the blood vessels and nerves of the muscle bundle are preserved at the deep surface of the muscle bundle to prevent accidental injury. The subscapular artery and vein are anastomosed, respectively, with the facial artery and vein at the healthy side (Fig. 11.23). After recovery of blood circulation, the immediate bleeding is observed in the section of the muscle bundle and the broken end of thoracodorsal nerve; thus, the compression hemostasis can be performed for a little while. The electrical nerve stimulator is used to select the bundle branch which can make the muscle bundle actively contract for carrying out perineurial suture with the branch of the buccal branch of the facial nerve. The proximal end of the main body of the muscle bundle is sutured and fixed with the corner of the mouth and the orbicularis oris muscle. The proximal muscle bundle is passed through the subcutaneous interstitial space of the lower lip and is transplanted into the orbicularis oris muscle at the affected side, and the percutaneous suture and fixation are performed. The distal end of the main body of the muscle bundle is sutured and fixed with the surface of the zygomatic arch and the temporal fascia according to the original tension. The distal muscle bundle is passed through the subcutaneous interstitial space of the lower eyelid and is transplanted into the orbicularis oculi muscle at the affected side, and the percutaneous suture and fixation are performed. The subcutaneous tissue in the incision of the nasolabial groove is sutured and fixed with the myolemma of the muscle bundle with several stitches to form the nasolabial folds. The proximal end of the thoracic dorsal nerve of the muscle bundle is stimulated with electricity again, and then it is observed that the corner of the mouth at the affected side moves upward and outward and is presented as a smiling appearance. If necessary, the loose skin at the affected side is removed, so that both sides of the face are symmetrical. The incision is sutured by means of interrupted suture, then the negative pressure drainage tube is placed, and finally the wound is wrapped loosely with cotton cushion.

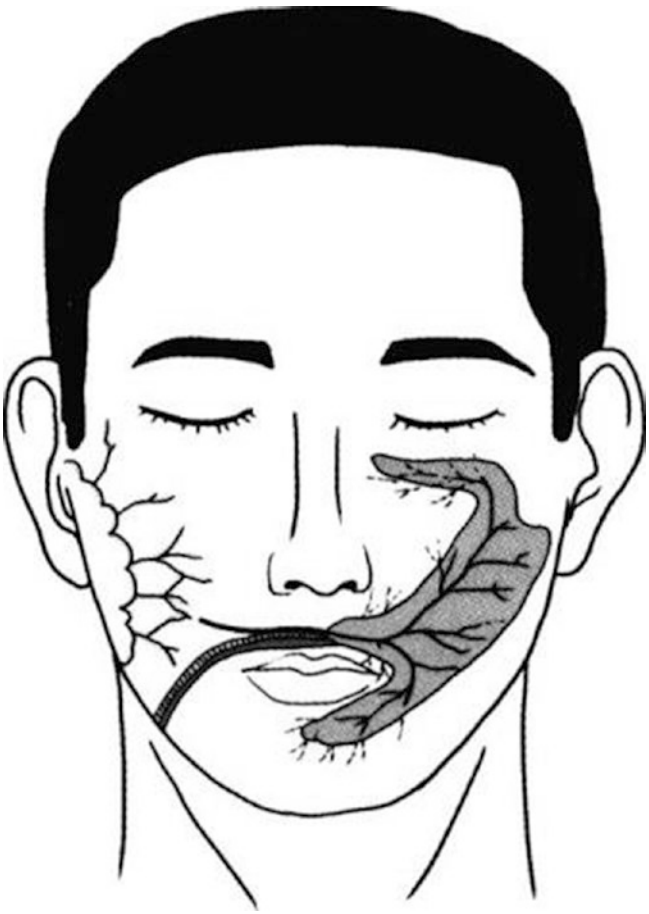

Fig. 11.23 Latissimus dorsi muscle with blood vessels and nerves

The schematic diagram for repair of facial paralysis with transplantation of the muscle bundle

2.8.3 Postoperative Treatment

After surgery, 250 ml of 10% low molecular dextran is intravenously injected twice a day; the preventive use of antibiotics is carried out for 5 days, and the neurotrophic drugs are used for more than 4 months. The reexamination is carried out once a month at the third month after surgery to understand the status of the nerve regeneration. If everything goes well, the functions of the transplanted muscle bundle start to be recovered 4–6 months after surgery and will be recovered to a stable level more than 2 years after surgery. Thereafter,

only the plastic surgery adjusting the facial symmetry can be performed according to the recovery condition and requirements of the patient.

2.8.4 Explanations Related to the Surgery

1. All previous free muscle transplantations are used as simple dynamic reconstruction, but in this surgical method, not only the muscle bundle with blood vessels and nerves can provide dynamic reconstruction but also after appropriate design, the nerves are preserved within the muscle bundle as much as possible, so that the broken ends of a large number of nerve branches exposed on various sections of the muscle bundle can contact closely with paralyzed muscles after transplantation and can make the paralyzed muscles regain innervation through three modes such as nerve-nerve regeneration, direct nerve-muscle regeneration, and muscle-nerve regeneration.
2. For the above reasons, the authors designed the repair of late facial paralysis with the transplantation of the muscle bundle of the latissimus dorsi muscle with blood vessels and nerves which consists of the main body and the proximal and distal ends of the muscle bundle. In addition to that, the main body of the muscle bundle itself may provide the dynamics to reconstruct the functions of the zygomatic muscle and risorius muscle to make the corner of the mouth at the affected side restore function, the orbicularis oris muscle and the quadrate muscle of upper lip can regain innervation and restore function through the proximal muscle bundle, and the orbicularis oculi muscle can regain innervation through the distal muscle bundle to achieve the purpose that multiple paralyzed muscles can restore functions only through transplantation of the muscle bundle of the latissimus dorsi muscle pedicled with a pair of artery and vein and a nerve.
3. From the perspective of postoperative recovery, if everything goes well, the orbicularis oris muscle begins to recover about 4 months after surgery, and then the main body of the muscle bundle has functional contraction gradually, and with a gradual increase in strength, the left and right orbicularis oculi muscles begin to recover about 1 year after surgery, which demonstrate as increased muscle tension of the lower eyelid, normally recovered palpebral fissure, and the disappearance of lagophthalmos when closing the eyes. Since the function of the orbicularis oculi muscle recovers more slowly, which only plays a role in supporting the lower eyelid, and closing the eye is synchronized with that in the healthy side, the patient often neglects the disappearance of lagophthalmos at the affected side. The nerve pedicle is up to 15 cm long, the nerve regeneration needs a long time, and the atrophic muscle fiber due to denervation after regaining innervation can fully recover only after exercise. Therefore, EMG detects the evoked motor unit action potential, only indicating that the muscle is innervated, and the appearance of the functional contraction will take much longer time. Once the nascent potential was recorded in the originally paralyzed muscles at the affected side of a patient 3 years after surgery, suggesting that there is still the process of reinnervation, therefore, it is necessary to fully understand the duration time of muscle reinnervation.
4. Although the electrical nerve stimulator has been used during surgery as far as possible to locate the buccal branch of facial nerve at the healthy side, it is very difficult to accurately locate every nerve bundle, and the nerve regeneration is not carried out according to the desire of the performer. Therefore, when the nerves regenerate, they may get lost and misplaced, so that the coordinated and symmetrical facial movements may be affected. After repair of the affected side, the limited facial expressions still cannot be compared to the facial expressions at the healthy side with a variety of changes, and we can say it will be a difficult problem in the repair of facial paralysis which needs to be researched further in the future. Nevertheless, the effects which have been achieved currently have greater progress compared with hundred years of various repair methods. Therefore, let the patients understand the possible outcomes after surgery and cooperate with the treatment, and retrain the regenerated nerves, which are very necessary for obtaining a satisfactory curative effect.
5. It is very important to select the patients with indications. For the patients with simple dynamic reconstruction, it only needs to reconstruct the motor function of the corner of the mouth, and there is no problem of muscle reinnervation. In order to make the perioral muscle and orbicularis oculi muscle reinnervated, it is required that these muscles have no severe atrophy and fibrosis. It is generally considered that the facial muscle fibers have irreversible changes at 1 year after denervation, which will not be restored after regaining innervation. But the time limit of denervation is often extended to 2 years in the clinic, because the patients with a course of the disease within a year are mostly treated with conservative treatment and are unwilling to accept major facial surgery, while among the patients with a course of the disease of more than 3 years, there are patients in whom multiple paralyzed facial muscles regain innervation and restore functions. Therefore, surgical indications may be extended appropriately; even though the paralyzed muscles are not reinnervated, the main body of the transplanted muscle bundle still can get repair effect as a simple dynamic reconstruction.
6. The first-stage surgery can repair some functions of the affected side, but the correction bilateral facial asymme-

try still requires the second-stage surgical adjustment. Two years after surgery, when the disease condition is stable, let the patient evaluate the effect of the first-stage surgery, and then make surgical adjustment in the site with facial asymmetry, including eyebrow lift at the affected side, repair of the lagophthalmos, and tightening of the facial loose skin.

2.8.5 Typical Case

Case XI The patient, female, 16 years old, had left facial paralysis after resection of left cheek hemangioma for 12 years. The repair of facial paralysis with free transplantation of the muscle bundle of the latissimus dorsi muscle with blood vessels and nerves was carried out, and the smiling facial expression was restored in the affected side after surgery (Fig. 11.24).

2.9 Repair of Ocular Malformations Caused by Facial Paralysis

The facial paralysis often causes the appearances of deformities such as lagophthalmos and ectropion of the eyelid in the eyes, and the relaxation of tissues around the eyes has also led to changes in the appearance of the eye. The following statements will describe the relevant plastic surgeries; these repair methods in the upper eyelid and lower eyelid should be completed separately, in order to avoid mutual influence of the upper and lower eyelids and thus result in a good surgical effect.

2.9.1 Upper Eyelid Repair

Because the facial paralysis patients have paralyzed orbicularis oculi muscles, their eyelid closure functions are affected, and cannot provide good coverage and protection, leading to the occurrence of lagophthalmos. At the same time, because the tear secretion declines, this will easily lead to the occurrence of corneal xerosis and damaged eyesight. In addition to the regular application of oculentum and eyedrops in the eye for protection, the gold piece is implanted in the upper eyelid, which uses the gravitational effect of the gold piece to close the eyelid, and is the most effective and simple surgical procedure among the methods for upper eyelid repair.

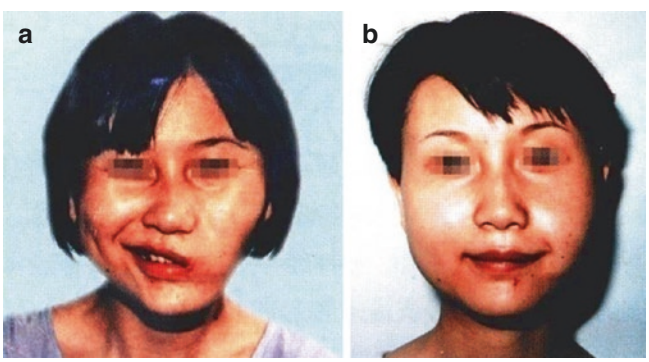

Fig. 11.24 Case XI. (**a**) Before surgery (the corner of the mouth was askew obviously when the patients smiled). (**b**) Two years after surgery (the corners of the mouth were symmetrical when the patients smiled)

1. Surgical method: It is required to determine the weight of the gold piece to be implanted at first, and the weight is generally 0.6–1.5 g. The gold pieces of different weights can be applied to be attached onto the upward side of the eyelash of the upper eyelid, respectively. The patient is asked to close his or her eyes, then the gold piece with lightest weight which can make the eye closed is selected for implantation, and the frequently used weight is about 1.0–1.3 g. Combined with the characteristics of the eyelids in Chinese people, the gold piece can be designed as long oval shape, with a length of about 15 mm and a width of 5 mm. The thickness varies owing to different weights; however, it is required that the gold piece is made into a shape with slightly thick center and gradually thinned periphery, and its radian is consistent with the corneal radian of the eyeball. Four circular holes with a diameter of 1 mm are drilled in the upper margin of the gold piece, so that the gold piece can be sutured and fixed with the tarsal plate. The surgery can be performed under local anesthesia, and the anesthetics can be injected into the double eyelid folds and the tarsal plate in the upper eyelid. An incision of about 2 cm is made along the double-fold eyelid line, and then the pretarsal tissue is separated to reach the tarsal plate; subsequently, a capsular bag is formed from the site above the tarsal plate to the site with a distance of about 2 mm from the eyelash to place the gold piece. The gold piece is placed into the capsular bag, and the gold piece is sutured and fixed with the aponeurosis of the levator palpebrae superioris muscle using 6-0 absorbable suture through the holes on the upper margin of the gold piece. The pretarsal tissues including the degraded orbicularis oculi muscle are used to cover the gold piece, and the layered suture is performed (Fig. 11.25).
2. Postoperative treatment: If the radian of the gold piece is inconsistent with that of the eye cornea, the local uplift of gold in upper eyelid will be exposed, thus affecting the appearance; the radian of the gold piece should be adjusted to make it more fit to the tarsal plate. The local dressing bandage is performed for 1 day, and the stitches are taken out at the first week after surgery.
3. Precautions: The gold piece has low chemical activity and good biocompatibility, and thus has a small body tissue reaction after implantation, but the gold piece is a foreign body; it is still possible to be exposed due to the body's rejection, thus the preventive measures should be taken during surgery. Generally, the weight of the gold piece should be not more than 1.5 g, and it must be made of 24 K

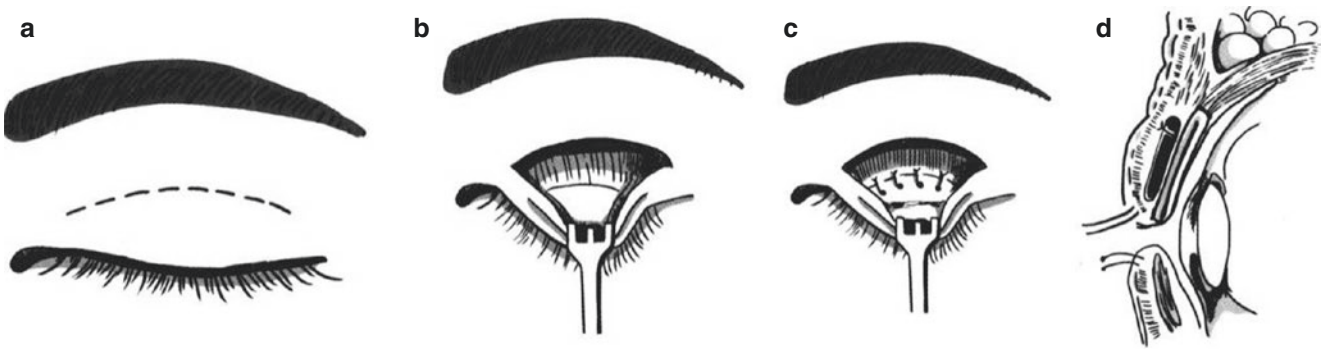

Fig. 11.25 Upper eyelid repair. (**a**) The double eyelid incision in the upper eyelid. (**b**) Exposure of the tarsal plate. (**c**) The gold piece is implanted, sutured, and fixed. (**d**) Implanted layers of gold piece

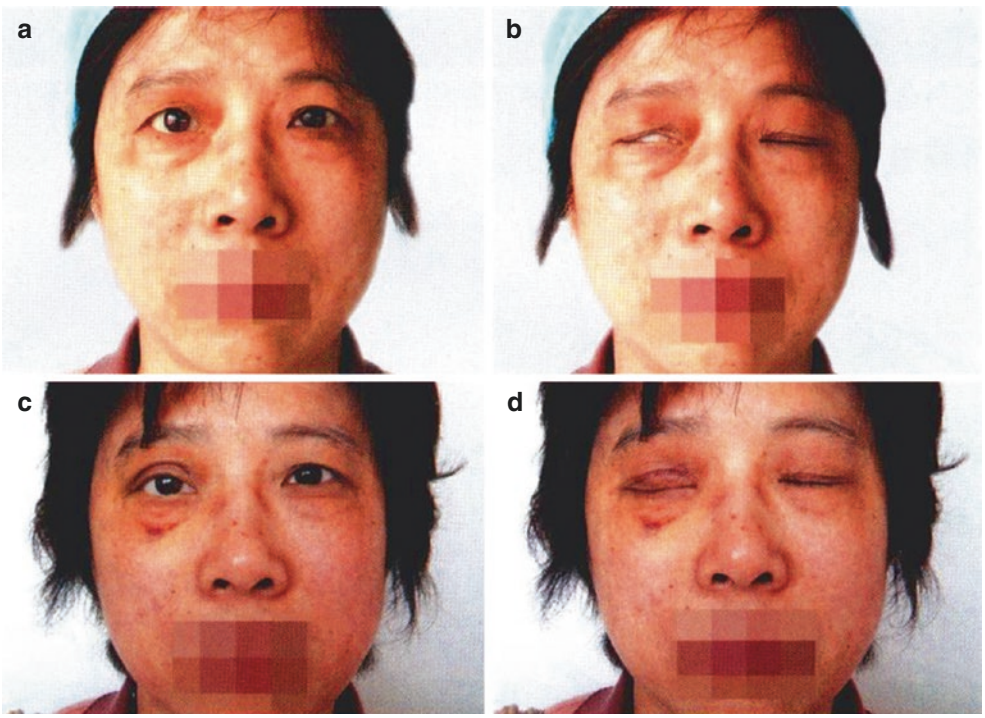

Fig. 11.26 Case XII. (**a**) Before surgery (the right eye fissure was too large when the eyes were open). (**b**) Before surgery (the lagophthalmos disappears when the eyes were closed). (**c**) At the first week after surgery (bilateral eye fissures were similar when the eyes were open). (**d**) At the first week after surgery (the lagophthalmos disappears when the eyes were closed)

gold (99.99%) to reduce the tissue response. The radian of the gold piece should be consistent with that of the eye cornea to improve the appearance of the upper eyelid. The margin of the gold piece is rounded and blunt, and should not be sharp, so as to reduce exposure and visualization of the gold piece. The gold piece can be treated with high temperature annealing before surgery; not only it can disinfect but also it is more flexible after annealing, which is conducive to intraoperative radian adjustment.

The gold piece should be placed on the upper margin at the front side of the tarsal plate. The skin in the lower margin of the upper eyelid near the eyelashes is thin; thereby, the gold piece is easily exposed here. Therefore, it is inappropriate to make a too wide gold piece, and the gold piece cannot be placed too close to the eyelashes. When the capsular bag is formed, the orbicularis oculi muscle should be retained and cannot be resected; otherwise, the gold piece will be visualized due to lack of tissue covering and can also easily penetrate out due to too thin skin. When the patient stands, the eyelid closure is accomplished by the gravity of the gold piece. The phenomenon that the eye cannot be closed when the patient sleeps will occur in individual patients after receiving this surgery, and thus attentions should be paid to protecting the cornea during sleep.

4. Typical case: Case XII, the patient, female, after resection of facial nerve tumor, had right lagophthalmos when the right eyes were closed, and thus the upper eyelid repair was performed (Fig. 11.26).

2.9.2 Repair of Lower Eyelid Laxity

The paralyzed lower eyelid should be assessed before lower eyelid repair, and the extent of the lower eyelid laxity can be assessed using the method of lifting and pinching the lower eyelid. When the ectropion of the eyelid is repaired, whether it is needed to repair the inner canthus of the lower eyelid is determined depending on the location of the lacrimal point of the lower eyelid and the affected functional status. The lower eyelid ectropion leads to lacrimal point valgus; when the lacrimal point does not contact with the eyeball, the lacrimal passage cannot introduce the tears into the nasal cavity, and the tears are retained in the lower eyelid area and excessively accumulated to lead to epiphora. On the other hand, the tarsal plate is separated from the eyeball when the lower eyelid ectropion occurs, so that the tarsal plate cannot moisten the cornea through closing the eyelid. Because the corneal drying stimulates and produces too much tears, the epiphora will occur frequently. The medial canthal ligament plasty and the tightening of the lateral canthus ligament of the lower eyelid are often used for repair of lower eyelid laxity:

1. Surgical methods
   (1) Lower eyelid medial canthal ligament plasty: Under the corneal anesthesia, the eye ointment is used to protect the cornea. The surgical incision is designed at first, then the horizontal incision is performed along the medial canthal ligament after local anesthesia, and the skin flap is dissected to expose the upper and lower canthal ligaments of the medial canthal ligament. After that, the outer portion of the medial canthal ligament of the lower eyelid is tightened and folded and then is sutured with the medial portion of the medial canthal ligament. After the skin flap at the lower margin of the incision is tightened, the redundant skin is removed, and the incision is sutured (Fig. 11.27).
   (2) Lower eyelid outer canthal ligament tightening surgery: The surgical incision is designed at first, then the horizontal incision is performed along the outer canthal ligament after local anesthesia, and then the skin flap is dissected to expose the upper and lower canthal ligaments of the outer canthal ligament; subsequently, the lower eyelid portion of the outer canthal ligament is cut off. After its medial portion is tightened, the upper eyelid portion of the outer canthal ligament is inserted into and penetrated out the appropriate place according to the condition of lower eyelid reduction, which is sutured and fixed with the medial periosteum above the attachment points at the lateral orbital margin of the outer canthal ligament after the redundant skin and conjunctiva are removed, and the incision is sutured (Fig. 11.28).
2. During postoperative treatment, attentions should be paid so that the incision is clean and the eyes are protected with ointment. The stitches are taken out at the first week after surgery.
3. Precautions: Because the orbicularis oculi muscle is paralyzed, and the lower eyelid loses the support of the orbicularis oculi muscle, the lower eyelid laxity may occur again a few years later.

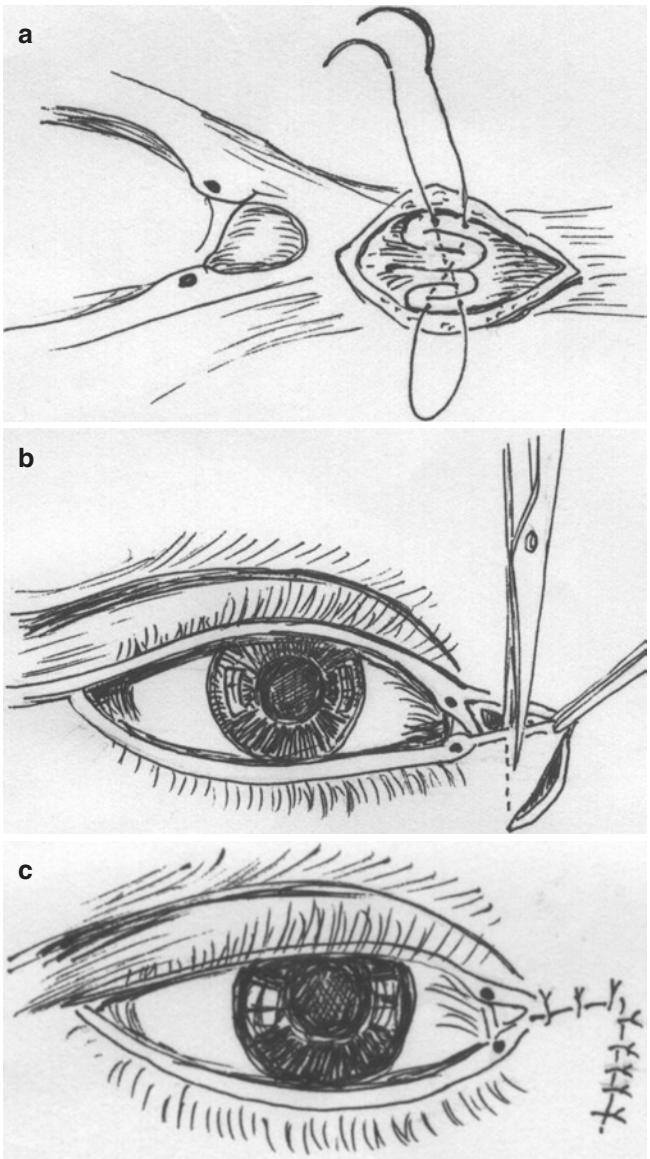

Fig. 11.27 Lower eyelid medial canthal ligament plasty. (**a**) The outer portion of the medial canthal ligament of the lower eyelid is tightened and folded, and then is sutured with the medial portion of the medial canthal ligament. (**b**) After the skin flap at the lower margin of the incision is tightened, the redundant skin is removed. (**c**) The incision is sutured

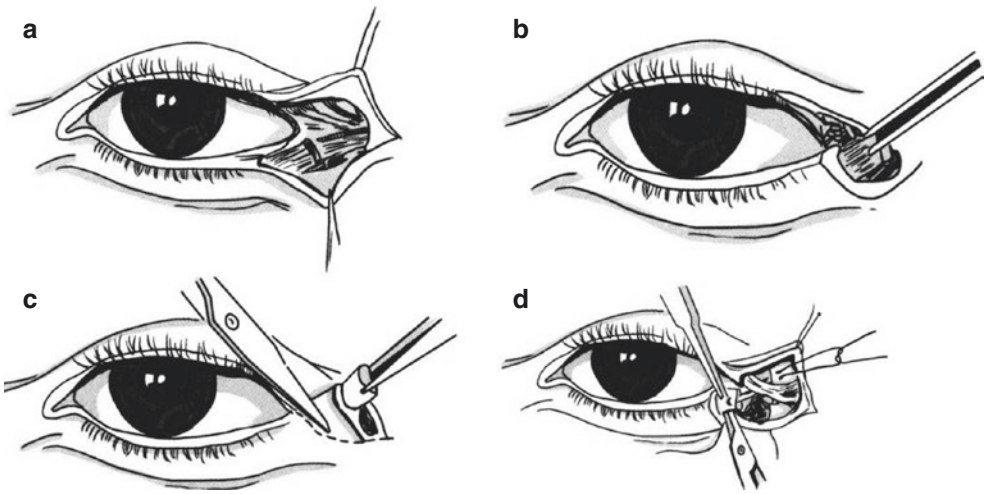

Fig. 11.28 Lower eyelid outer canthal ligament tightening surgery. (**a**) The horizontal incision is performed along the outer canthal ligament, and the skin flap is dissected to expose the upper and lower canthal ligaments of the outer canthal ligament. (**b**) The lower eyelid portion of the outer canthal ligament is cut off, and its medial portion is tightened. (**c**) The redundant skin and conjunctiva are removed. (**d**) The upper eyelid portion of the outer canthal ligament is inserted into and penetrated out the appropriate place which is sutured and fixed with the medial periosteum above the attachment points at the lateral orbital margin of the outer canthal ligament

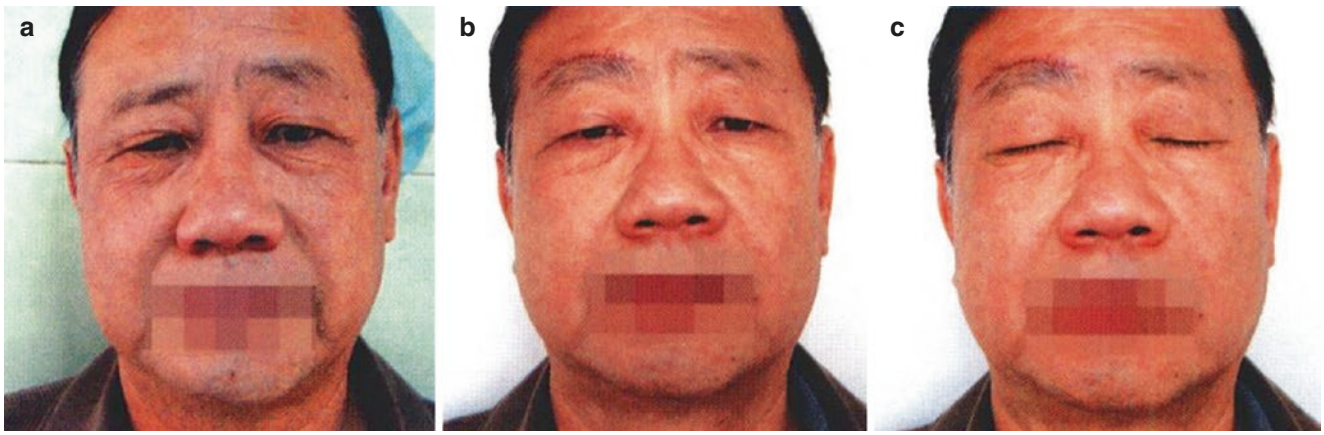

Fig. 11.29 Case XIII. (**a**) Before surgery. (**b**) The result after eyebrow suspension (the patient looked at the front horizontally). (**c**) The result after eyebrow suspension (the eyes were closed)

2.10 Repair of Facial Asymmetry

2.10.1 Repair of Eyebrow Ptosis

The tumor invasion or tumor surgery leads to facial paralysis. Due to the paralysis of the frontal muscle, the eyebrow ptosis occurs at the affected side. It can be repaired through unilateral or bilateral eyebrow suspension. The bilateral eyebrow suspension is suitable for the elderly, and the unilateral eyebrow suspension has a better effect in younger patients. The height of eyebrow suspension at the affected side should be designed at a static state, and the key issue is that the eyebrow suspension cannot be carried out excessively; otherwise, it will aggravate the closure insufficiency of the affected eye. The eyebrow suspension can be performed simultaneously with the placement of the gold piece, but the surgical design should be fully estimated.

Case XIII The patient, male, had right eyebrow ptosis due to the paralysis of the right frontal muscle after tumor resection, which was repaired with eyebrow suspension (Fig. 11.29).

2.10.2 Repair of Cheek Sagging

The facial paralysis patients have facial skin laxity due to paralyzed facial muscles, and the facial deformity at the affected side is obvious, especially for the elderly patients who cannot receive major surgery because of physical weakness; the facial wrinkle surgery can significantly improve the facial symmetry, and it should be regarded as a standard repair surgery. Since this surgical method has been described in detail in a variety of cosmetic surgery books, only the surgical effects of clinical cases are briefly introduced here, and the unnecessary details will be not described.

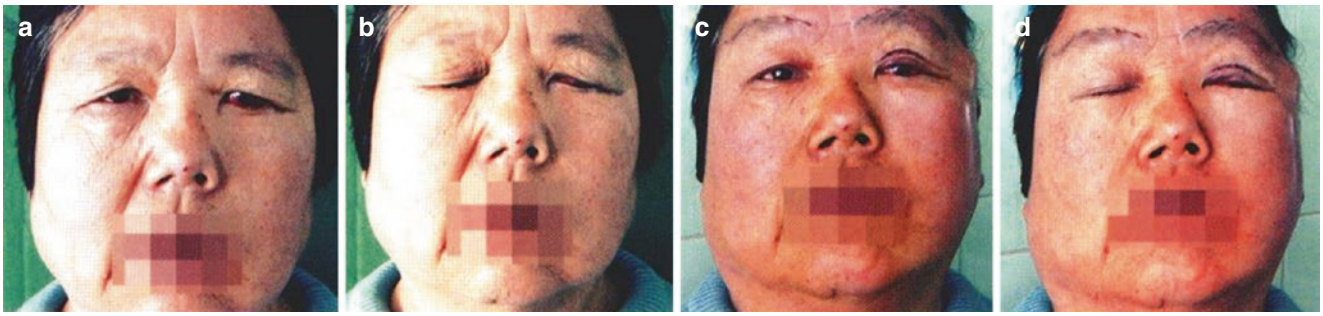

Fig. 11.30 Case XIV. (**a**) Before surgery, when the eyes were open. (**b**) Before surgery, the left lagophthalmos when the eyes were closed. (**c**) After bilateral eyebrow suspension, the gold piece was placed in the left upper eyelid. After the left cheek was tightened, both sides of palpebral fissure were similar when the eyes were closed, and the facial symmetry is obviously improved. (**d**) After surgery, the left lagophthalmos disappeared when the eyes were closed

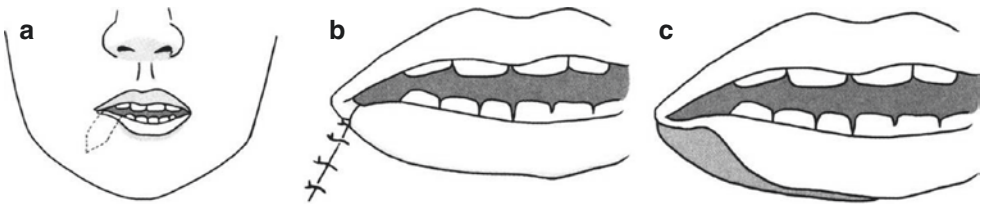

Fig. 11.31 Repair of asymmetrical lips. (**a**) Partial resection of the lower lip at the affected side. (**b**) The lower lip at the affected side was closed and then was sutured by layers. (**c**) For the excessive narrowing deformity of the lower lip, a strip of spindle-shaped skin can be removed inward along the vermilion of the lower lip to lead to the slight valgus of the vermilion

Case XIV The patient, female, had complete facial paralysis after left brain tumor resection; before surgery the patient had left eyebrow ptosis, cheek sagging, exposure conjunctivitis congestion of the left eye, and left lagophthalmos when the eyes were closed; thus, the repair of cheek sagging was conducted (Fig. 11.30).

2.10.3 Repair of Lip Deformity

The repair of the symmetry and function of the mouth can be completed through the plastic repair of the lips. The paralysis and atrophy of the orbicularis oris muscle are manifested as the narrow vermilion at the affected side, and the paralyses of the depressor anguli oris muscle and depressor labii inferioris muscle further aggravate the lip deformity at the affected side. An incision of 7–10 mm may be made at the medial side of the corner of the mouth at the affected side for the reparative and reconstructive surgery, and the wedge-shaped lip tissue with a length of about 2 cm and a width of 2.0–2.5 cm wedge is removed downward. The width should be designed considering the three-dimensional morphology of the lip, and the downward incision should not exceed the buccal labial sulcus. During surgery, the lateral incision can be made at first, then the lower lip is pulled to the lateral side, and the resected amount of the lower lip is estimated. For the excessive narrowing deformity of the lower lip, a strip of spindle-shaped skin can be removed inward along the vermilion of the lower lip to lead to the slight valgus of the vermilion (Fig. 11.31).

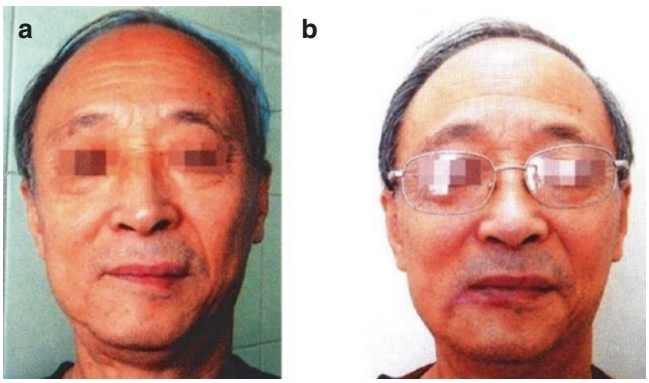

Fig. 11.32 Case XV. (**a**) The excessive narrowing deformity of the right lower lip before surgery. (**b**) Bilateral sides of the lower lip were symmetrical after surgery

Case XV The patient, male, had excessive narrowing deformity of the right lower lip; thus, the lip repair was performed (Fig. 11.32).

All surgical photographs published in this chapter have been approved by the patients themselves.

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Defect Repair After Resection of Scalp Malignant Tumors

12

Yunliang Qian, Yixin Zhang, and Zan Li

1 Overview

1.1 Diagnosis

The most common scalp malignant tumors include basal cell carcinoma, squamous cell carcinoma, malignant melanoma, fibrosarcoma, and so on. In general, the scalp cancers locating at the body surface are more easily diagnosed. They are usually manifested as cauliflower-like masses or prolonged unhealed ulcers; when the dura mater is invaded, the meningeal irritation will occur; when the intracranial area is invaded, there may be symptoms of intracranial hypertension. Particular attention should be paid to that the scalp cancer often occurs in the site with scars. If the prolonged unhealed ulcer appears in the site with scars, it is better to carry out biopsy. CT or MRI is the examination the patients with scalp cancer must undergo, and it can accurately assess the scope and depth of tumor invasion to guide further treatment.

1.2 Applied Anatomy

The scalp is a layer of compact soft tissue covered on the skull surface and consisting of all kinds of different tissue structures. There are rich hair follicles, sebaceous glands, and sweat glands within the scalp, and the thick hairs grow on the scalp surface.

The anteroposterior scalp diameter ranges from the occipital cervical hairline to the superciliary arch of the frontal bone, while its left-right diameter reaches both zygomatic soft tissues. The scalp surface is covered with hair except the forehead.

The scalp is composed of the skin, subcutaneous tissue, galea aponeurotica, loose connective tissue, and exocranium, respectively. The skin, subcutaneous tissue, and galea aponeurotica are connected closely by dense fascia fiber bundles to form a thick and dense soft-tissue anatomical layer. The subcutaneous tissue layer contains rich blood vessels and lymphatic vessels. The galea aponeurotica is located at the top of the head. The anterior part is connected to the frontal muscle, while the posterior part is connected to the occipital muscle, and both parts are taken, respectively, as attachment points of the abovementioned muscles; both sides are connected to superficial temporal fascias at the temporal line of the skull to form into the aponeurosis layer of the entire scalp area. The forepart of the frontal muscle stops under the eyebrows and is connected to the corrugator and orbicularis oculi muscle, and its activities are controlled by the frontal branch of the facial nerve temporal branch. The rear part of the occipital muscle ends at the occipital tuberosity and the neck line, and its innervation is mainly controlled by facial nerve and its retroauricular branch. There is a layer of loose clearance between the galea aponeurotica and the skull, which is also known as the subgaleal layer. The blood vessels are rare in this layer, and the separation is performed here after the scalp is incised during head surgery. At the same time, this layer has become the potential predilection site of the traumatic scalp avulsion, hematoma, and infection. The periosteum is covered on the surface of the skull and is closely connected to the skull at the cranial suture.

The blood supply of the scalp mainly comes from the superficial temporal artery, the posterior auricular artery, and the occipitoposterior artery of the external carotid arterial system as well as the supraorbital artery and the supratrochlear artery of the internal carotid arterial system, and all abovementioned arteries have accompanying veins with the same name. These blood vessels primarily locate in the subcutaneous layer of the scalp, and there are rich anastomoses of vascular networks

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between each other. The scalp blood vessels can penetrate through the periosteum and skull to communicate with the meningeal blood vessels and provide nutrition to the skull.

The sensory nerves of the scalp are very rich, and various sensory nerves are distributed in corresponding areas to overlap each other as well as trans-regionally control. The main sensory nerves of scalp include two supraorbital branches of the trigeminal nerve, supratrochlear sensory nerve, great occipital nerve, great auricular nerve, auriculotemporal nerve, and the zygomaticotemporal nerve.

1.3 The Scopes and Depths of Resection of the Scalp Malignant Tumors

The scopes and depths of resection of various scalp malignant tumors are determined based on the clinical symptoms and the results of imaging and histopathological examination before surgery. The scope of lesion resection must include the normal tissues in the surrounding and deep areas.

For common skin malignant tumors such as basal cell carcinoma, squamous cell carcinoma, and malignant melanoma, the scopes of conventional surgical resection of surrounding normal tissues are 5–10 mm, 10–20 mm, and 20–30 mm, respectively, and the resected deep tissues include inviolated deep subcutaneous fascia. However, this conventional surgery will be limited by a series of factors such as the possible organ deformities and dysfunctions caused by resection which can aggravate the surgical complications and lower the postoperative quality of life. Therefore, an experienced surgeon will fully estimate the safety range of resection of normal tissues surrounding the tumor according to preoperative clinical diagnosis. Surgeons should make acquaintance of the tumor growth pattern and thickness, the extent of tumor invasion of deep tissues, with or without ulceration, and the different pathological changes of different tumor tissue during operation and repair the defected tissues and organs simultaneously. The prognosis of the skin malignant tumor connected closely to the property and thickness of the tumor, the depth and range of invaded skin tissue, and the range and extent of the surgical resection. For example, if the skin malignant melanoma is thicker than 1.5 mm and the depth of the invaded subcutaneous tissue reach grade 5, the prognosis of the patient is poor. When the lesion is resected, the extensive radical resection should be performed, including resection of surrounding lymph nodes. The routine intraoperative frozen section examination of incisal margins is conducive to the thorough resection of the tumor.

The resection scope and depth of scalp malignant tumors should not only follow the surgical principle of malignant skin tumors but also be determined according to the scalp tissue layers invaded by the tumor tissue and the nature of the tumor. The partial palliative tumor resection should not be performed because of concerns that the tumor resection will lead to difficulty in repair of the scalp and skull defects. In clinical practice, we have encountered a patient with recurrence of malignant melanoma of the scalp more than 2 months after surgery due to incomplete local resection. After the extended resection of recurrent tumor including normal scalp as well as skull and dura mater within 5 cm of surrounding area, no local tumor recurred within 5 years. In our opinions, when the malignant melanoma of the scalp is more superficial and the galea aponeurotica is not infiltrated, the surgical resection should be performed under subgaleal layer, and the exocranium is reserved; if the tumor tissue has invaded the galea aponeurotica, the resection scope must include the exocranium and outer table of skull; when the malignant tumor invades the skull, the resection scope must include the full-thickness scalp and the endocranium, and it is necessary to invite the neurosurgeons to participate jointly in this kind of surgery.

2 Repair of Simple Scalp Defects

The tissue defects after resection of scalp malignant tumors can be divided into simple scalp defects and complex scalp defects. The simple scalp defects mainly refer to the defects with intact exocranium, skull, and dura mater retained in the wound surface, and the complex scalp defects refer to the defects involving multiple tissues such as scalp, periosteum, skull, or endocranium. The repair requirements and methods for two types of scalp defects are different, but the basic requirement is that the defect wound is closed at the first stage, and no obvious bald deformity is left after surgery.

The repair methods for simple scalp defects mainly include the following three types.

2.1 Direct Suture Method

The method is applicable to patients with scalp defect wounds of less than 3 cm in diameter. The scalp tissue is very dense and inflexible, and the tension is bigger when the wound is directly closed and sutured, so the complete dissection should be performed under the normal scalp galea aponeurotica at bilateral sides, and bilateral wound margins are

closed directly and sutured interruptedly after relaxation of the scalp. The wound margins should be sutured through the full-thickness scalp and occluded well to prevent the postoperative bleeding and hematoma.

2.2 Free Skin Transplantation

This method is suitable for patients with larger area of scalp defect, in whom the wound cannot be directly closed or the donor site is still not closed completely and directly after local skin flap transfer. Since the exocranium is left intact in the scalp wound, the use of free skin graft can achieve the purpose of early wound repair. The full-thickness skin graft is preferred because of its good quality of abrasive resistance. The disadvantage of this method is that there are patches of baldness in scalp after surgery, but in the later period, the scalp expansion operation can be performed to repair the alopecia deformity. The method is simple and practical and is easy for surgeons to master.

2.3 Scalp Flap Transfer

The scalp flap transfer is the more commonly used repair technology of scalp defect in clinic which can achieve the purpose of preventing postoperative scalp alopecia or covering the skull to repair the exposed wound. In clinical practice, the scalp flap transfer can repair the maximum defect area accounting for about 20% of the scalp. The method is suitable for plastic surgical patients with primary and secondary scalp defects which can be closed at the first stage. The surgery is technically demanding, and the scope of surgery is extensive with more intraoperative bleeding; therefore, it is required that the plastic surgeons have skilled and sophisticated surgical techniques, and the patients should be healthy. The methods for scalp flap transfer mainly include the rotation of scalp flap and the advancement and transposition of scalp flap.

2.3.1 Rotation of Scalp Flap

This method is suitable for patients with the defect in the hair-contained scalp and is surrounded by plenty of normal scalp. The surgical method is that one or several rotation skin flaps are designed according to the size of the wound. The skin flap area should exceed the defect area, the length of the skin flap should be sufficient, the pedicle of the skin flap is preferably located in the range of well-known blood vessels of the scalp, and excessive tension should be avoided when the skin flap is sutured. When the secondary wound after rotation of skin flap is sutured, the undermining dissection can be performed under the scalp at one side, and the galea aponeurotica will be incised into multiple strips along the direction of the wound to relax the scalp and reduce the suture tension. When the galea aponeurotica is incised, attentions should be paid to preventing damage to blood vessel network of the scalp.

Case I The patient, male, 32 years old, was admitted into the hospital because of the canceration of the chronic ulcer of frontoparietal scar into squamous cell carcinoma, and the skull had been violated and destructed. Preoperative examination showed that the general condition was fine, and the cervical lymph nodes were not palpated. The tissues cancerated from the frontoparietal scar were extensively resected, while the skull which had been violated and destructed was resected. The intraoperative pathological examination showed that the local dura mater had also been invaded by tumor cells, and thus the removal of dura mater led to enormous defects in scalp, skull, and dura mater in frontoparietal area. After the dura mater was repaired with patch, the scalp flap pedicled with right superficial temporal vessels was designed in frontoparietal area adjacent to the defect area. The scalp in the area of the vascular pedicle of the skin flap was incised at first, and then the scalp was dissociated toward bilateral sides at the superficial surface of superficial temporal fascia. The dissociation and dissection of the scalp must be performed carefully to prevent the injury of scalp hair follicles and the superficial temporal vessels. The temporal superficial fascia tissue of sufficient width was retained around the superficial temporal vessels to form into a wider vascular pedicle with subcutaneous fascia. This technology can prevent stretch and twist of blood vessels in the process of scalp flap transfer and reduce the vascular tension; at the same time, it can also increase the blood supply of the scalp flap. After that, the incision line was designed along the scalp flap, and then the scalp was incised deeply to the skull periosteum, and the whole scalp flap was elevated at this level. After the scalp flap was elevated, the blood supply of the scalp flap showed well. The scalp flap was transferred to the frontoparietal area. After the defect was completely repaired, the donor site of scalp flap was covered by split-thickness skin graft, and the packaged fixation was performed. The transferred scalp flap survived completely at the 3rd week after surgery. The wound healed at the first stage, and the patient recovered and was discharged (Fig. 12.1). One year follow-up was carried out after surgery, and the patient did not have local or systemic tumor recurrence.

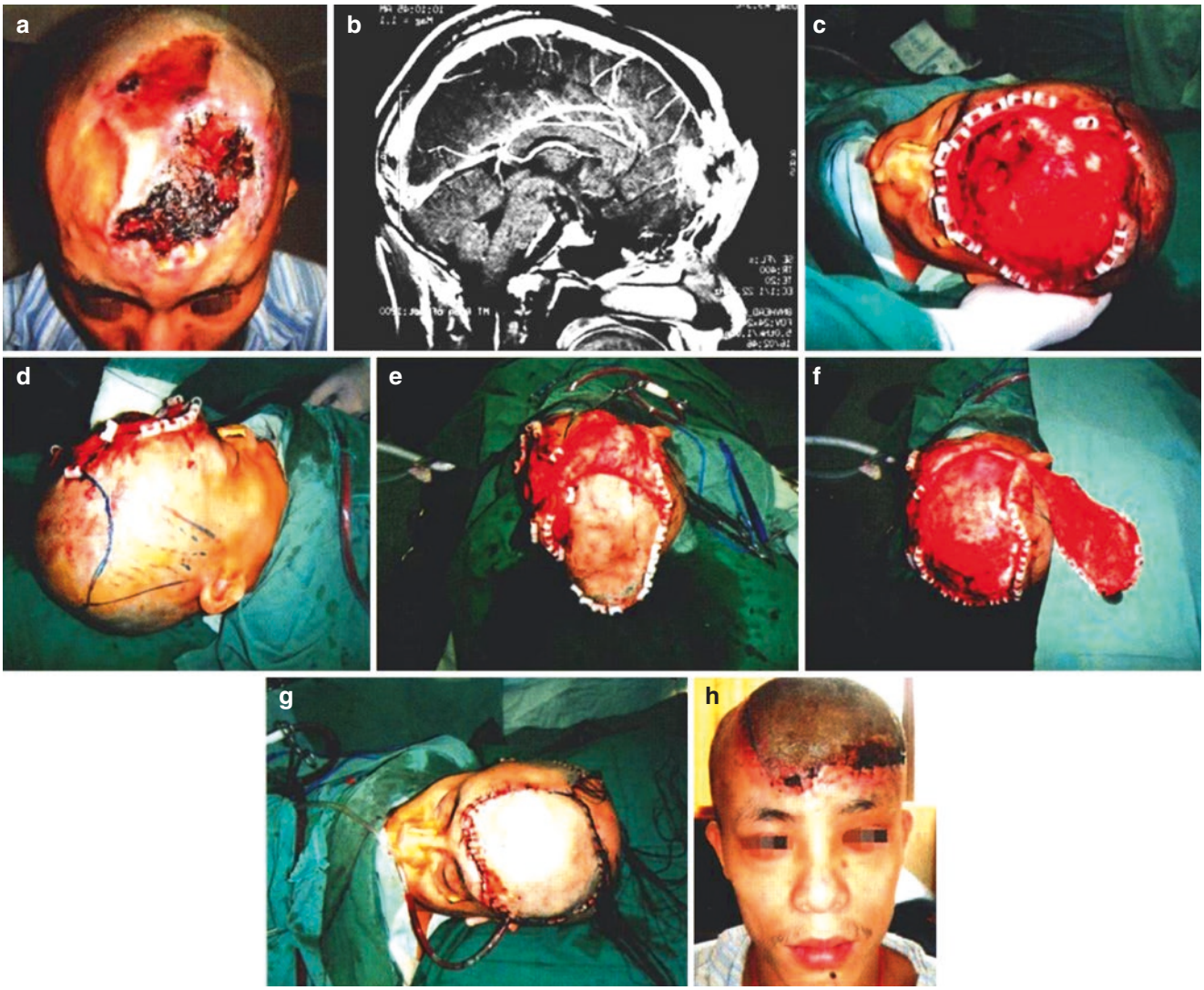

Fig. 12.1 Case I. (**a**) Before resection of frontoparietal squamous cell carcinoma. (**b**) CT showed that the tumor had invaded the full-thickness skull and dura mater. (**c**) The cancerated tissues in the frontoparietal area were extensively resected, while the skull which had been violated and destructed was resected. (**d**) The scalp flap pedicled with right superficial temporal vessels was designed. (**e**) The temporal superficial fascia tissue of sufficient width was retained around the superficial temporal vessels to form into a wider vascular pedicle with subcutaneous fascia. (**f**) The scalp flap pedicled with right superficial temporal vessels was harvested. (**g**) The pedicled scalp flap was transferred to repair frontoparietal scalp defect. (**h**) At the second month after surgery

2.3.2 Advancement of Scalp Flap

The advancement of scalp flap is most commonly applied to the repair of scalp defects located in hairline. The transposed scalp flap contains the well-known blood vessels of the scalp, and the area of the scalp flap is not limited to length-to-width ratio, so it belongs to the axial skin flap. The typical transposition of frontoparietal scalp flap supplied blood by the branch of the superficial temporal vessel can repair the scalp defects at the hairlines in the frontal and temporal area, and the length can reach the contralateral region. In the patients with larger scalp defects at the hairlines, the scalp defect can be repaired by advancement of bilateral temporoparietal scalp flaps, and the donor site of scalp flap can be closed directly or through skin graft [1].

3 Repair of Complex Scalp Defects

3.1 Repair Method

When the malignant tumor locally spreads and invades the deep exocranium or skull, the scope of the tumor resection

should be extended to various layers of tissues of the invaded skull, including full-thickness scalp, periosteum and skull, and even the dura mater. It is a more serious complex scalp and skull defects in clinic; the surgery must repair simultaneously defects in dura mater, skull, and scalp to effectively protect the exposed meninges and brain tissue. Repairing the defect wounds in skull and scalp at an early stage is one of the objectives pursued by modern plastic and reconstructive surgery. The commonest dura mater repair usually included the autologous fascia lata graft and the artificial meninges and allogeneic dura mater. Among the materials for repairing the skull defects, in addition to bone tissue such as autologous rib, the biological materials such as titanium alloy grid and Medpor are often used as the alternative materials for skull. These materials should have good biocompatibility as well as reliable hardness and plasticity, and the hardness of the skull can effectively protect the brain and have aesthetic skull appearance. When repairing the skull defects, Plastic surgeons transplant simultaneously the soft tissue flaps with good blood supply to cover the reconstructed skull. These soft tissue flaps can be derived through the abovementioned local scalp flap transfer, or the repair is carried out with free flap transplantation by microsurgical technique. The trapezius myocutaneous flap, free latissimus dorsi myocutaneous flap, and anterolateral thigh flap are often used in clinic. If the range of the scalp defect is too large and the donor site of harvested free skin flap is too broad to be directly sutured, the donor site must be covered by skin graft. However, the skin graft will increase a new wound in skin harvesting area and extend the healing time. In this case, the skin flap in donor site can be designed into 2–3 skin flaps according to the different perforator vessels, and the skin flaps after harvesting are joined together to repair the wound; therefore, the donor site could be closed and sutured directly, which minimizes the damage to the donor site [2–4].

3.2 Typical Case

1. Case II. The patient, female, 52 years old, was admitted into the hospital because of recurrence of the parietooccipital scalp leiomyosarcoma at the third month after surgery. The preoperative examination showed that there was a skin graft area slightly on the right side of the parietooccipital area. There were several nodular masses with local skin ulceration in the center of transplanted skin graft, and the whole skin graft was closely adhered to the deep periosteum without mobility. Preoperative examination found no tumor metastasis. The recurrent scalp tumor was extensively resected under general anesthesia, and the full-thickness scalp and periosteum were removed by extending 2 cm along the margin of the original skin transplantation area. During the removal process, the intraoperative frozen section examination was carried out by layers for various layers of removed tissues to guide the scope and layers of the removal. The results showed that the tumor tissue had invaded the meninges, and the removal of all tumor tissues led to defects in scalp and skull and dura mater. The exposed wound of brain tissue was 12 cm × 12 cm. We harvested the latissimus dorsi muscular flap and part of serratus anterior muscle fascia for free transfer to cover the brain tissue, harvested the femoral fascia lata to repair the dura mater defect, used the Medpor biological materials to repair the skull defects, carried out the microvascular transplantation of free latissimus dorsi muscle flap to cover the Medpor, and finally carried out the free transplantation of split-thickness skin graft to repair the scalp wound on the transplanted latissimus dorsi muscle. The body of the patient recovered well after surgery, and the wound healed at the first stage. The removed tissues were definitely diagnosed as leiomyosarcoma of the scalp by the paraffin pathological section examination, and the patient insisted on taking traditional Chinese medicine after surgery. After a four and a half years follow-up, the ulceration appeared at the original surgical site, and a mass was found at the right retroauricular area, which was resected and then was diagnosed as recurrence of scalp melanoma and lymph node metastasis by pathological examination. The patient and her family insisted on reoperation. It was intraoperatively found that the tumor tissue had invaded the original repair tissue, local brain tissue, and sagittal sinus, and all lesion tissues could not be removed completely. Therefore, the burning electric coagulation was performed for the involved tissues at the superficial surface of the brain tissue and sagittal sinus, and the original repair tissue was removed, and then the transplantation of free latissimus dorsi myocutaneous flap was performed under microscopy to repair the scalp defect. The myocutaneous flap survived after surgery, but the inflammatory tissue oozed out under the flap continuously after surgery, and a prolonged unhealed chronic inflammatory sinus tract was formed; thus, only long-term dressing change could be performed to keep the wound clean and maintain smooth drainage under the flap (Fig. 12.2). The patient died of systemic tumor metastasis and multiple organ failure 1 year after surgery.
2. Case III. The patient, female, 43 years old, was admitted into the hospital because of parietooccipital squamous cell carcinoma with ulcers for 7 years. The surgical extensive resection of tumor tissue was performed to remove part of the skull and meningeal tissue, and a wound of about 12 cm × 12 cm was exposed. The double-lobe

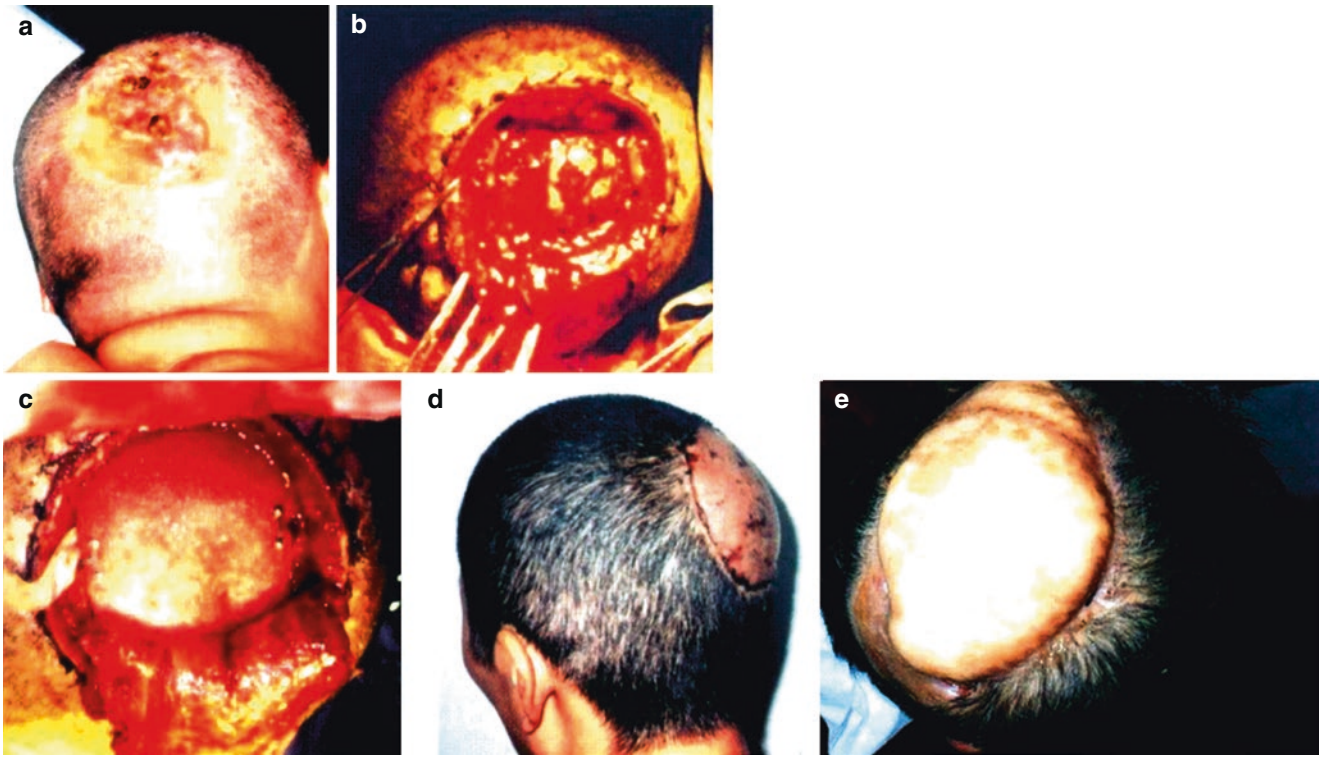

Fig. 12.2 Case II. (**a**) Three months after resection of the parietooccipital scalp leiomyosarcoma, there were several nodular masses with local skin ulceration in the center of grafted skin slightly on the right side of the parietooccipital area, and the whole skin graft was closely adhered to the deep periosteum without mobility. (**b**) The scalp tumor was extensively resected; a scalp, skull, and dura mater complex defect was formed; and the exposed wound of brain tissue was 12 cm × 12 cm. (**c**) The femoral fascia lata was resected to repair the dura mater defect; the Medpor biological materials was used to repair the skull defects, and the titanium plate fixation was carried out. (**d**) The free latissimus dorsi muscle flap was transplanted to cover the Medpor, and then the skin graft was performed on the latissimus dorsi muscle. The wound healed at the first stage after surgery. (**e**) Four and a half years after surgery, the ulceration appeared at the original surgical site, and the tumor recurred; thus the reoperation was performed, and the transplantation of free latissimus dorsi myocutaneous flap was performed under microscopy to repair the scalp defect. The myocutaneous flap survived after surgery, and a prolonged unhealed chronic inflammatory sinus tract formed under the flap

latissimus dorsi myocutaneous flap was used for repair. The latissimus dorsi myocutaneous flap with double lobes of respective 12 cm × 6 cm and 12 cm × 6 cm was designed on the right side of the back according to the tension of the skin. The double lobes of the skin flap were connected with each other by the deep latissimus dorsi muscle, and a certain width was maintained to ensure the blood supply to the distal end of the skin flap. During harvesting, it was noted that the skin flap and its underneath muscle were not dissociated excessively to avoid affecting the blood supply to the top end of the skin flap. After harvesting, the double-lobe flaps were rotated and jointed into a large flap to be transferred onto the head, and the thoracodorsal blood vessels were anastomosed with right superficial temporal artery and vein. This design can make the donor site of the back be closed and sutured directly, and all skin flaps survived after surgery, and the donor site healed well (Fig. 12.3).

3. Case IV. The patient, female, 16 years old, had a prolonged unhealed chronic scarring ulcer in parietooccipital area for 13 years. The pathological examination at admission showed squamous cell carcinoma. The surgical extensive resection of the tumor tissue was performed to remove part of the skull and meningeal tissue and expose the wound of about 17 cm × 19 cm. The three lobe latissimus dorsi myocutaneous flap was used for repair. The latissimus dorsi myocutaneous flap with three lobes of respective 16 cm × 6.5 cm, 17 cm × 6 cm, and 16 cm × 6 cm was designed on the right side of the back according to the tension of the skin. The three lobe skin flaps were connected between each other by the deep latissimus dorsi muscle, and a certain width was maintained to ensure the blood supply to the distal end of the skin flap. During harvesting, it is noted that the skin flap and its underneath muscle were not dissociated excessively to avoid affecting the blood supply to the top end of the skin

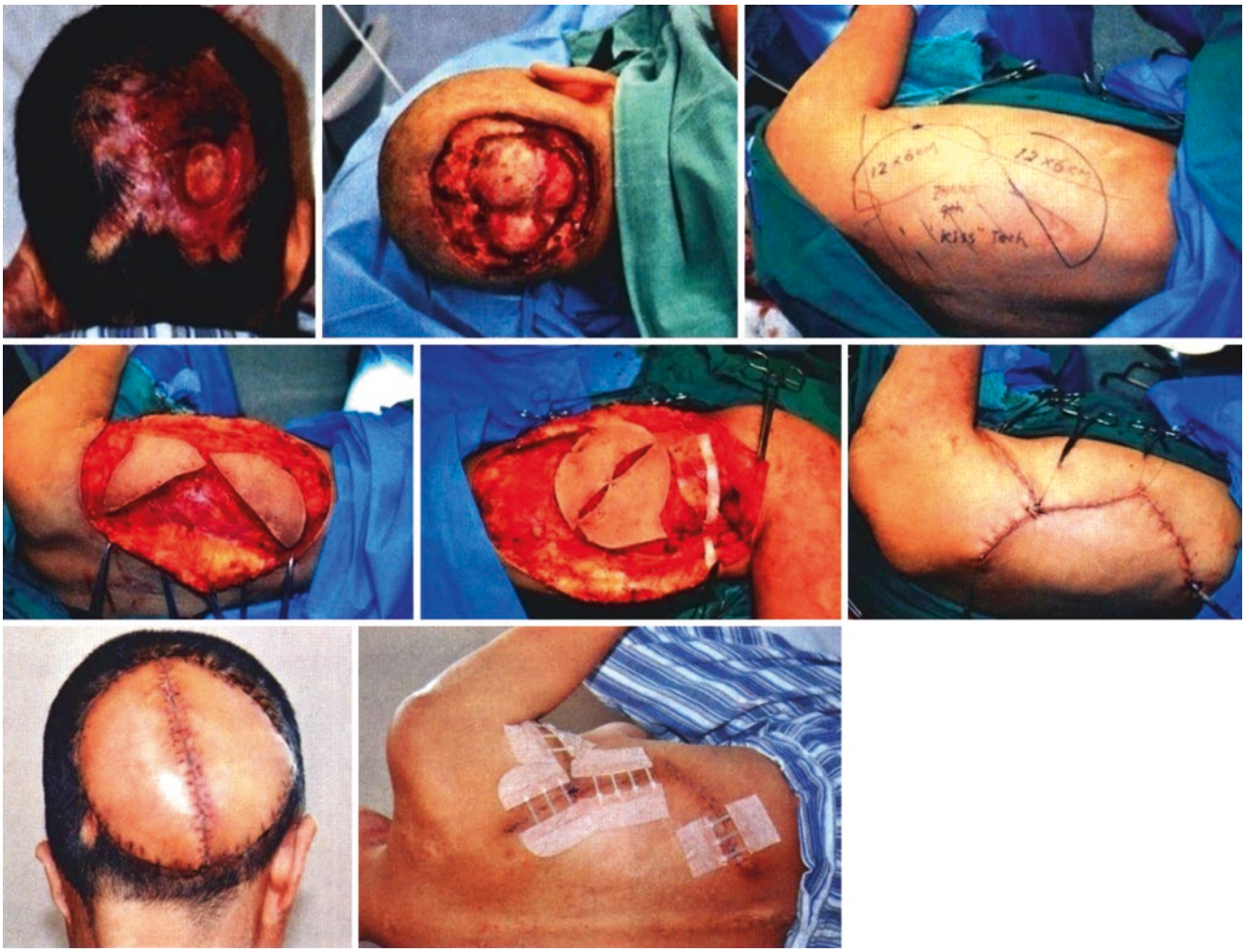

Fig. 12.3 Case III. (**a**) Before resection of parietooccipital squamous cell carcinoma. (**b**) The full-thickness scalp defects occurred during surgery. The defect of meninges was repaired with artificial meniux, and Medpor material was used to repair the skull defects. (**c**) The double-lobe latissimus dorsi myocutaneous flap was designed. (**d**) The double-lobe latissimus dorsi myocutaneous flap was prepared. (**e**) The latissimus dorsi myocutaneous flap with double lobes was jointed into a large flap. (**f**) The donor site was directly closed and sutured. (**g**) Two months after surgery, the skin flap in scalp defect area healed well. (**h**) The donor site of latissimus dorsi myocutaneous flap healed well

flap. After harvesting, the three lobe skin flaps were rotated and jointed into a large flap to be transferred onto the head; the thoracodorsal blood vessels were anastomosed with right superficial temporal artery and vein. This design can make the donor site of the back be closed and sutured directly, and all skin flaps survived after surgery (Fig. 12.4).

4. Case V. The patient, male, 67 years old, was admitted into the hospital because of exposed skull and prolonged unhealed ulcer on the edge of the scalp 1 year after resection of scalp squamous cell carcinomas. Pathological biopsy: highly differentiated squamous cell carcinoma. The patient underwent extensive resection of scalp cancer and full-thickness resection of part of skull. The titanium mesh was used to repair skull defects, and the anterolateral thigh flap was designed, and then the blood vessels were anastomosed with the right superficial temporal vessel, and finally the free transplantation was performed to repair the scalp defect (Fig. 12.5).

All surgical photographs published in this chapter have been approved by the patients themselves.

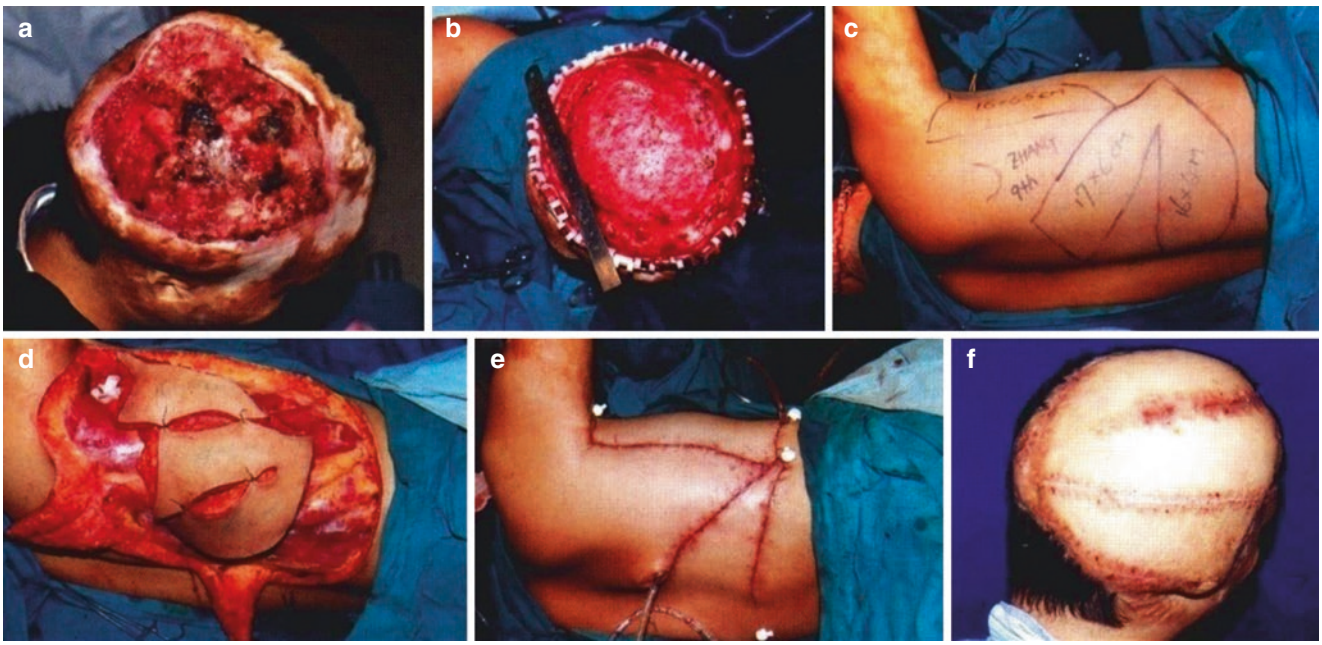

Fig. 12.4 Case IV. (**a**) Before resection of parietooccipital chronic scarring ulcer. (**b**) The intraoperative defect in scalp, skull, and meningeal tissues. (**c**) The three lobe latissimus dorsi myocutaneous flap was designed. (**d**) The latissimus dorsi myocutaneous flap was prepared, and the latissimus dorsi myocutaneous flap with three lobes was jointed into a skin flap. (**e**) The donor site of latissimus dorsi myocutaneous flap was directly closed and sutured. (**f**) Two months after surgery, the skin flap in scalp defect area healed well

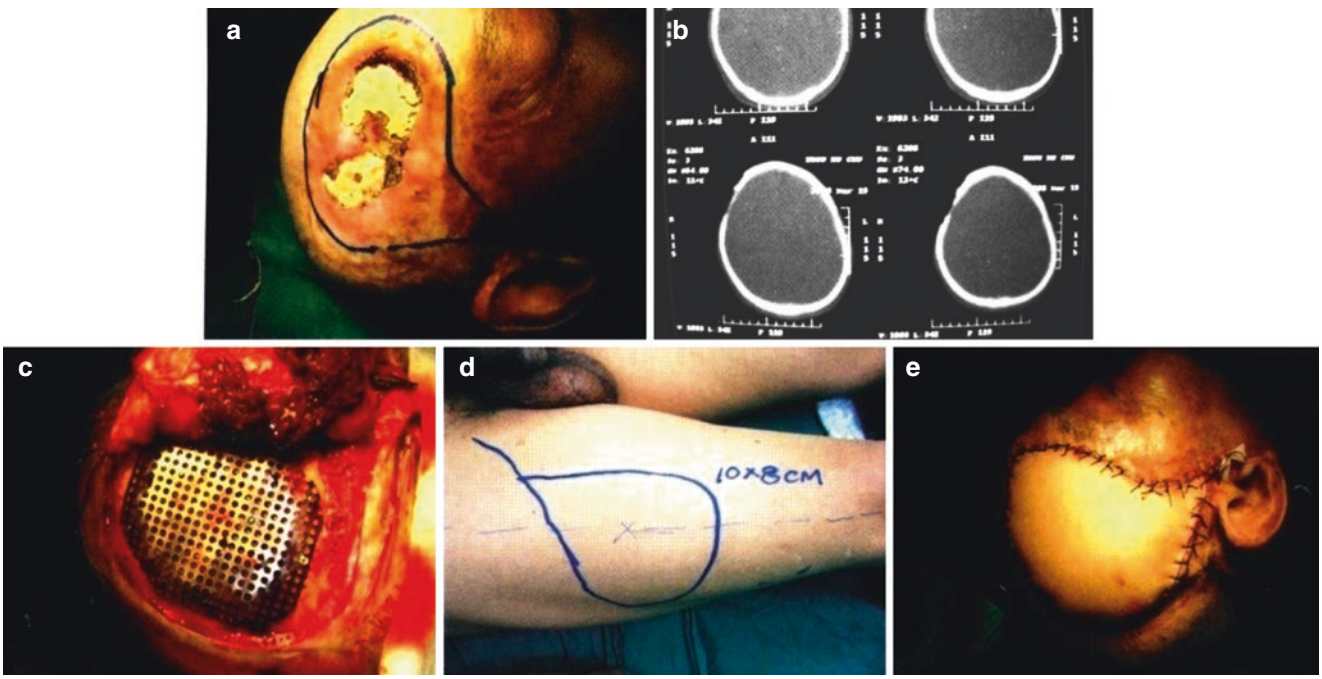

Fig. 12.5 Case V. (**a**) One year after resection of scalp squamous cell carcinomas, the skull was exposed, and there was prolonged unhealed ulcer on the edge of the scalp. (**b**) CT showed full-thickness defect in the skull. (**c**) The scalp cancer was extensively resected, and the skull defects after full-thickness resection were repaired with titanium mesh, and then the titanium screw fixation was performed. (**d**) The right anterolateral thigh flap was harvested. (**e**) The right anterolateral thigh flap was used to repair the scalp defect, and the blood vessels of the skin flap were anastomosed with the right superficial temporal artery and vein

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Repair and Reconstruction of Cranial and Maxillofacial Defects

13

Jian Sun and Yi Shen

1 Overview

In the early 1960s, when the combined craniomaxillofacial resection was carried out for the defects in the skull base and craniomaxillofacial area left after the combined craniomaxillofacial resection, such as exposure or defects of the dura mater, the researchers represented by Ketcham et al. [1, 2] (1963, 1966) adopted the method of direct closure and suture or free skin graft transplantation. The survival rate after free skin graft transplantation is low, and the cerebrospinal fluid leakage easily occurs. The severe cases can lead to intracranial infection and even be life-threatening. According to the report of Ketcham et al. [2] (1966), after repair of dura mater defect with free skin graft transplantation, both the incidence and mortality rates of the cerebrospinal fluid leakage are high. Whereafter, the adjacent local tissue flaps such as forehead flap, temporal muscle flap, and a variety of skull flaps are used to repair a variety of cranial base defects. Although the success rate of repair of skull base or craniomaxillofacial defects with the adjacent local tissue flaps is high, only small- and medium-sized defects can be repaired because of limited tissue volume [3]. For example, the total forehead flap was used to reconstruct the skull base defect in 13 patients in our department. Although the skull base defects had been repaired well, multiple patients had concurrent skull osteomyelitis due to necrosis of skin graft or partial skin flap after the new wound resulting from transfer of forehead flap was repaired with free skin graft or scalp flap. Moreover, the repair effect of reconstruction of middle skull base defect with the forehead flap was not good, and it was difficult to completely cover the defect [4]. In the 1970s, the regional tissue flaps such as pedicled pectoralis major myocutaneous flap, latissimus dorsi myocutaneous flap, and trapezius myocutaneous flap were used to repair large skull base or craniofacial defects, but due to restriction of the location of the pedicle, it was often difficult to completely transfer the regional tissue flap to cover the skull base defect; thus repair effect was not satisfactory [5, 6].

With the rise and development of microsurgery, since the 1980s, a variety of vascularized free tissue flap such as the latissimus dorsi myocutaneous flap, transverse rectus abdominis myocutaneous flap, and anterolateral thigh flap have been used to immediately repair large skull base or craniofacial defects and have achieved satisfactory results. The success in immediate repair of complex craniofacial defects effectively promotes further popularization and application of the combined craniomaxillofacial resection. For example, Neligan et al. from Toronto General Hospital of Canada (1996) published their more than 10 years of experiences in repairing different types of skull base defects in 90 patients. The article is considered to show the leading role of vascularized free tissue flap transplantation in repair of the large skull base defects or craniofacial complex defects, namely, the establishment of the modern concept of the skull base reconstruction. Their research showed that the overall complication rates of local tissue flap and free tissue flap were 38.8% and 33.5%, respectively, while the overall complication rates of regional tissue flap were as high as 75%; compared with the regional tissue flap, the main advantages of free tissue flap lie in aspects such as the primary healing wound rate, the success rate of skin flap, and the incidence rates of cerebrospinal fluid leakage, meningitis, and abscess [6–8]. Sun Jian et al. [9] (2001) reported the experiences in the use of 32 vascularized free tissue flaps to repair 25 cases of skull base defects after radical resection of malignant tumors in our department from 1980 to 1999. The success rate of free tissue flap was 93.8%. In addition to that, one patient died of acute cerebral edema, no other serious complications occurred, and the qualities of life were effectively improved. Thus, it can be seen, the medium and small skull base defects should be repaired preferably selecting the adjacent local tissue flap, while the large skull base defects or complex craniofacial defects should be repaired using the vascularized free tissue flap. Currently, the

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functional reconstruction of large skull base defects or complex craniofacial defects has entered a completely new stage when the vascularized composite tissue flap combined with titanium mesh and biological implant materials such as Medpor as well as the planting technology and prosthesis technology is used to carry out three-dimensional repair, which greatly improves the quality of life after craniofacial tumor surgery. This chapter will briefly introduce the methods for repairing the defects of different craniomaxillofacial areas and different types and promote the concept that the selection of indications for combined craniomaxillofacial resection, defect repair methods, and donor sites should comprehensively consider the balance of the radical treatment of tumor with the postoperative function, survival rate, and quality of life [9–11].

2 The Scope and Classification of Defects After Resection of Cranial and Maxillofacial Tumors

After the skull base tumors or craniomaxillofacial tumors are treated with combined craniomaxillofacial radical resection, since the scope of surgery is broader, multiple organs and different anatomical regions are often involved, which will lead to combined multiple organ defects or complex tissue defects of diverse ranges including the brain parenchyma, dura mater, skull base, mucosa, muscle, and skin. If the defects are not promptly repaired, on one hand, this can lead to huge craniofacial deformities and dysfunction; on the other hand, if the dura mater is exposed to sinus cavities such as the pharyngonasal cavity, oral cavity, or paranasal sinuses, severe complications such as meningitis and encephalitis will occur, which even endanger the lives of patients.

In short, these are the following main difficulties in repair and reconstruction of defects after craniomaxillofacial tumor surgery:

1. The volume of defected tissue is large, and the range is large.
2. The anatomical structure of the defected site is extremely complex and is closely related to the life-threatening blood vessels.
3. The scope of surgery includes a variety of sinus cavity structure, and it is a polluting surgery.
4. There is a lack of available adjacent tissue material for repair.
5. There exists the possibility of the occurrence of recessive dead space and cerebrospinal fluid leakage.
6. The local infections can lead to fatal intracranial infection.
7. The defect area has poor tissue condition due to radiation and/or multiple surgeries.

Therefore, the reconstruction of defects after craniomaxillofacial tumor surgery is a challenge with complex technology and significant risk.

2.1 The Partition of the Skull Base

In order to clarify the location and scope of the lesion and correctly select the surgical approach, it is necessary to partition the skull base. If the bony plate of the skull base is taken as the boundary, the skull base can be divided into intracranial and extracranial skull bases, which are also called the upper surface of the skull base and the lower surface of the skull base. At present, most scholars agree with the partitioning method proposed by Irish et al. [5] that the intracranial skull base is divided into three regions (Fig. 13.1), of which, region I is the anterior cranial fossa, region II is the middle cranial fossa, and region III is the posterior cranial fossa. The partitioning method for the extracranial skull base is not yet fully unified. Krespi et al. [3] (1984) drew a sagittal line respectively at the sites where bilateral internal carotid arteries cross the petrous parts of temporal bones and divided the extracranial skull base into the middle skull base in the middle part and the lateral skull bases on the two sides (Fig. 13.2).

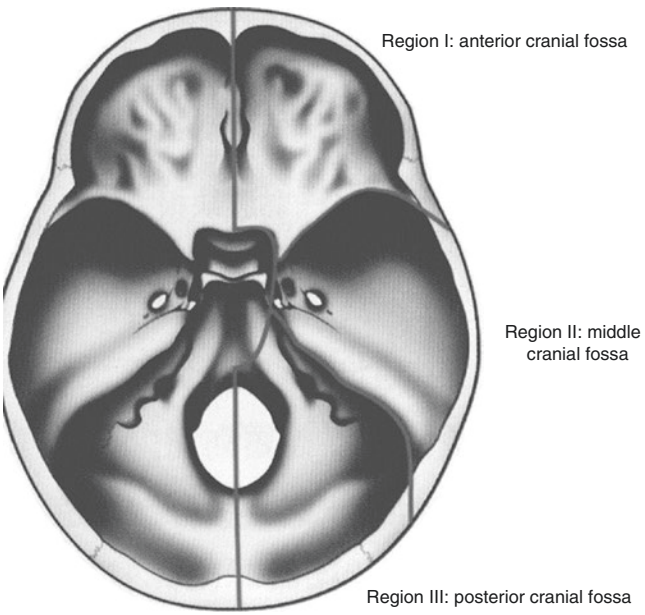

Fig. 13.1 Three-partition method for the upper surface of the skull base

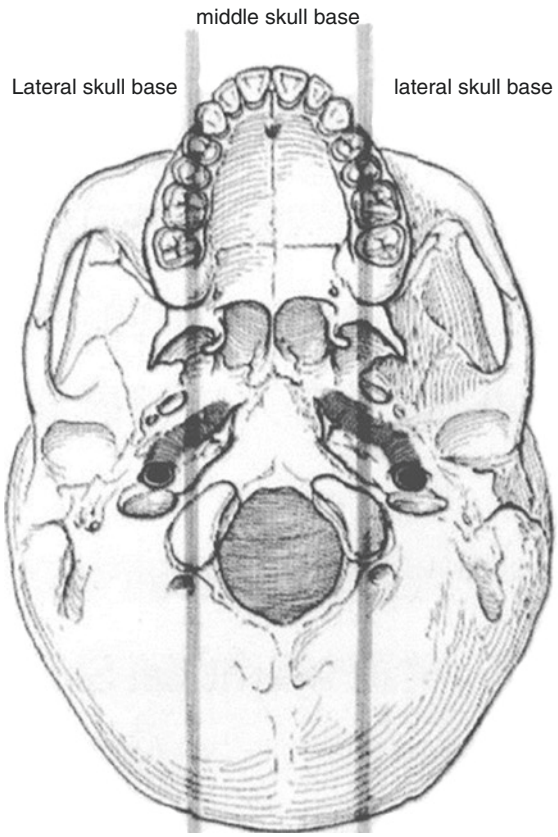

Fig. 13.2 Krespi partitioning method for the lower surface of the skull base

2.2 The Range of the Defects After Craniomaxillofacial Tumor Surgery

As mentioned above, the defects after craniomaxillofacial tumor surgery often include a diverse range of complex tissue defects. Thinking from different perspectives, the contents included in complex tissue defects also differ to some extent. In terms of tissue types, the defects after craniomaxillofacial tumor surgery may include parenchymal defect, the dura mater defect of the skull base, the bone structure defects of the skull base, craniomaxillofacial bone defect, defect of the upper respiratory tract mucosa, intraoral mucosal defect, and skin and soft tissue defect, and the defects after craniomaxillofacial tumor surgery are often the complex defects consisting of abovementioned different tissue types. From the perspective of coronal position, the craniomaxillofacial area can be divided into different anatomical areas such as frontal area, temporal area, orbital area, zygomatic area, suborbital area, nasal area, and lateral facial area, and the defects after craniomaxillofacial tumor surgery are often the complex defects involving multiple areas among abovementioned areas. From the perspective of the skull base partition, the anterior cranial fossa defects can include the dura mater, skull base bone, orbital contents, nose, maxilla, and palate; the middle cranial fossa defects can include the dura mater, skull base bone, maxillary bone, soft tissues in preauricular area and the parotid area, mandible, external ear, and temporal bone, and the posterior cranial fossa defects can include the dura mater, skull base bone, occipital bone, retroauricular soft tissue, external ear, and temporal bone. The defects after craniomaxillofacial tumor surgery are often the complex defects consisting of different areas among abovementioned partitions.

2.3 Classification of the Defects After Craniomaxillofacial Tumor Surgery

Because the defects after craniomaxillofacial tumor surgery are more complicated with a wider range, currently, there are rare classifications for the defects after craniomaxillofacial tumor surgery at home and abroad. The vast majority of the literatures are based on the partitions of the intracranial or extracranial skull base to assess the defects after craniomaxillofacial tumor surgery. Since the partitioning methods for the extracranial skull base have not been unified, the use of the method according to the partitions of the skull base to classify the defects after craniomaxillofacial tumor surgery will lead to confusion in the classification of the defects after craniomaxillofacial tumor surgery, which is not conducive to selecting the appropriate repair method and comparatively analyzing the curative effects and survival parameters of different data. Furthermore, the partitioning method of the skull base usually does not include the anatomical structures adjacent to the skull base such as the brain, orbit, nasal cavity, paranasal sinuses, and upper and lower jaw bones, which actually has certain differences with the clinical practice. American Memorial Sloan Kettering Cancer Center (2007), depending on different scopes of the defects after craniomaxillofacial tumor surgery, presented a relatively simple classification method for the defects after craniomaxillofacial tumor surgery (Fig. 13.3). They divided the upper surface of the skull base into two parts of anterior cranial fossa and middle cranial fossa in a horizontal direction at first, and then the defects in anterior cranial fossa are divided into three types of lateral defect, central defect, and anterolateral defect. In the coronal direction, any type of anterior cranial fossa and middle cranial fossa defects can include one or several anatomical defects among the nasal cavity, maxilla,

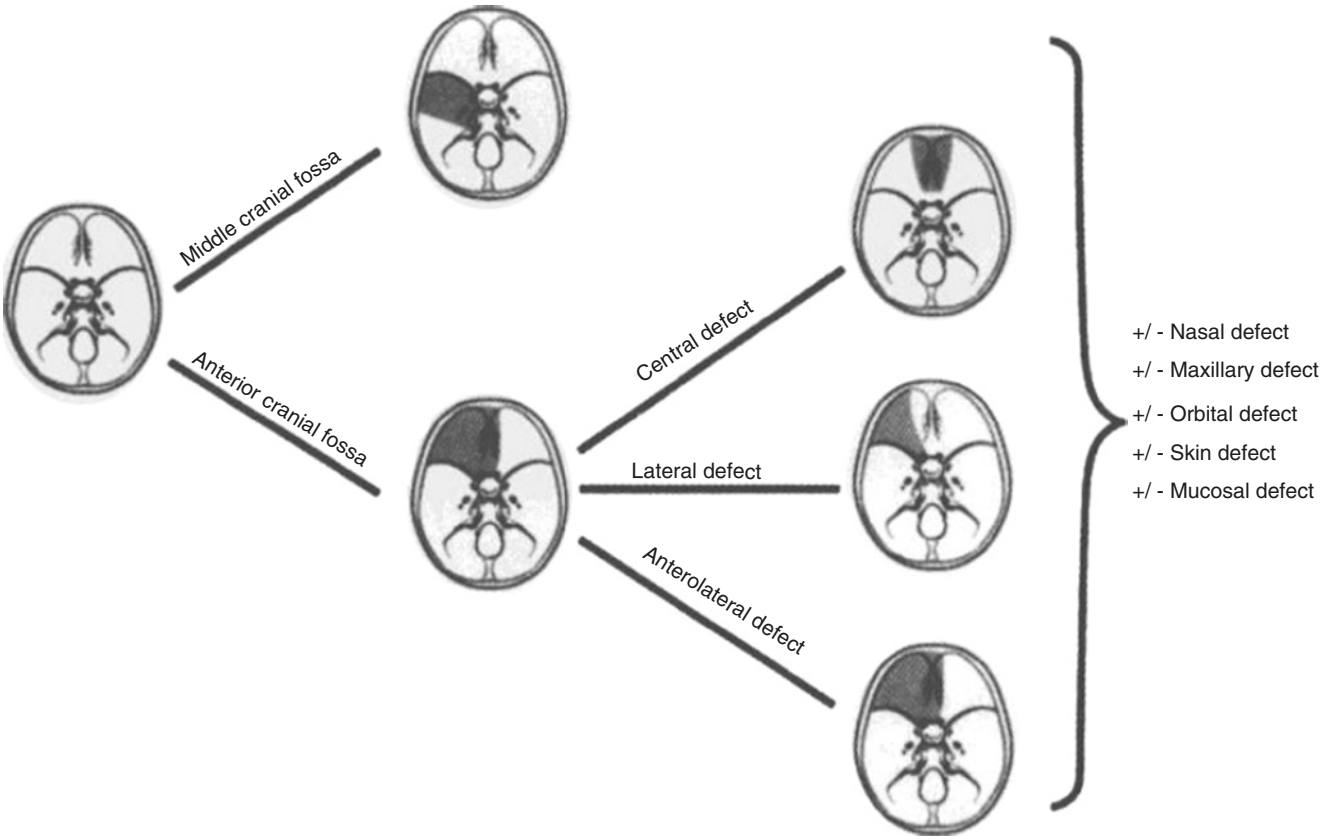

Fig. 13.3 Classification method for the defects after craniomaxillofacial tumor surgery of the American Memorial Sloan Kettering Cancer Center

orbit, mandible, skin, and mucous membrane. The classification method is relatively simple, but the defects of tissues such as the posterior cranial fossa and the adjacent external ear and parotid gland are not taken into account.

3 Functional Reconstruction of Defects After Resection of Cranial and Maxillofacial Tumors

No matter in the past or present, all treatments of craniomaxillofacial tumors attach great emphasis to the thoroughness of the first treatment, and the concepts of en bloc resection or block resection, super-radical surgery or extended radical surgery, as well as the surgical methods such as combined craniomaxillofacial resection, carotid artery resection, and total tongue – total throat resection – successively appear. However, on the one hand, the abovementioned super-radical surgery or extended radical surgery provides a certain guarantee for the thoroughness of the surgery; on the other hand, it leads to the loss of a large amount of craniomaxillofacial and cervical tissues, secondary deformity, and disability, thus severely affecting the quality of life of patients. With the progress of technology and the improvement of malignant tumor cure rate, at the same time of pursuing the cure of the tumors, both doctors and patients are also eager to restore the original appearance and function, and the change in concepts promotes the development of resection and the repair and reconstruction of craniomaxillofacial tumors. The functional reconstruction of defects after craniomaxillofacial tumor surgery is to carry out immediate or delayed reconstruction of craniomaxillofacial tissue defects or organ loss due to tumor resection, so as to achieve the purpose of restoring the function and appearance. The functional repair and reconstruction of defects after craniomaxillofacial tumor surgery are the emerging technologies which are developed on the basis of craniomaxillofacial oncological surgery and are the results of the rapid development of reconstructive surgical techniques, extensive application of medical biological materials, and especially the application of microsurgical techniques and dental implant surgical technique combined with oncological surgical techniques. With the development of perforator skin flap, fascia skin flap, and sensory skin flap as well as the application of materials such as absorbable reconstruction plate, screws, and implants, the modern concepts on repair and reconstruction require the reconstruction surgeons to carry out individualized repair and reconstruction which are tailored and varied with each individual with minimal tissue damages and complications, so as to maximize the recovery of the appearance and function of the

craniomaxillofacial area and improve the quality of life of patients. This section will introduce the repair and reconstruction of defects after craniomaxillofacial tumor surgery with different ranges and different types.

3.1 Advantages and Objectives of Functional Reconstruction of Defects After Craniomaxillofacial Tumor Surgery

Since the end of the twentieth century, especially in the last 10 years, the immediate repair and reconstruction of defects after craniomaxillofacial tumor surgery have become the mainstream and preferred surgical method, which is due to that the immediate repair and reconstruction have more advantages.

3.1.1 Advantages of the Immediate Repair and Reconstruction of Defects After Craniomaxillofacial Tumor Surgery

1. The immediate repair and reconstruction of defects are conducive to protecting important exposed tissues or organs, such as the carotid artery and brain tissue, so as to reduce the incidence of postoperative complications.
2. The basic anatomic structure and morphology can be recovered early in patients, which contributes to early implementation of other subsequent combination therapy and early recovery of physiological functions.
3. It is beneficial to the rehabilitation of patients after surgery to eliminate or reduce the psychological and psychiatric injuries of the patients due to residual defects.
4. It can save medical resources and medical costs.

3.1.2 Objectives of Repair and Reconstruction of Defects After Craniomaxillofacial Tumor Surgery

For different types of defects after craniomaxillofacial tumor surgery, their objectives of repair and reconstruction are also not the same. In terms of small defect of the cerebral tissue, its objectives of repair and reconstruction are to restore anatomically the integrity of the cranial cavity and the structures which maintain the normal intracranial pressure and prevent the brain and its nerves and bloods as the vital center of the human body from suffering the physical traumas (mechanical trauma, freezing, hyperthermia, and ionizing radiation), chemical damage, and microbial attack. In terms of a wide range of complex craniomaxillofacial defect, its objectives of repair and reconstruction are as follows:

1. To repair the defect or cover the exposed dura mater and prevent the brain tissue exposure, cerebrospinal fluid leakage, retrograde intracranial infection, and cerebral herniation.
2. To support the brain tissue and eyeballs and periorbital tissues. The skull defects due to surgery may cause serious complications such as encephalocele and epilepsy as well as exophthalmos and enophthalmos in patients. Therefore, properly repairing the skull and its subsidiary structure to restore the normal anatomical structure of the cranial cavity as far as possible in this type of surgery has very important significances for preventing the complications after craniomaxillofacial tumor surgery and ensuring the success of the operation.
3. To separate traffic between the brain tissue and oronasal cavities, provide sufficient tissue to fill the dead space, and restore the nasal and oral mucosal lining as far as possible.
4. To reconstruct the orbital, nasal, and oropharyngeal cavities and reconstruct the three-dimension morphology and function of craniomaxillofacial bones and soft tissues. From the perspective of aesthetic form, the skull is the basis to construct the contour of the upper face. For the skull defects due to surgical resection, the accurate and appropriate repair not only creates an anatomical basis for reshaping the craniofacial appearance but also plays a very important role in the remodeling the self-confidences and social psychologies of the patients and improving their quality of life.

3.2 The Principles for Functional Reconstruction of Defects After Craniomaxillofacial Tumor Surgery

Because the defects after craniomaxillofacial tumor surgery are mostly the complex defects comprising of different types of tissues and different anatomical structures, different types of tissues have their own reconstruction principles. For example, the principles for repair of dura mater defect are that the dura mater sac is completely closed without cerebrospinal fluid leakage, the repaired tissues have strong anti-infection ability and no rejection reaction, and the adhesion between the cerebral cortex and the repaired tissues is reduced, while the repair of skull base defects should primarily focus on the coverage and protection of the dura mater to reduce the chance of meningeal and intracranial infections. Therefore, the principle for skull defect reconstruction is to basically restore the integrity of the bony cranial cavity, isolate and prevent the infection of extracranial source, and reconstruct the shape of the skull. As for soft tissue defects, the appropriate repair method should be selected according to the scope of the defect. The medium and small skull base defects should be repaired preferably selecting the adjacent local tissue flap, and the large skull base defects or craniomaxillofacial complex defects should be repaired preferably

selecting revascularized free tissue flap. The indications for repair of craniomaxillofacial defects with revascularized free tissue flap are as follows: ① The massive soft tissue defect which must be repaired. ② There is obvious dead space in the skull base. ③ Serious damages to maxillofacial anatomical morphology. ④ The defects in the temporal fossa, infratemporal fossa, parotid bed, and midface region. ⑤ Carotid artery exposure. ⑥ The patients have previous history of radiotherapy or craniofacial surgery.

Currently, the method of carrying out hard tissue reconstruction for skull defect in the same period remains controversial. Domestic and foreign scholars believe that the skull defects which are less than 4 cm^2 can be filled with myoplasm and skin graft or repaired with pad or repaired with through transposition of nasal septum to get a good effect; the skull defects which are more than 4 cm^2 can be repaired with the free temporal bone and iliac bone; the harvested bone block is made into a wedge shape and embedded in the defect area at first and then is fixed with thick silk or knot tying silk. And then the pre-prepared split-thickness skin graft is lined on the nasal surface of the skull base after the bone is fixed, which is greater than the bone defect by 1–2 cm^2, and subsequently the iodoform strip is packed in its underneath to prevent slippage or untight fitting; thus such three layers of materials form a sandwich-like artificial skull base to get a good effect. The advantage of the abovementioned repair method is simple, but it only applies to patients with tumors that primarily occurred in the ethmoidal sinus in which the partial maxilla (frontal sinus) is resected and most of the maxilla exists, which can play a good role in supporting the repaired tissues. If a wide range of complex defects after craniomaxillofacial tumor surgery are repaired with free bone and free skin graft transplantation, this will easily lead to necrosis, falling off, and failure of the repaired tissues.

1. Imola et al. [10] (2003) believed that the indications for repair of the defects after craniomaxillofacial tumor surgery with bone tissue are as follows: ① The large defect in the bone of the skull base which leads to brain herniation. ② The near-total or total orbital roof defect which can lead to exophthalmos. ③ The lateral orbital wall or orbital floor defect which can lead to exophthalmos. ④ The cranio-orbital defects which lack adequate soft tissue support or generated craniofacial deformities. ⑤ The defects in the maxilla, mandible, and the glenoid fossa of the temporomandibular joint which cause facial deformities, occlusal disturbance, and chewing dysfunction
2. We consider that the indications for hard tissue reconstruction of skull defects in the same period are as follows [12]: ① The bony defect in skull vault ≥3.0 cm. ② The bony defect of the skull base ≥1.5 cm. ③ The bony defect of the skull base <1.5 cm but with dura mater defect, or there are larger dead spaces in epidural area. ④ The intracranial important neurovascular structures are exposed in the skull defect area, and the thickness of the skin and soft tissue is insufficient to protect their safety. ⑤ The important sites such as frontal orbit affect the appearance.

As for the materials for hard tissue reconstruction, the titanium mesh, nonvascularized bone grafts, or vascularized bone graft can be selected according to defect status.

3.3 The Influencing Factors on the Selection of Functional Reconstruction Methods for the Defects After Craniomaxillofacial Tumor Surgery

Imola et al. [10] (2003) considered that the influencing factors on the selection of functional reconstruction methods for the defects after craniomaxillofacial tumor surgery include: the size of the dura mater defect, the degree of openness between the cranial contents and the upper digestive tract (upper respiratory tract) (including the range of craniomaxillofacial skin, soft tissue, bone, and mucosa defects), whether the patients have preoperative radiotherapy or plan to have postoperative radiotherapy, whether the patients have local and systemic disease factors which affect the healing, and the reliability of local tissue to be used for repair.

3.3.1 Sizes of Dura Mater Defects

According the sizes of dura mater defects, the direct closure, repair with periosteum and muscular fascia, repair with artificial patch, repair with fascia, and composite repair with myocutaneous flap can be selected.

1. Direct closure. If the dura mater around the defect area has blood supply and strong anti-infection ability and the closed suture can be performed, then the direct suture is performed as far as possible.
2. Repair with the periosteum and muscular fascia. The pedicled periosteum or muscular fascia also has good repair and anti-infection abilities and is the good material for repair of the dura mater. Especially when the outer side is directly exposed to the sinus cavity and/or pharyngonasal cavity, it is the best way to repair the dura mater with double pedicled periostea. This method is mostly used for repair and reconstruction of the anterior skull base.
3. Repair with artificial patch. When no dural repair material can be harvested around the surgical field, the variant

[homogeneity and/or heterogeneity] and artificial patches have good histocompatibility and are easy to obtain, and this is a good choice.
4. Repair with fascia. The autograft fascia has good anti-infection ability but can increase the surgical trauma of the patient; if necessary, it is a good choice.
5. Composite repair with myocutaneous flap. The myocutaneous flap is a commonly used material for tissue repair, with strong anti-infection ability, but because the muscle tissue itself has electrical activity and muscular contraction and its direct contact with the brain cortex may stimulate the latter, which can cause seizures, it is not taken as the preferred material.

3.3.2 The Degree of Openness Between the Cranial Contents and the Upper Digestive Tract and/or Upper Respiratory Tract

The defects after craniomaxillofacial tumor surgery can be divided into types such as local defect, single defect, complex defect, and extensive defect according to the degree of openness between the cranial contents and the upper digestive tract and/or upper respiratory tract. The local defect refers to the unilateral skull base defect which is confined to a single anatomic site + skin and mucous membrane defects, such as unilateral orbital roof defect, middle skull base defect, and cribriform plate defect. The single defect refers to skull defect + soft tissue and skin and mucous membrane defects. The complex defect refers to the skull defect + dura mater defect + skin and mucous membrane defects. The extensive defect refers to the local skin and mucous membranes and soft tissue defects combined with bilateral skull base defects, or skull base defects simultaneously involving more than two areas such as anterior, middle, and posterior skull bases, or a skull base area but involving the midline structure, or skull base defects combined with the involvement of atlanto-occipital joint and cervical vertebra.

3.3.3 Whether the Patients Have Preoperative Radiotherapy or Plan to Have Postoperative Radiotherapy

For the patients with defects after craniomaxillofacial tumor surgery who have a history of preoperative radiotherapy or plan to have postoperative adjuvant radiotherapy, in order to ensure that the repair tissues have a reliable blood supply, the revascularized free tissue flaps should be selected to repair the defects. On the contrary, for the patients with medium and small defects after craniomaxillofacial benign tumor surgery which do not require adjuvant radiotherapy, the adjacent local tissue flaps or nonvascularized bone graft can be used for repair.

3.4 The Commonly Used Repair Methods for the Defects After Craniomaxillofacial Tumor Surgery

3.4.1 Repair of Dura Mater Defects

The autologous fascia or artificial patch is selected for repair according to the abovementioned principles for repair of dura mater defects and the sizes of the mater defects. If the tight suture still cannot reach the watertight, the tissue glue, free tissue, or pedicled tissue can be additionally used on the outside of the dura mater for sealing.

3.4.2 Repair of Skull Defects

The free or pedicled autologous bone (the iliac bone or skull is commonly used) can be selected as the repair materials, and currently the titanium mesh is mostly taken as the material for repair of the skull (base) bone. The latter material is easy to obtain and had good histocompatibility, whose rigidity and strength meet the requirements. It can be shaped and fixed at random, and especially it has basically no effect on the imageological examinations such as MRI. The main points of the surgery include two aspects: ① In order to ensure it to withstand stresses from intracranial and extracranial areas, respectively, the repair material should completely cover the defect site and is firmly fixed, and ② the repair material must be shaped in accordance with the original shape of the defect site, especially the site which directly affects the appearance and affects the function of surrounding tissues, such as orbit and temporomandibular joint fossa.

3.4.3 Repair of Skin and Soft Tissue Defect

The extensive and complex skull base defects are almost always accompanied by larger soft tissue defects, and therefore, closing the exposed dura mater, repairing the skull base structure, and repairing the skin, mucous membranes, and soft tissues are one of the most critical steps for the type of skull defects. Usually the repair with the revascularized free tissue flap is more obviously effective than other methods; when the abovementioned methods cannot be applied due to various factors (anatomical limitation and too large tissue defect), the adjacent pedicled periosteal flap or myofascial flap can be applied, or the multilayer composite structures simultaneously block the communications between the cranial cavity and body cavity in the epidural area and on the outside of the skull, supplemented by local packing with iodoform strip or free fatty tissue, in order to achieve the purpose of preventing the cerebrospinal fluid leakage and retrograde intracranial infection as well as supporting the partial skull base.

3.5 Typical Case

According to the abovementioned principles, the following article will introduce a typical case respectively for repair of the defects after craniomaxillofacial tumor surgery with the adjacent local tissue flap and the revascularized free tissue flap.

3.5.1 The Anterior Cranial Fossa Defect: Repair with Local Tissue Flap

Case I The patient, male, 56 years old, had recurrence after chemoradiotherapy after resection of the left maxillary, and the left ethmoidal sinus, orbit, and anterior cranial fossa were invaded. The patient underwent the combined craniomaxillofacial resection + orbital exenteration + temporal muscle flap + titanium plate reconstruction under general anesthesia.

1. The preoperative imaging showed the lesion statuses as in Fig. 13.4.
2. The patient underwent the combined craniomaxillofacial resection + orbital exenteration + temporal muscle flap + titanium plate reconstruction, and the surgical steps were as follows:
   (1) Designed the left temporal parietal coronary incision and Weber-Fergusson incision. Incised the scalp after injection of hemostyptic liquid medicine and used the scalp clip to stop bleeding. Turned up the tissue flap, then incised the temporal muscle attachment at the superior temporal line, then turned up the temporal muscle flap outwardly, and subsequently turned up the upper lip and buccal flap to expose the craniofacial frontal bone and temporal bone. Designed the bone windows in the left frontal bone and temporal bone. According to the design line, drilled open, sawed off and took down the frontal bone-temporal bone flap with the craniotomy drill and milling cutter drill. Then incised the dura mater and exposed the brain parenchyma (Fig. 13.5).

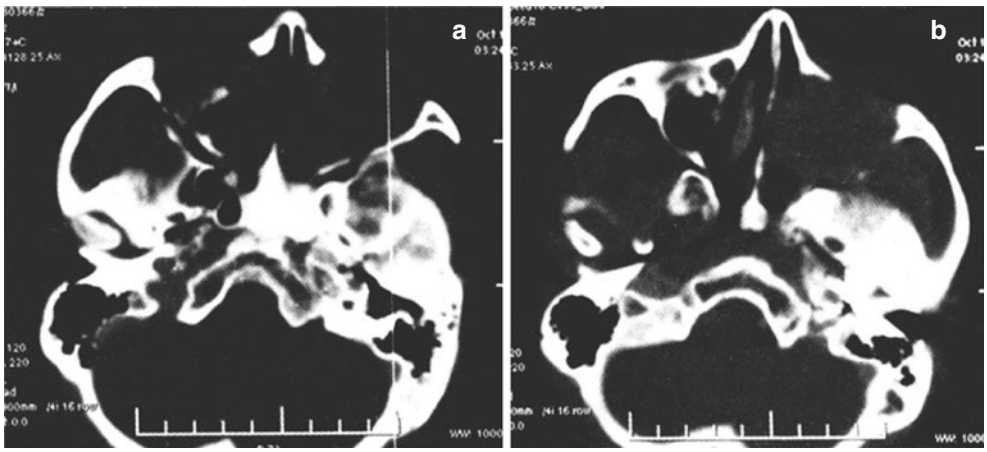

Fig. 13.4 Preoperative imaging (**a**) tumor invaded left ethmoidal sinus, orbit, and anterior cranial fossa (**b**) tumor invaded left maxillary sinus, nasal cavity, infratemporal fossa

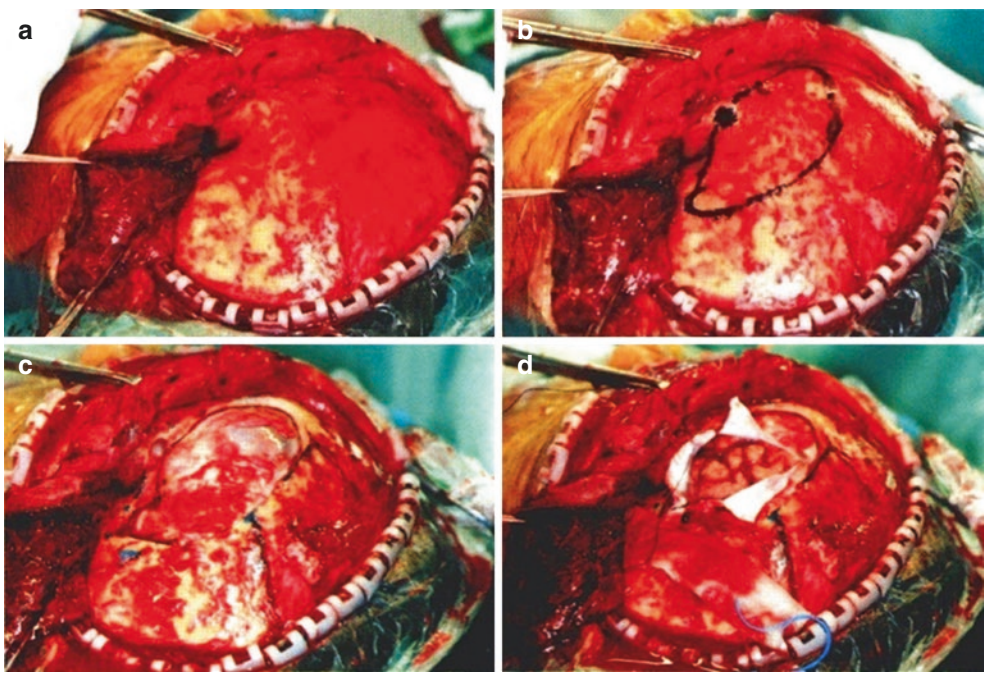

Fig. 13.5 Case I. Surgical step 1. (**a**, **b**) Exposed the left craniofacial frontal bone and temporal bone and made the bone windows in the left frontal bone and temporal bone. (**c**) Drilled open and took down the frontal bone – temporal bone flap – with the craniotomy drill and milling cutter drill. (**d**) Incised the dura mater to expose the brain parenchyma

(2) Incised the dura mater and then gently pulled open the frontal lobe of the brain and exposed and separated off the optic nerve. Then incised the Weber-Fergusson incision and turned up the upper lip and buccal flap outwardly to expose the left craniofacial frontal bone, temporal bone, malar and zygomatic arch, and maxilla (Fig. 13.6).

(3) Separated the brain tissue and the skull, performed osteotomy with a chainsaw from the maxillary alveolar process and the midline of palate, zygomatic arch midpoint, and the frontal bone above the nasofrontal suture, chiseled off the pterygomaxillary fissure with a bone chisel, ligated and cut off the optic nerve, and then removed the left maxilla, orbit and ocular contents, partial frontal bone, and sphenoid bone which contained the tumors (Fig. 13.7).

(4) The wound complete hemostasis was carried out, and the incised dura mater was put back into place and sutured. After the dura mater was suspended with 5-0 absorbable suture, the harvested frontal bone and temporal bone were put back into place and then were fixed with the skull fixator. The temporal muscle was harvested and transferred to fill the dead space in skull case. The full-thickness skin graft in

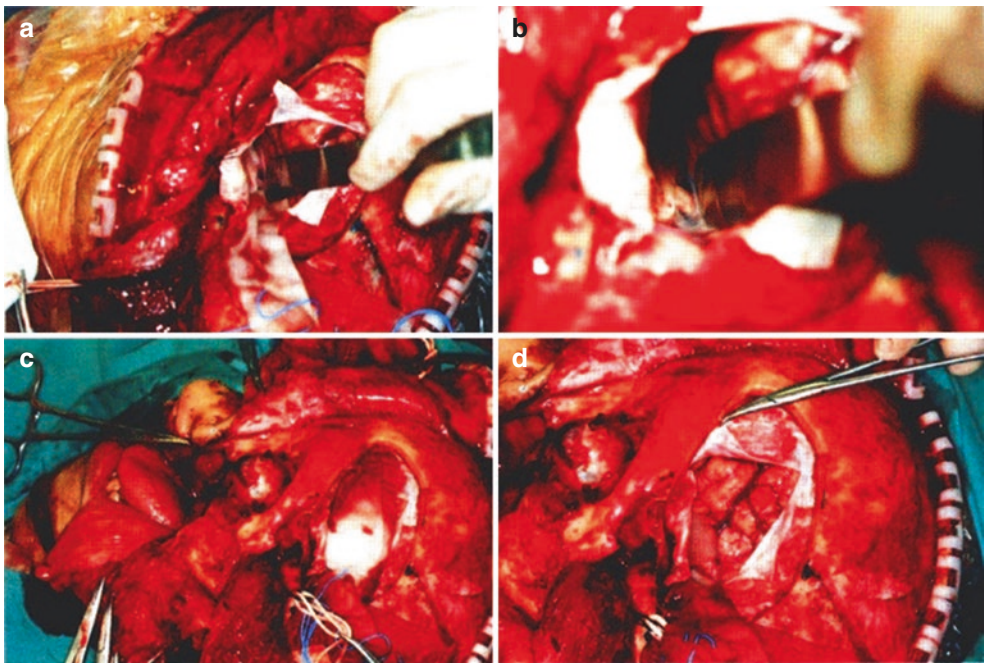

Fig. 13.6 Case I. Surgical step 2. (**a**) Pulled open the frontal lobe of the brain. (**b**) Exposed and separated off the optic nerve. (**c**) Incised the Weber-Fergusson incision again and turned up the upper lip and buccal flap outwardly. (**d**) Exposed the left craniofacial frontal bone, temporal bone, malar and zygomatic arch, and maxilla

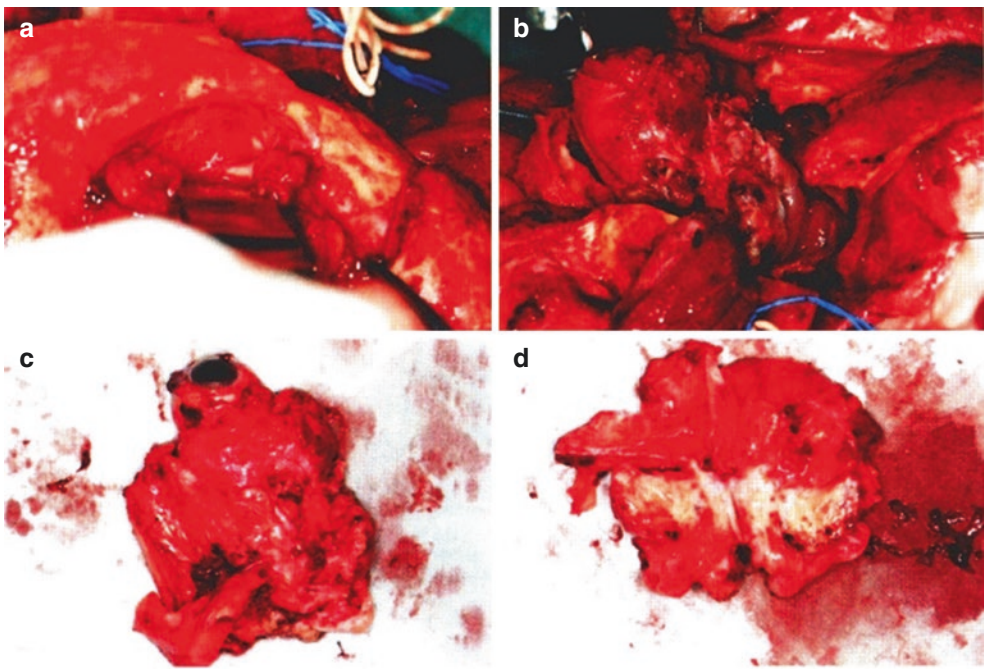

Fig. 13.7 Case I. Surgical step 3. (**a**) Ligated and cut off the optic nerve. (**b**) Removed the left maxilla, orbit and ocular contents, partial frontal bone, and sphenoid bone which contained the tumors. (**c**) The resected specimen. (**d**) Cross section of resected specimen

the lower abdomen was harvested to cover the surface of the masticatory muscle within the oral wound, and the iodoform strips and oil gauzes were used for tie-over dressing. The scalp flap and the buccolabial flap were put back into place and then sutured by layers, and a negative pressure drainage tube was placed (Fig. 13.8).

3.5.2 The Anterior Cranial Fossa Defect: Repair with Vascularized Tissue Flap

Case II The patient, female, 44 years old, had recurrence of left maxillary osteosarcoma after postoperative radiotherapy. The patient underwent the combined craniomaxillofacial resection + titanium mesh + the repair with latissimus dorsi myocutaneous flap under general anesthesia. The surgical steps are as follows:

1. Designed the right temporal parietal coronary incision, Weber-Fergusson incision, and the incision around the tumor, then incised the scalp after injection of hemostyptic liquid medicine, and then used the scalp clip to stop bleeding.
2. Turned over the scalp flap inwardly, incised the skin incision at the lateral side of the tumor, and then turned over the flap along the superficial face of the masseteric fascia.
3. Incised the temporal muscle attachment at the superior temporal line, turned over the temporal muscle flap downwardly, exposed the right craniofacial frontal bone and temporal bone, and designed the combined frontal-temporal bone flap (Fig. 13.9). Incised the Weber incision again.

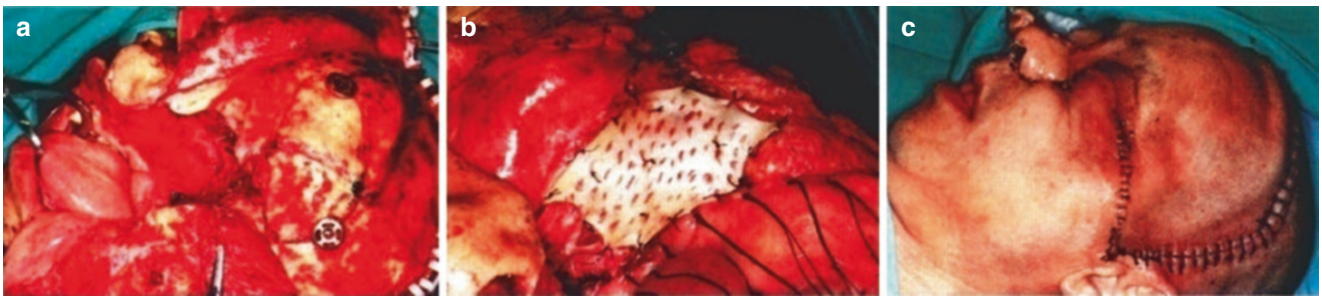

Fig. 13.8 Cases I. Surgical step 4. (**a**) The harvested frontal bone and temporal bone were put back into place and then were fixed with the skull fixator. (**b**) The skin was transplanted onto the surface of the masticatory muscle. (**c**) Lateral view after suture

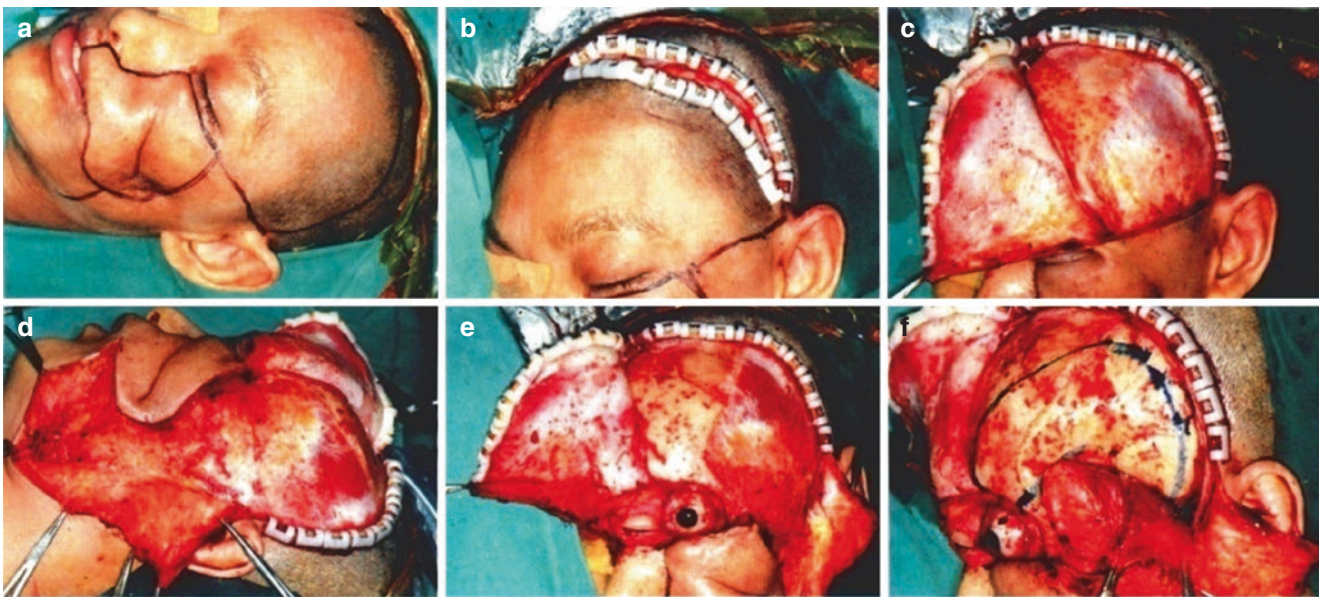

Fig. 13.9 Case II. Surgical step 1–3. (**a**) Designed the right temporal parietal coronary incision and Weber-Fergusson incision. (**b**) Incised the scalp and used the scalp clip to stop bleeding. (**c**) Turned over the scalp flap inwardly. (**d**) Incised the skin incision at the lateral side of the tumor and turned over the flap along the superficial face of the masseteric fascia. (**e**) Incised the temporal muscle attachment at the superior temporal line. (**f**) Designed the combined frontal-temporal bone flap

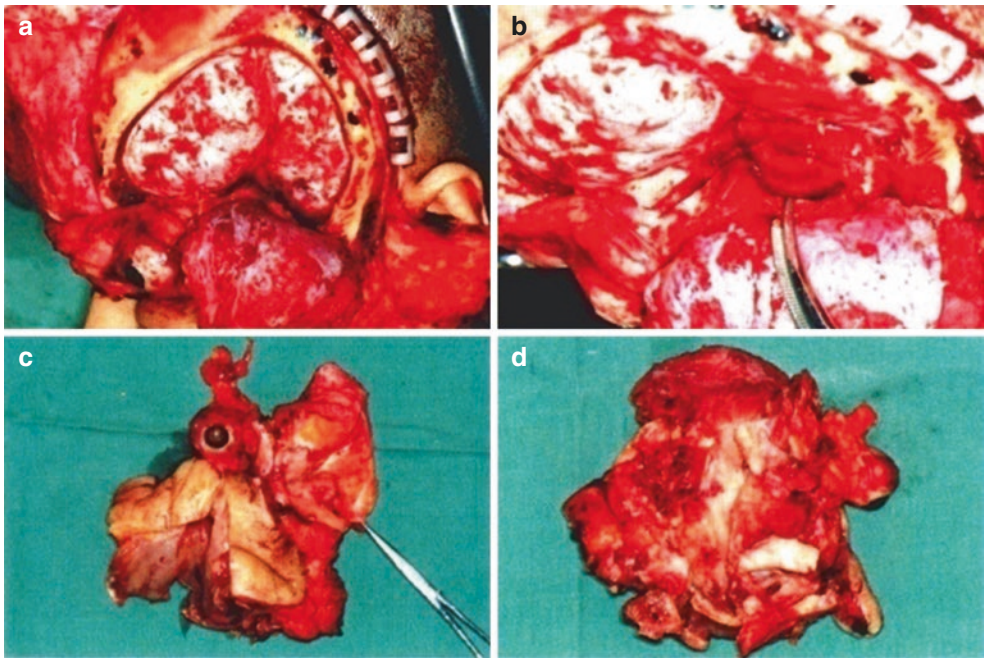

Fig. 13.10 Case II. Surgical step 4. (**a**) After the dura mater was separated, no visible tumor invasion was in the dura mater. (**b**) Removal of the left upper maxillary bone, orbit, intraocular content, part of the frontal bone, and sphenoid bone containing tumors. (**c**) Resected specimen. (**d**) Section of the resected specimen

4. The bone flap was drilled open and harvested to form the bone window with craniotomy drill and milling cutter drill according to the design line. After the dura mater was protected and separated, it was observed that the dura mater was not invaded by the tumor. The osteotomy was performed with electric saw in the site of the normal bone at the lateral side of the tumor, then the optic nerve was ligated and cut off, and finally the left maxilla, orbit and ocular contents, partial frontal bone, and sphenoid bone which contained the tumors were removed (Fig. 13.10).
5. After the dura mater was suspended with 5-0 absorbable suture, the harvested frontal bone and temporal bone were put back into place and then were fixed with the titanium plate, the skull base bone defect was repaired with titanium mesh, and the self-drilling titanium screws were used for fixation.
6. The position of the body was changed, and then the latissimus dorsi myocutaneous flap with a size of 23 cm × 9.5 cm on the left side of the back was designed based on the design defect size. After the vascular pedicle was cut off, the back wound was sutured by layers after reducing tension, and a negative pressure drainage tube was placed.
7. The position of the body was changed again, then the latissimus dorsi myocutaneous flap and the serratus anterior flap were placed onto the craniofacial defect, then the latissimus dorsi muscle was sutured and fixed with the facial muscle tissue, and subsequently the serratus anterior muscle was used to fill the orbit. The facial artery and vein were dissected out as the blood vessels of the donor site, then the thoracodorsal artery and vein were anastomosed with the facial artery and vein under the microscope, and finally the good venous reflux was confirmed by three blood vessel patency tests (Fig. 13.11).
8. The wound complete hemostasis was performed. The scalp and facial wound were put back into place and then were sutured by layers. Finally two negative pressure drainage tubes and a drainage rubber sheet were placed (Fig. 13.12).

3.6 Postoperative Treatment

The patient is immobilized routinely after surgery for 1 week. The mannitol and glucocorticoid are used for dehydration treatment according to the surgical situation conditions for 5–7 days. The penicillin or cephalosporins which can pass through the blood-brain barrier should be used as antibiotics. If the cerebrospinal fluid leakage occurs, the flushing or filling should be avoided in order to prevent intracranial infection.

The body position may be appropriately adjusted, and the majority of cerebrospinal fluid leakages can heal themselves; if the serious cerebrospinal fluid leakage cannot heal itself, the surgical sealing should be considered. If the patients undergo the repair with vascularized free tissue flap, they should be treated routinely with anticoagulant drugs after free tissue flap transplantation. If patients have symptoms such as headaches, nausea, and fever, the clinicians should be alert to the possibility of intracranial infection, and if not promptly treated, it could be life-threatening.

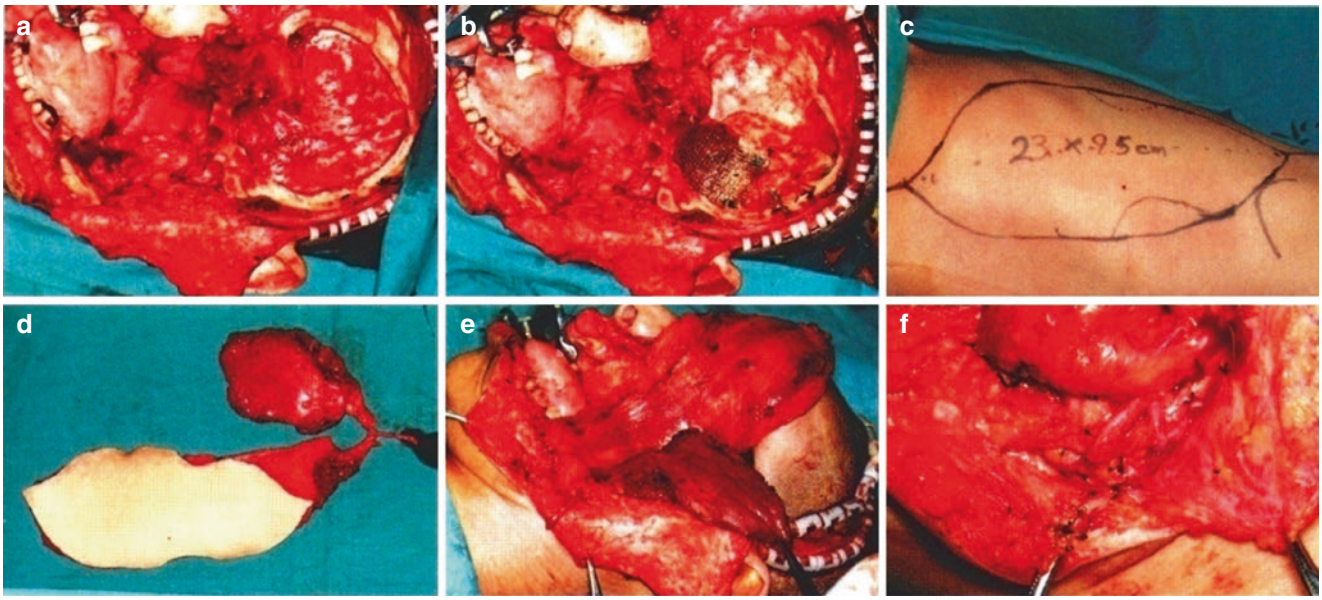

Fig. 13.11 Case II. Surgical step 5–7. (**a**) The wound surface after lesion resection. (**b**) The harvested frontal bone and temporal bone were put back into place and then were fixed with the titanium plate. The skull base bone defect was repaired with titanium mesh, and the self-drilling titanium screws were used for fixation. (**c**) Designed the latissimus dorsi myocutaneous flap with a size of 23 cm × 9.5 cm on the left side of the back. (**d**) The prepared latissimus dorsi myocutaneous flap and the serratus anterior flap. (**e**) The latissimus dorsi myocutaneous flap and the serratus anterior flap were placed onto the craniofacial defect. (**f**) After, the thoracodorsal artery and vein were anastomosed with the facial artery and vein

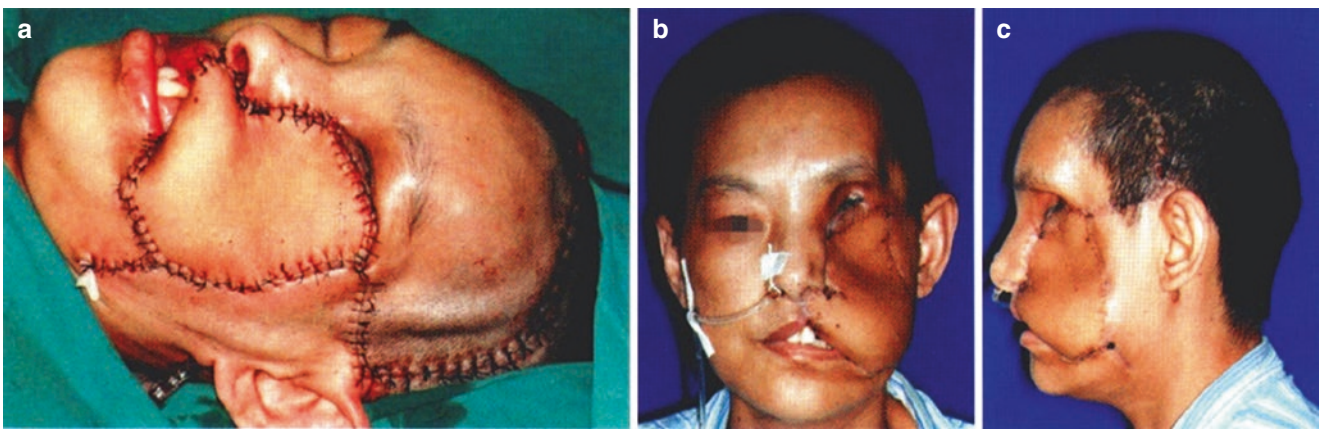

Fig. 13.12 Case II. Surgical step 8. (**a**) Lateral view after suture. (**b**) Frontal view at the 3rd week after surgery. (**c**) Lateral view at the 3rd week after surgery

3.7 Experience and Reviews

The repair of defects after combined craniomaxillofacial resection is a complex surgery with significant risk, and thus the surgeons should strictly grasp the indications and strengthen communication and close cooperation between related disciplines; before deciding to perform an operation, the surgeons should fully estimate the postoperative life quality and survival rate of the patient. For the defect after tumor resection, it should be repaired and reconstructed in stages and in a planned way on the basis of not violating the principle of tumor resection.

For dura mater defects, if they can be drawn close and sutured, they should be closed and sutured as far as possible; if they can't be drawn close and sutured, there is an option of repairing them with artificial patch, autologous fascia, allogeneic dura mater, or surrounding cranial flap, and the exposed dura mater should be covered with 1–2 layers of tissue flap with rich blood supply. Because the tumor destroys the bone of the skull base, the dead space due to

exposure of dura mater and the larger skull base bone defect caused by tumor resection should be repaired and covered, while the reconstruction of the skull base bone is an effective method for preventing the postoperative cerebrospinal fluid leakage and infection. Since the dura mater is preserved or repaired, the main purposes of the reconstruction of the skull base bone are to cover the dura mater, fill and destroy the dead space, repair the defects in the skull base bone, and restore the facial appearance. Some scholars have suggested that the skull base bone defect with a diameter less than 4–5 cm cannot be repaired and can be repaired with simple soft tissues; the skull base bone defect with a diameter more than 4–5 cm often needs to be repaired with bone flap or solid skull base reconstruction using titanium mesh. And we think that it should be considered to carry out bone repair or titanium mesh reconstruction for the skull bone defects which meet the following three conditions: ① skull base bone defect ≥1.5 cm; ② skull base bone defect <1.5 cm but combined with dura mater defect, or there are larger epidural dead spaces; and ③ there are important intracranial neurovascular structures exposed in the skull defect area, and the thickness of the skin and soft tissue is not sufficient to protect safety. Currently, in addition to the use of free skull or ilium in reconstruction of articular fossa of the temporal bone, we use the titanium mesh in repair of the vast majority of skull base defects, and no postoperative complications such as intracranial pneumatosis and cerebrospinal fluid leakage occur. Therefore, we believe that in the reconstruction of the skull base, the titanium mesh can compensate the disadvantage of limited bone volume available for donation compared with the traditional skull and can avoid the increase of the trauma in new donor site and the issues of complication and shaping compared with the ilium and ribs. Due to its good biocompatibility, the titanium mesh combined with CAD/CAM and rapid prototyping technology can safely, effectively, and precisely reconstruct the larger complex bone defect in the skull base.

It should be kept in mind that the vascularized free tissue flap is not the necessary repair means, and only selecting the most appropriate repair method for specific defects according to actual circumstances can complete the ideal repair and reconstruction. Our principles are as follows: For patients with small to medium soft tissue defects or dead space, the adjacent temporal muscle flap or temporal muscle flap and sternocleidomastoid muscle flap transfer can be used to simply cover and protect the dura mater and fill and eliminate dead space. For patients with larger dead space or a wide range of complex defect or patients who have received radiation therapy in the past, the temporal muscle flap is located in the surgical area. The material range of temporalis muscle flap is large. It is convenient to rotate, easy to survive, and its donor site is concealed. According to the repairing needs, the muscle flap, fascia flap or myofascial flap can be prepared. When the patients' soft tissue is in large defect, temporal muscle and deep temporal fascia, and the extension of galea aponeurotica can be carried by the flap. And when the patients' bone tissue is also in defect, a small piece of skull flap can sometimes be included. We recommend that the adjacent tissue flaps with pedicles such as the temporal muscle flap and sternocleidomastoid muscle flap are preferably selected for repair of circumscribed soft tissue defects in the skull base. For patients with a wide range of soft tissue defects, especially patients with the lesions involving the coronoid process of the mandible, the removal of the coronoid process may destroy the blood supply of adjacent temporal muscle flap, and the amount of tissue is insufficient. Therefore, it should be considered to carry out repair with free tissue flaps such as anterolateral thigh flap, latissimus dorsi myocutaneous flap, and pectoralis major myocutaneous flap, so as to provide soft tissues of sufficient volume to cover the dura mater, fill and eliminate the dead space, restore the appearance of the head and face, and prevent serious complications such as the intracranial and extracranial infections and cerebral hernia.

All surgical photographs published in this chapter have been approved by the patients themselves.

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Defect Repairs After Resections of Laryngeal Cancer, Hypopharyngeal Cancer, and Cervical Esophageal Cancer

14

Jie Chen and Yuejun Chen

1 Anatomy and Physiology of the Throat

The throat, hypopharynx, and cervical esophagus are the closely connected vital organs, and they are not only the passage of air entering into the body but also the only way the food must pass through; meanwhile the throat body producing sound is a basic condition for the human verbal communication. Any abnormal anatomy and physiology of the throat not only affect the person's breathing, pronunciation, or sound quality but also affect the eating and swallowing functions.

The supports of the throat are composed of the thyroid cartilage, cricoid cartilage, arytenoid cartilage, cuneiform cartilage, and corniculate cartilage. The epiglottic cartilage covered by the mucosa constitutes the epiglottis and is not involved in constituting the cartilage support of the laryngeal cavity. According to the tissue origin of embryonic development, the throat body is divided into supraglottic portion (the epiglottis laryngeal surface, aryepiglottic fold, ventricular band, and laryngeal ventricle), glottic portion (bilateral vocal cords and anterior commissure), and infraglottic portion (can be divided into left and right side walls), and such anatomical partitions have important clinical significances. Because there are sparse lymphatic vessels in the glottic portion, and there is a very rich lymphatic drainage in the supraglottic portion, the mode of local spreading of laryngeal cancer depends on the primary site of the tumor and its scope [1]. The staging of primary laryngeal cancer depends on the following aspects: the scope of tumors in different positions within the same partition, whether the tumor crosses different partitions, whether the tumor exceeds the laryngeal cavity and invades the adjacent tissues, and whether there are vocal cord movements. The vocal cord fixation means that the deep tissues are invaded.

The laryngopharynx is the lowest part of the pharynx. It starts up from the level of the epiglottis tip, stops at the inferior margin level of the cricoid cartilage, and is connected downwardly by the esophagus. According to different partitions of the lower pharyngeal cavity, the lower hypopharyngeal area is often divided into pyriform sinus area, posterior hypopharyngeal wall area, and postcricoid area. The medial wall of the pyriform sinus area is the outer wall of the aryepiglottic folds; the lateral wall is close to the lamina of thyroid cartilage, and the posterior part is connected with the posterior hypopharyngeal wall. The posterior hypopharyngeal wall area refers to the posterior pharyngeal wall between the bottom of the epiglottic vallecula (equivalent to the level of the upper margin of the hyoid bone) and the lower margin of the cricoid cartilage; the postcricoid area is the area of lamina of cricoid cartilage, ranges from the level of the interarytenoid area to the lower margin of the cricoid cartilage, and the outside is adjacent to the pyriform sinus. Bilateral pyriform sinus, posterior pharyngeal wall, and postcricoid area form three anatomic areas, and various areas interlap with each other and have no absolutely clear boundaries. Physiologically, the laryngopharynx is a part of the upper aerodigestive tract and is connected with the larynx and esophagus. Due to the anatomical specificity, early-stage primary tumors in hypopharyngeal area have few symptoms, and it is difficult to find them. When a considerable part of the patients were diagnosed with hypopharyngeal cancers, their primary tumors often have been at a slightly more advanced stage. In addition, the lymphatic vessels in hypopharyngeal area are very rich, and thus the lymph node metastasis may occur in the early course of the disease, and the cervical lymph node metastasis occurs in two thirds of

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patients with hypopharyngeal cancers in clinics. The cervical lymph node metastasis means that patients have a serious condition, and the stage of disease is later. Therefore, when most of the primary hypopharyngeal cancer patients are diagnosed and treated, they have been at advanced stage. Among them, stage III patients account for 36%, and stage IV patients account for 42%, while stage I and II patients account for a total of about 22%. The surgical treatment of hypopharyngeal cancer will affect the swallowing and phonation functions and even cause respiratory aspiration.

The cervical esophagus starts from the lower end of the hypopharyngeal area that is the lower boundary of the cricoid cartilage, and it stops at the level of the thoracic entrance. The primary tumors in the cervical esophagus are not common, but it is commonly seen that the primary tumors in the postcricoid area or the posterior hypopharyngeal wall invade the esophagus downwardly [2]. Because the cervical esophagus is connected with the postcricoid area, and the anterior part is adjacent to the throat and trachea, it is necessary to not only consider the removal of the primary tumor but also simultaneously focus on the issues of resection and functional reconstruction of the throat and cervical trachea in the surgical treatment of cervical esophageal cancer.

Although the main purpose of the treatment of laryngeal, hypopharyngeal, and cervical esophageal cancers is radical treatment of tumors, protecting the laryngeal pronunciation function and pharyngeal swallowing function of the patient is the direction the head and neck surgeons have been trying to go, and the best treatment method must be selectively used for treating the laryngeal, hypopharyngeal, and cervical esophageal cancers according to the involvement degree of the throat.

Many years of clinical practice make us realize that nearly half of hypopharyngeal cancers have not invaded the throat. Even though the normal tissues of the throat are resected, their prognoses cannot be improved; with the development of partial laryngectomy, the hypopharyngeal surgery should also protect the normal part of throat structures. Since the mid-1970s, the hypopharyngeal cancer surgery preserving laryngeal function has been carried out, and the first-stage repair and reconstruction of the upper digestive tract are performed, and the surgery is gradually made to be of standardization, systematization, and routinization.

For patients with laryngeal, hypopharyngeal, and esophageal cancers, the tongue root and the lateral wall of the pharynx must be examined by palpation to assess whether there is submucosal tumor infiltration. In addition to preoperative imageological examination, the endoscopy of the pharynx, larynx, and esophagus must also be carried out, and special attentions should be paid to those hidden parts during endoscopy, whose scope includes the tongue root, tip of the pyriform sinus, laryngeal cavity, postcricoid area, and esophagus [3–5].

2 The First-Stage Repair of Defects After Resection of the Hypopharyngeal and the Cervical Esophageal Cancer

2.1 The Hypopharyngeal Cancer Resection with the Preservation of Laryngeal Function

2.1.1 Simple Resection of Piriform Fossa

The piriform fossa cancer $T_{1–2}$ lesions are the best indication, and a few selected T_3 lesions may also be considered. Ipsilateral vocal cord fixation, thyroid cartilage damage, involvement of postcricoid area, the tip of piriform fossa, and cricopharyngeus muscle or tongue root, the cervical lesions difficult to resect, and poor pulmonary function are contraindications. After local resection of the limited cancer in the lateral wall of the piriform fossa, the smaller pharyngeal opening can be directly closed and sutured, and the larger pharyngeal opening can be closed through turning over the platysma myocutaneous flap to the pharyngeal defect area [6, 7].

2.1.2 Resection of Posterior Pharyngeal Wall Cancer

$T_{1–2}$ lesions limited to the posterior pharyngeal wall area are suitable for the hypopharyngeal cancer resection with preservation of laryngeal function. The resection range of $T_{1–2}$ cancers in the posterior and lateral pharyngeal wall includes the posterior one thirds of the thyroid cartilage, the posterior and lateral pharyngeal wall, and part of the outer wall of piriform fossa. After resection of lesions, when the posterior pharyngeal wall defect is larger, the decellularized oral-repairing membrane or transplantation of the split-thickness skin graft on the surface of the musculus longus colli or platysma myocutaneous flap can be selectively used for repair and reconstruction to close the pharyngeal opening. The entering approach of incising the lower lip, mandible, and tongue body through the midline incision is suitable for patients with $T_{1–2}$ and selected T_3 lesions or limited recurrence of posterior pharyngeal wall cancer after radiotherapy. For the posterior pharyngeal wall cancer in which the throat body needs to be retained, entering from the unilateral piriform fossa to remove the tumor is conducive to the blood supply of the pharyngeal flap, but the surgeons should be especially careful of the incisal margins of the tumor to avoid insufficient safe incisal margins in lateral pharyngeal walls on both sides to lead to tumor recurrence.

2.1.3 Resection of Postcricoid Cancers

It is suitably used for patients with $T_{1\sim2}$ lesions and carefully selected T_3 cancer. Its contraindications include patients with T_4 cancer, the old and infirm, and those with poor lung function. The en bloc resection of the posterior halves of the throat and trachea and the postcricoid cancer is carried out, then the anterior halves of the throat and trachea are closed and sutured, and then the sternohyoideus muscle is twisted backward to reinforce and elevate the posterior wall of the upper laryngeal orifice. Subsequently the pronunciation and swallowing protection function can be restored after surgery.

2.2 The First-Stage Repair After Resection of Hypopharyngeal and Cervical Esophageal Cancers with Preservation of Laryngeal Function

2.2.1 Repair of Lateral Hypopharyngeal Wall Defect with Platysma Myocutaneous Flap

For patients after resection of part of the pyriform sinus and half of the throat, the anterior cervical myocutaneous flap can be used to repair the defects in the throat and pyriform sinus to restore laryngeal function. Surgical methods: the anterior cervical and platysma myoides rectangular flap of about 3 cm × 6 cm and 4 cm × 8 cm are prepared at the level of lamina of thyroid cartilage, which ranges up from the level of upper margin of the thyroid cartilage down to the level of the cricoid cartilage. The skin and platysma muscle are incised deeply to reach the myolemma of the infrahyoid muscles, and the anterior free margin exceeds the midline to the contralateral side, while the outer side reaches the anterior margin of the sternocleidomastoid muscle, and it is taken as the pedicle, which is equivalent to a rotatable door. The superficial layer split skin graft is lifted up again from the platysma myocutaneous flap from the anterior margin of about 3 cm to form the double skin flaps with the same pedicle [8]. The pharyngeal cavity is entered into from the posterior margin of the thyroid cartilage. The medial wall of the pyriform sinus and arytenoid cartilage are protected; meanwhile the primary tumor is resected and the cervical lymph nodes are dissected. After the pathological examination shows that the incisal margins have no cancers, the underlying platysma myocutaneous flap is transferred into the pharyngeal cavity, then the free margin is sutured with the mucous membrane of the posterior pharyngeal wall, and then the skin margins of its corresponding skin flap are sutured with the medial wall of the pyriform sinus and the lateral mucosa of the arytenoid cartilage; subsequently the pharyngeal fistula is closed. Finally, the lifted skin graft is put back to the anterior cervical area and is sutured with the surrounding skin, and the skin flap from surrounding area can be transferred to the site which lacks skin and then is sutured. We carried out two cases of surgery. The trachea cannula was removed at half month after surgery. After that, the patients had no choking cough, and the eating and pronunciation returned to normal. One year later, the reexamination showed normal results. Because the platysma myocutaneous flap not only has rich blood supply but also can provide a skin flap of 10 cm × 5.5 cm, and the muscle is thin and is easily obtained with fewer traumas, the success rate is higher. But the patients who have undergone neck radiotherapy and have resection of the facial artery should not receive the repair with the platysma myocutaneous flap [9].

Case I The patient, male, 65 years old, was admitted into the hospital because of having a sore throat for 2 months. The mass in the lateral wall of the left pyriform sinus was 2 cm × 1.5 cm, which looked like cauliflower. Admission diagnosis: left hypopharyngeal cancer $T_1N_0M_0$. The patient underwent resection of the lateral hypopharyngeal wall with preservation of throat + lymph node dissection in areas II, III, and IV + the repair of hypopharyngeal defect with platysma myocutaneous flap under general anesthesia (Fig. 14.1). Postoperative pathological examination report: left hypopharyngeal highly differentiated squamous cell carcinoma, and no cancer was observed in the incisal margins and cervical lymph nodes.

2.2.2 Repair of the Hypopharyngeal Defect with Submental Flap

The blood supply of submental flap comes from the branch of the facial artery. The submental artery starts at about 5 mm below the mandible; runs forward to the upper margin of the submaxillary gland, superficial surface of the mylohyoid muscle, and the anterior belly of the digastric muscle; and gives off one to four artery perforators on the way to the platysma muscle and submental skin. The submental artery has one to two accompanying veins which converge into the facial vein. When the skin flap is prepared, the incision is made at the upper incisal margin of the skin flap at the level of about 2 cm from the lower margin of the mandible, and the facial artery and vein and the marginal mandibular branch of the facial nerve are protected. Then the submandibular gland and surrounding lymph nodes are removed, and attentions should be paid to protecting the blood vessel branches and perforators of the submental flap. The skin flap includes the skin, platysma muscle, and part of the anterior belly of

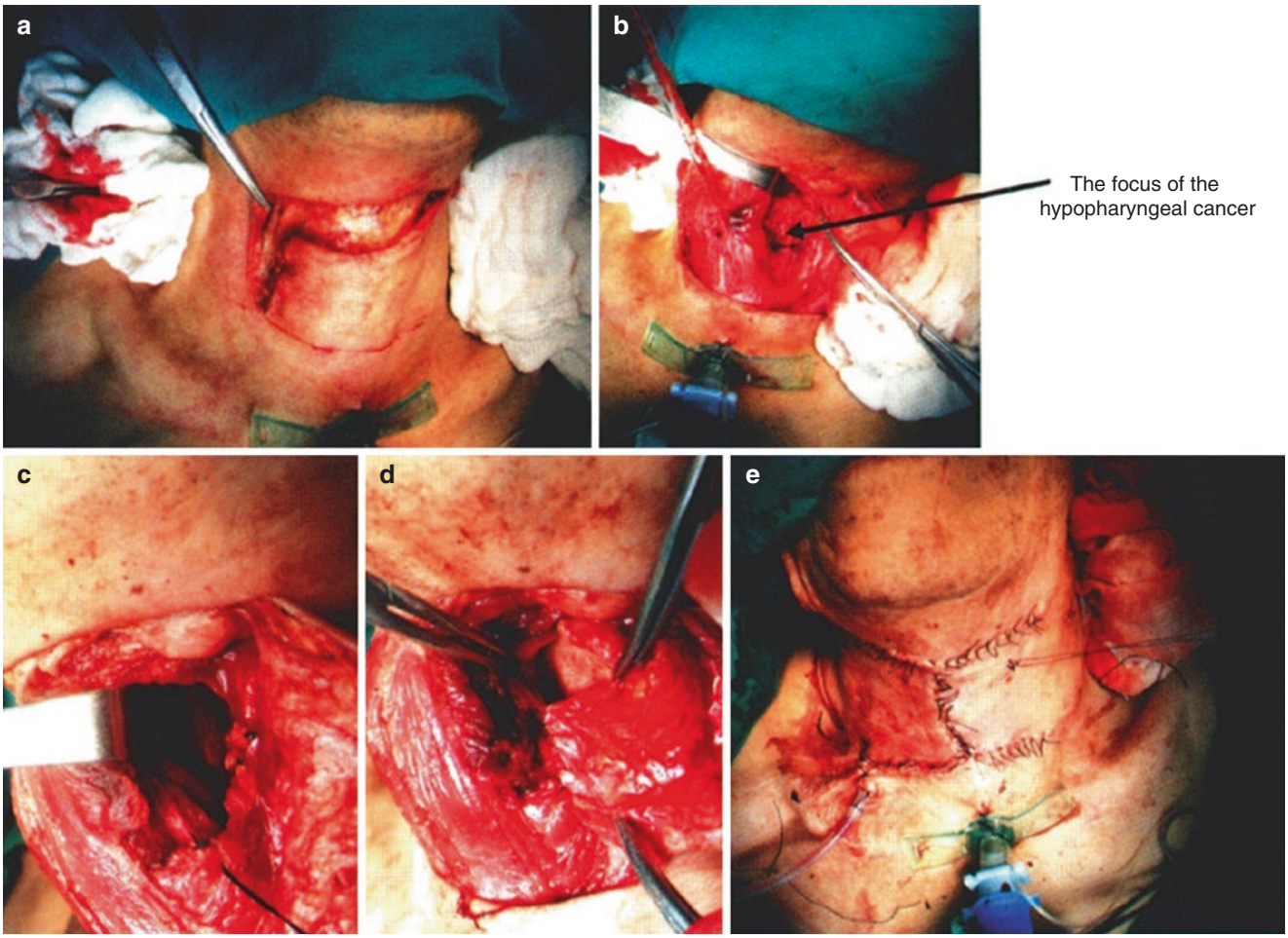

Fig. 14.1 Case I. (**a**). Design of platysma myocutaneous flap. (**b**) The primary focus of the hypopharyngeal cancer was resected. (**c**)The hypopharyngeal defect after resection of the primary focus. (**d**) The platysma myocutaneous flap was used to repair the hypopharyngeal defect. (**e**) The situation when the surgery was completed

digastric muscle. The skin flap can maximally reach to 6 cm × 8 cm with a thickness of 1–2 cm, and the vascular pedicle is 6 cm in length. After the removal of the primary focus and cervical lymph nodes, the cervical lymph node dissection is performed, while the external maxillary artery and vein are retained and protected from damage. After the primary focuses of the laryngeal cancer and hypopharyngeal cancer are resected, the submental flap is transferred into the pharyngeal cavity, and the skin of the skin flap is sutured with the pharyngeal and residual laryngeal mucosa, and then the hypopharyngeal defect at one side after half laryngectomy is repaired. We applied this skin flap to repair the hypopharyngeal defect in 33 patients, and all patients achieved successful results, but the disadvantage was that the beard grew out from the pharyngeal flap of the male patient. Finally the laser is used to point fire the hair follicles for dehairing [10].

Case II The patient, male, 62 years old, was admitted into the hospital because of having a sore throat for 3 months and hoarseness for 1 month. The mass in the medial wall of the left pyriform sinus was 2.5 cm × 1.5 cm, and the surface was ulcerated. Admission diagnosis: left hypopharyngeal cancer $T_2N_0M_0$. The patient underwent resection of the left vertical part of the throat and hypopharyngeal cancer; lymph node dissection in areas II, III, and IV; and the repair of hypopharyngeal and laryngeal defects with submental flap (Fig. 14.2). Postoperative pathological examination report: left hypopharyngeal highly and moderately differentiated squamous cell carcinoma, and no cancer was observed in the incisal margins and cervical lymph nodes.

2.2.3 Repair of Posterior Pharyngeal Wall Defect with Forearm Skin Flap

The repair of posterior pharyngeal wall defect can use the skin transplantation, forearm skin flap, free jejunum, and platysma myocutaneous flap [11]. When the resection is only limited to the mucous layer, it may be allowed to heal by itself, or the split flap is transplanted. When the split flap

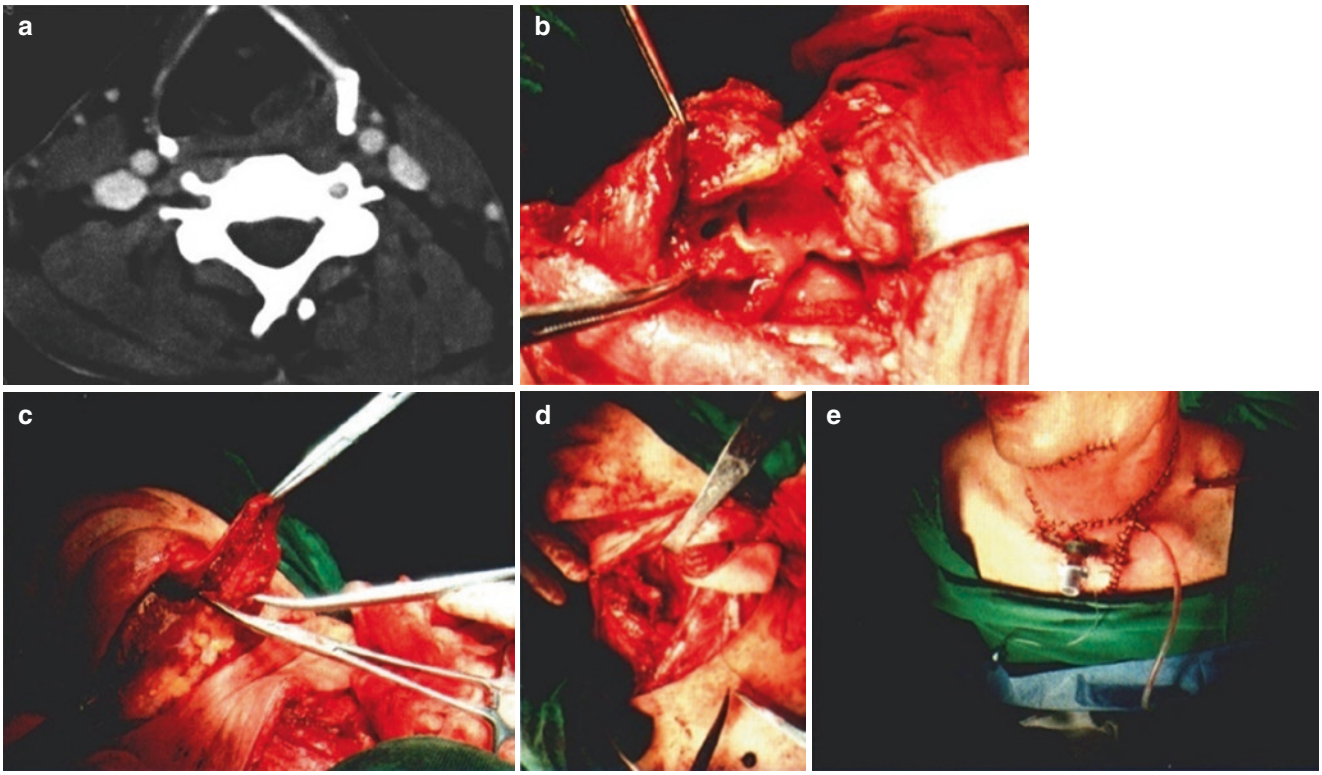

Fig. 14.2 Case II. (**a**) Preoperative CT showed lesions within the medial wall of the pyriform sinus. (**b**) The primary focus was resected, and the right half of the throat was preserved. (**c**) The submental flap was prepared. (**d**) The left laryngeal and hypopharyngeal defects were repaired with the submental flap. (**e**) The surgery was completed

is transplanted, the apposition suture of the peripheral side and the mucosal margin of the posterior pharyngeal wall is performed, and the middle part is pinned and sutured to the prevertebral fascia with a 3-0 silk thread by an interval of 1 cm. Peng Jieren reported that acellular artificial tissue patch was used to repair the posterior pharyngeal wall defect, because the basic structure of the artificial tissue patch is the fibroblast-populated collagen lattice, and the immune response induced by the allogenic skin plays main effects on components such as epidermal cells, dermal fibroblasts, and endothelial cells, while the noncellular components in the dermis such as extracellular matrix protein and collagen are immunoincompetent relatively [12]. After repair of the laryngeal wall defect, the mucosal cells in normal incisal margins crawl along the scaffold of the tissue patch and finally cover the entire defect area to become the mucosal epithelia. The incidence rate of pharyngeal fistula is low, and the preoperative and postoperative radiotherapies do not affect the tissue patch transplantation. The platysma myocutaneous flap can also be prepared through lateral pharyngeal incision approach and covered onto the posterior pharyngeal wall defect. The larger posterior pharyngeal wall defect requires meticulous surgical reconstruction. Because of its moderate thickness, the radial forearm free flap has become the suitable skin flap for repair of skin and mucosal defects which are not necessary to be repaired with thick soft tissue, and it is the best material for hypopharyngeal reconstruction. After it is repaired and sutured tightly with the mucous membrane, the swallowing function of the patient can be satisfactorily recovered. The forearm skin flap of 5 cm × 6.5 cm is designed upward at the site with a distance of 3 cm from proximal horizontal grain line of the left wrist, and the skin, subcutaneous tissue, and superficial fascia are incised on the forearm midline along the running direction of the radial artery; meanwhile the superficial branch of the radial nerve is protected and preserved. Between the brachioradialis muscle and the flexor carpi radialis muscle, the radial artery and its accompanying veins are exposed, and the dissection is performed upward to ligate the small branches of arteries and veins. The distal ends of the radial artery and the accompanying veins are ligated and cut off at the end of the skin flap close to the wrist, and attentions are paid to protecting the close linkage of the blood vessels with the skin flap. Between the brachioradialis muscle and pronator teres muscle, the vascular pedicle is dissociated to site at 5 cm near the elbow joint and then is ligated and cut off, so that the length of vascular pedicle of the skin flap can reach up to about 10 cm. After the preparation of skin flap is completed, the radial artery and vein are anastomosed with the

superior thyroid artery and vein or the facial artery and vein. The skin flap can also be placed in appropriate location of the posterior pharyngeal wall, before vascular anastomosis, and three fourths of skin flap is sutured with the mucosa. To avoid esophageal stenosis, when the posterior wall of the cervical esophagus is sutured with the free skin flap, the middle of the posterior wall of the esophagus may be ripped off longitudinally by a small portion, and the wedge-shaped skin is implanted. Our department also successfully repairs the posterior pharyngeal wall defect using the anterolateral thigh flap. It is noted that the skin flap should be trimmed thinly during surgery using the perforator flap technique.

Case III The patient, male, 58 years old, was admitted into the hospital because of having a sore throat for 2 months. The posterior pharyngeal wall mass was 2.0 cm × 1.5 cm, and the surface was ulcerated. Admission diagnosis: right hypopharyngeal cancer $T_1N_0M_0$. The patient underwent resection of posterior pharyngeal wall cancer with preservation of throat + lymph node dissection in right areas II, III, and IV + the repair of posterior pharyngeal wall defect with free forearm skin flap under the general anesthesia (Fig. 14.3). Postoperative pathological examination report: left hypopharyngeal highly and moderately differentiated squamous cell carcinoma, and no cancer was observed in the incisal margins and cervical lymph nodes.

2.2.4 Repair of Posterior Hypopharyngeal Wall Defect with Free Jejunum

After resection of T_2 and selected T_3 lesions in posterior hypopharyngeal wall area, the defects can be repaired with free jejunum. The jejunum wall far away from the mesentery is split off to form the jejunum graft, which is sutured with the mucosal margin of the pharyngeal defect, and the jejunum mucosal surface is taken as the pharyngeal mucosa, and then the mesenteric artery and vein are anastomosed with the appropriately selected artery and vein. The esophageal invasion of the posterior hypopharyngeal wall cancer often causes most of hypopharyngeal and cervical esophageal defects, and thus the free jejunum can be selected to repair the hypopharyngeal and cervical esophageal defects, while the pronunciation function of the throat body is preserved [13, 14]. The jejunum segment is used to repair the pharyngeal defect above esophageal entrance, and the mesenteric margin corresponding to the jejunum segment should be split off longitudinally, and the form of the jejunum graft is used to repair the pharyngeal defect. The lower jejunum segment

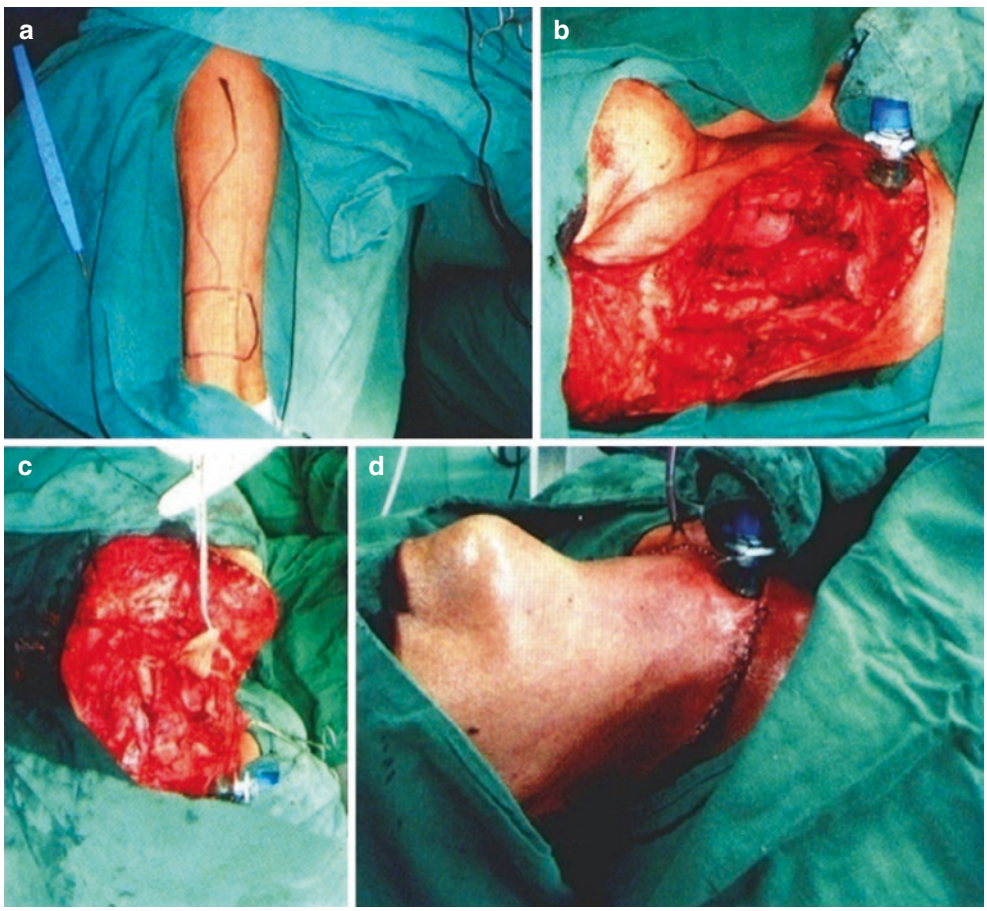

Fig. 14.3 Case III. (**a**) Design of forearm skin flap. (**b**) The defects in the right lateral and posterior walls of the laryngopharynx after resection of hypopharyngeal cancer. (**c**) Repair of posterior pharyngeal wall defect with forearm skin flap. (**d**) The surgery was completed

is anastomosed with the cervical esophagus stump, and the mesenteric artery and vein are anastomosed with the appropriately selected artery and vein. The surgery is relatively simple, but the walls of the mesenteric artery and vein are thin, and a high level of microvascular anastomotic techniques and clinical experiences are required. The ideal supplying arteries include the facial artery, thyroid artery, lingual artery, or transverse cervical artery. In the abdominal surgery group, the upper middle abdominal incision is made, and the jejunum segment is selectively transplanted. The proximal jejunum segment has richer vascular arcades and is more suitable for transplantation. The end-to-end anastomosis between the jejunum segment and esophagus is very ideal. Among the ideal blood vessels of the jejunum segment, there is an artery and a vein running into the mesenteric root. The blood vessels within the mesentery feeding the jejunum are not cut off at first, and they will be treated when the transplantation is performed. In order to ensure that the jejunum segment wriggles downward from upper to lower levels, it is necessary to make a mark in the jejunum wall, anastomose the proximal jejunum segment with the pharyngeal area, and anastomose the distal jejunum segment with the cervical esophagus stump. Such wriggling way is conducive to swallowing. The transplanted jejunum segment is implanted into the cervical area at first, and the nasogastric tube is inserted into the jejunum segment. Later, the pharynx-jejunum anastomosis and the jejunum-esophagus anastomosis are performed, and then the vascular anastomosis is performed under the microscope. The length of the jejunum segment should be appropriate, and if it is too long, the speed of swallowing can be slowed down. Due to the maturity of the laparoscopic technique, the donor jejunum can be harvested under the laparoscope to reduce the abdominal complications [15].

Case IV The patient, male, is 53 years old. The admission examination showed cauliflower-shaped mass in the posterior hypopharyngeal wall and esophageal entrance, and the esophageal entrance was narrow, so the gastroscope could not enter through it. Bilateral vocal cords had good activity, and the laryngeal structures were normal. Admission diagnosis: hypopharyngeal and cervical esophageal cancers. After admission, the esophageal barium swallow X-ray inspection showed cervical esophageal mucosal disorders of about 4 cm with irregular filling defect. When the resection of hypopharyngeal and cervical esophageal cancers combined with left cervical lymph node dissection was performed, it was observed that the mass mainly invaded the posterior hypopharyngeal wall, esophageal entrance, and 5 cm cervical esophagus, but the postcricoid mucosa was normal, and bilateral arytenoid cartilages and throat body were normal; thus it was decided to preserve the throat body and perform the esophageal replacement with free jejunum. 15 cm jejunum was harvested and transplanted to the cervical area, then the intestinal wall of 4 cm was incised longitudinally at the contralateral side of the mesentery in the upper end, and then it was tiled and sutured with the retropharyngeal mucosa and postcricoid mucosa to repair the posterior hypopharyngeal wall defect; the end-to-end anastomosis between the lower end of the jejunum and the esophageal stump (equivalent to the level of the clavicle) was performed. Under the microscope, the mesenteric artery was anastomosed with the superior thyroid artery, and the mesenteric vein was anastomosed with the external jugular vein; meanwhile it was noted that the recurrent laryngeal nerve and the myolemma of the posterior cricoarytenoid muscle were not damaged. The blood supply of the jejunum was good after surgery. The anti-inflammatory, supportive, and symptomatic treatments were carried out after surgery, and the patient healed well. The reexamination was performed at 1 year after surgery, and the eating and swallowing functions returned to normal except when the patient was eating, a few choking coughs and a mild hoarseness would occur.

Case V The patient, male, is 69 years old. The admission examination showed that the posterior hypopharyngeal wall cancer invaded the esophageal entrance and the cervical lymph node metastatic cancer invaded the thyroid gland and the internal jugular vein at one side, and the combined radical resection of hypopharyngeal cancer was performed, and the throat was preserved. After the hypopharynx and two thirds of the cervical esophagus were resected, the invaded thyroid gland and internal jugular vein were resected simultaneously. Under the microscope, the cervical esophageal and posterior hypopharyngeal wall defects were also repaired with free jejunum. The mesenteric artery was anastomosed with the transverse cervical artery, and the mesenteric vein was anastomosed with the external jugular vein, and the postoperative recovery was good, and the pronunciation and eating functions were basically normal.

Case VI The patient, male, 56 years old, was admitted into the hospital because of having a sore throat for 2 months. The admission examination showed a posterior pharyngeal wall mass of 6.0 cm × 3.5 cm with an ulcerated surface, and the cervical esophagus was invaded. Admission diagnosis: hypopharyngeal cancer $T_3N_0M_0$. The patient underwent resection of hypopharyngeal and cervical esophageal cancers with preservation of throat + left cervical lymph node dissection in areas II, III, and IV + the repair of cervical esophageal and posterior hypopharyngeal wall defects with free jejunum under the general anesthesia (Fig. 14.4). Postoperative pathological examination report: hypopharyngeal highly and moderately differentiated squamous cell carcinoma, and no cancer was observed in the incisal margins and cervical lymph nodes.

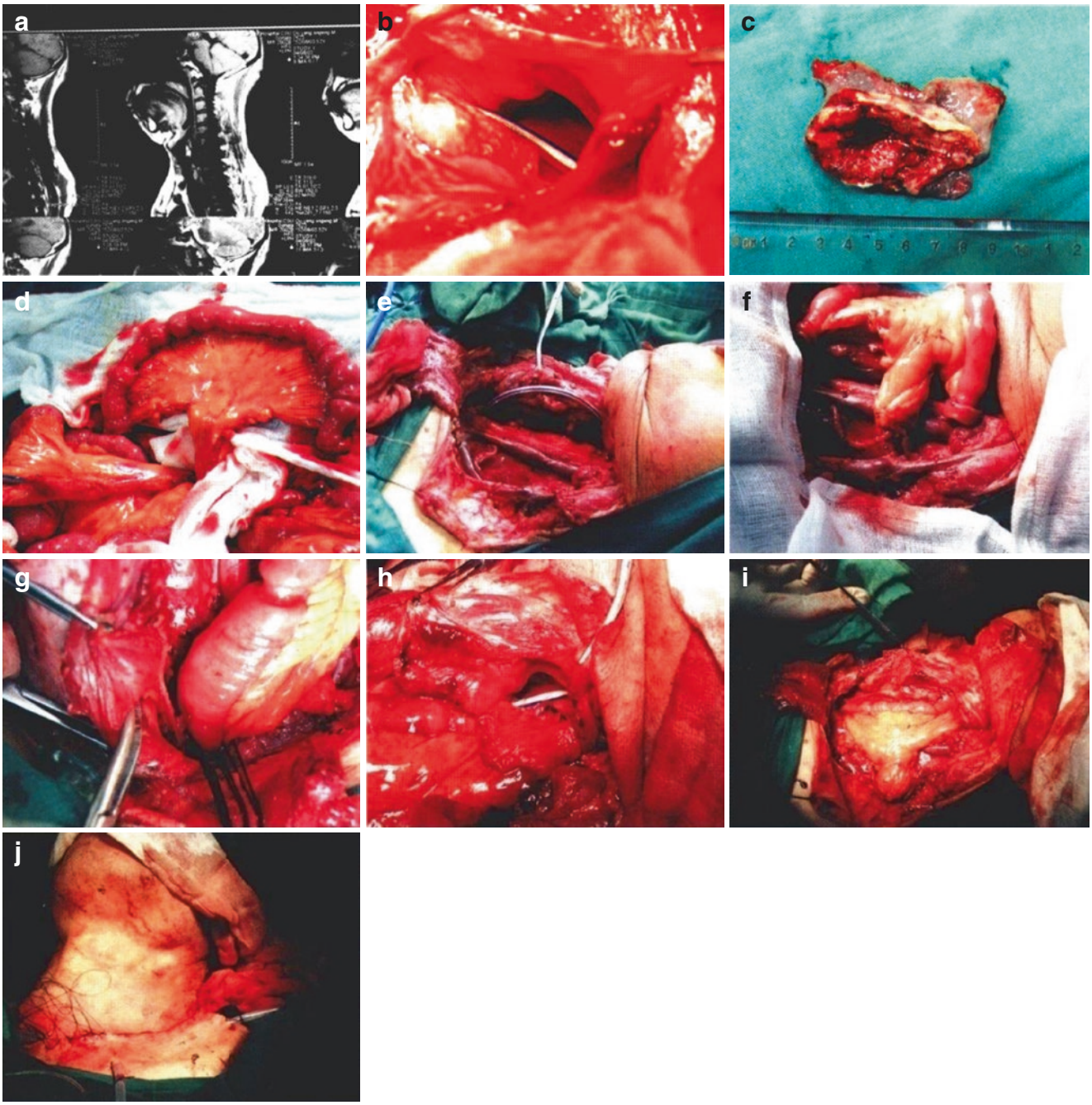

Fig. 14.4 Case VI. (**a**) Preoperative MIR showed the protrusion of the posterior hypopharyngeal wall mass. (**b**) Incised the medial wall of the pyriform sinus. (**c**) Surgical specimens. (**d**) Free jejunum. (**e**) The cervical esophageal and hypopharyngeal defects. (**f**) Microvascular anastomosis of free jejunum. (**g**) The jejunum was anastomosed with the esophagus at the level of the thoracic entrance. (**h**) The jejunum was cut open to repair the mucosa defects in postcricoid area and posterior hypopharyngeal wall. (**i**) The free jejunum repair was completed. (**j**) The surgery was completed

2.2.5 Replacement of Esophagus with Pulled-Up Stomach for Repair of Pharyngeal and Cervical Esophageal Defects

Some patients with the hypopharyngeal cancers invading the cervical esophagus or the primary cervical esophageal cancers need to undergo resection of the hypopharynx or whole throat. When multiple tumors occur in the esophagus and the lower incisal margin is extended to retrosternal area, it is impossible to use free jejunum to repair the esophageal defect, and the stomach can be pulled up to repair the pharyngeal and esophageal circular defects and reconstruct the pharyngeal and cervical esophageal functions.

After tracheotomy with general anesthesia, the patient is placed in supine position, and the shoulders are elevated. A large cervical U-shaped incision is made, and then the skin, subcutaneous tissue, and platysma muscle are incised; subsequently the skin flap is separated up to the upper margin of the hyoid bone and down to the level of the clavicle. The isthmus of the thyroid gland is cut off, then the blood vessels of the left lobe of the thyroid gland are ligated, and part of the left thyroid tissue is removed; subsequently the tracheoesophageal groove is exposed, and the superior mediastinum is explored to assess whether the pharyngeal or cervical esophageal cancer can be removed. When the tumor can be removed after assessment, the resection of cervical primary focus and the gastric dissociation in the abdominal group can be carried out, and the resection of the primary focus is performed. The superior laryngeal artery and the cricothyroid artery are ligated, while the normal thyroid and parathyroid gland are retained, then the trachea is cut off, and, finally, the tissues around the larynx are dissociated but not cut off and are connected to the esophageal entrance, so that the overall removal of the whole throat, whole hypopharynx, and whole esophagus is performed. When the membranous part of the trachea cannot be separated from the esophagus, it is required to remove the anterior wall of the trachea and the throat body, and the connection between the membranous part and posterior wall of the trachea, and the trachea is reserved until the next step of the operation is performed. The upper thoracic segment of the esophagus is separated with fingers and long instrument, then the esophagus and all sides of the throat body are dissociated, and then the surrounding tissues are gradually separated to the periphery of the upper thoracic segment of the esophagus. When separating the tissues around the esophagus, attentions are paid to ligating and cutting off the blood vessels feeding the esophagus for stopping bleeding, until the esophagus is dissociated to the level of the tracheal carina.

After deciding to perform total esophagectomy and replacement of the esophagus with pulled-up stomach, the surgeons of the thoracoabdominal group make the upper abdomen median incision to enter into the abdominal cavity and then explore the liver and colon, expose the anterior wall of the stomach, cut off the transverse ligament and gastrosplenic ligament, dissociate the gastric body, and separate the duodenum and pancreatic head to increase the range of motion of the stomach. The left gastric blood vessels and short gastric vessels are separated, ligated, and cut off. The right gastroepiploic vessels are preserved, and the right gastric blood vessels are retained as far as possible, which can also be ligated and cut off. The peritoneum around the esophageal opening is cut off, and a 1.5 cm long incision is made on the cervical esophagus at the level of thoracic entrance; then the esophagus stripper is inserted, and the stripper head is sent downward from the thoracic segment of the esophagus to the stomach, and then the gastric cardia connection is cut off; subsequently the lower end is passed through by coarse silk thread and is sutured and fixed to the stripper. The ligature line is the long ribbon gauze, and the surgeon holds the handle of the stripper and sustainedly and slowly draws it toward the direction of the neck to perform the invert stripping. On the one hand, the esophagus is stripped; on the other hand, the ribbon gauze is taken in from the abdominal cavity to the stripped esophagus bed for compression hemostasis. The stripped esophagus is in an inverted state, and it is taken out from the thoracic entrance. The upper and lower ends of the ribbon gauze are left on the outsides of the cervical and abdominal incisions. A tubular stomach is formed with a width of approximately 5 cm using a mechanical stapling along the lesser curvature side of the cardia, then the plasma muscularis suture is performed at the highest point of the tubular stomach, and then three 4-0 lines are used for traction lines; subsequently, the three traction lines are ligated at the ventral side of the ribbon gauze within the esophagus bed, and in general, the hemostatic gauze oppression is carried out for about 10 min. Then the ribbon gauze is pulled up from the neck, and thereby the stomach can be brought from the esophagus bed to the neck and is anastomosed with the esophageal stump or the hypopharynx. The posterior walls are anastomosed at first, and then the duodenal feeding tube is sent into the upper segment of the jejunum through the anastomotic stoma. Subsequently the stomach tube is sent into the stomach, and finally the anterior walls are anastomosed.

After the cervical wound is washed, 2–3 negative pressure drainage tubes are placed on the operation side, then the tracheal fistula is made, and subsequently the platysma muscle, subcutaneous tissue, and skin are sutured.

After the abdominal wound is routinely washed, the layered closure of the abdominal cavity is performed, and the routine X-ray chest examination is carried out in the operating room. If the patient has hydropneumothorax, it is required to carry out the thoracic closed drainage.

The advantage of the gastric replacement of the esophagus is that the upper gastrointestinal tract is repaired at the first stage, and there is only one anastomotic stoma; moreover, the supplying vessels are superior to those of other tissues, and the anastomotic stoma is not prone to stricture and leakage. Currently, after the use of the tubular stomach to replace the esophagus, the oppressions on the heart and mediastinum mitigate are alleviated, and the complications are reduced.

The gastric replacement of the esophagus is contraindicated for three types of patients as follows: patients with gastric and duodenal ulcers, gastric cancer, and absence of right gastric artery or insufficient blood supply, patients who have undergone thoracic and mediastinal or abdominal surgery, and patients who have the pharyngeal tumors involving the oropharynx and hypopharynx.

2.2.6 Subtotal Laryngectomy plus Pronunciation Tube Reconstruction

When the cancer in the unilateral medial hypopharyngeal wall invades a broader laryngeal range, retaining some part of the throat has a certain degree of difficulty. At that moment, the unilateral hypopharyngeal cancer and the invaded throat can be resected, the contralateral arytenoid cartilage and the posterior wall of the laryngeal cavity are retained, the remnant laryngeal cavity mucosa and the contralateral pyriform sinus mucosa and subglottic area are stitched into an air duct with a diameter of about 8 mm, the first and second tracheal rings are removed, and subsequently the trimmed tracheal wall is stitched into a dome cavity with the top opening opened into the mucous membrane duct. After surgery, the nozzle of trachea cannula is compressed and covered, and the air from the trachea can pass through the mucous membrane duct to enter into the pharyngeal cavity and make a sound under the assistance of the oronasal cavity. If there are fewer remnant mucosas, the submental flap can be used to repair the mucosa defect.

Case VII The patient, male, 58 years old, was admitted into the hospital because of having a sore throat combined with hoarseness for 2 months. The admission examination showed a mass of 2.0 cm × 2.5 cm in the epiglottis laryngeal surface, which invaded bilateral false vocal cords and vocal cords, with left vocal cord fixation and surface ulcers. Admission diagnosis: supraglottic laryngeal carcinoma $T_3N_0M_0$. The patient underwent subtotal laryngectomy with preservation of the right arytenoid cartilage + left cervical lymph node dissection in areas II, III, and IV + the repair of pharyngeal defects with submental flap under the general anesthesia (Fig. 14.5). Postoperative pathological examination report: hypopharyngeal highly and moderately differentiated squamous cell carcinoma, and no cancer was observed in the incisal margins and cervical lymph nodes.

2.2.7 Repair of Total Laryngeal Defect with Pectoralis Major Myocutaneous Flap or Anterolateral Thigh Flap

All patients with hypopharyngeal cancers which have invaded the throat and tongue root and have a wider range need to undergo total laryngectomy or partial hypopharynx resection. At this time, the pharyngeal mucosa defect is larger; thus, it is difficult to close the pharyngeal fistula. The pectoralis major myocutaneous flap is an excellent material for repair of pharyngeal defects, and it is the pedicled myocutaneous flap which takes the pectoral branch of the thoracoacromial artery as the axial blood vessel. Furthermore, the thick pectoralis

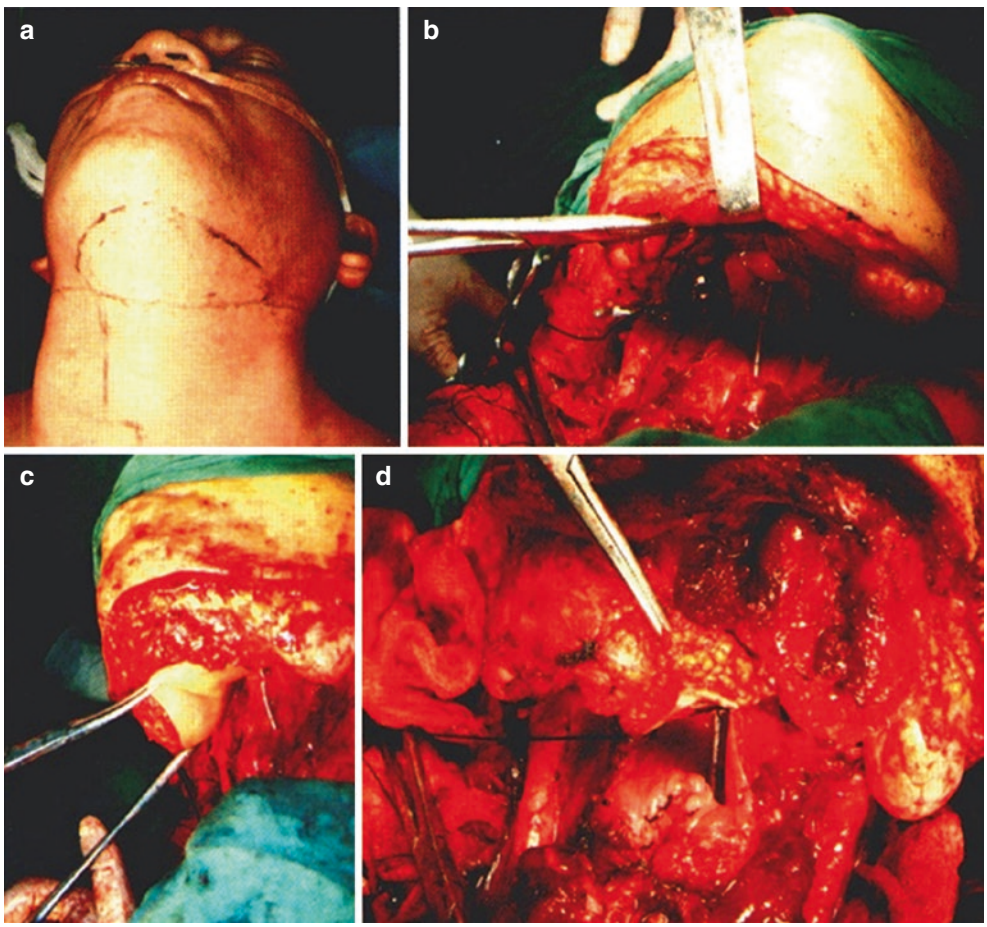

Fig. 14.5 Case VII. (**a**) Submental flap design. (**b**) Laryngeal and hypopharyngeal defects after laryngectomy. (**c**) The submental flap was implanted into the pharyngeal cavity. (**d**) Pronunciation tube reconstruction + the repair of hypopharyngeal defect with submental flap

major muscle can ensure a good blood supply to the skin flap. Generally speaking, the pectoralis major myocutaneous flap is harvested from the pectoralis major muscle at the same side of the pharyngeal defect requiring repair. After carrying out ipsilateral cervical lymph node dissection, total laryngectomy and/or tongue base resection, and partial hypopharynx resection, the size of the pectoralis major myocutaneous flap and the length of muscle pedicle are designed according to the size of the pharyngeal defect. The distance between the midpoint of the clavicle and the distal end of the pharyngeal fistula defect is measured at first, and then this point is used to mark the distance downward to the distal end of the pectoralis major myocutaneous flap. After the medial pectoralis major muscle and skin are incised, the pectoralis major muscle is removed from the rib surface until reaching the space between the muscle membranes of the pectoralis major and minor muscles. Thus the pectoral branch of thoracoacromial artery can be found in the deep surface of the muscle membrane of the pectoralis major muscle. The blood vessel is taken as the axis to make a pedicled skin flap with a pedicle width of 5 cm to be transferred into the cervical area, and the skin surface of skin flap faces toward the pharyngeal cavity and is sutured with the residual pharyngeal mucosa to close the pharyngeal fistula. Its muscle pedicle can cover and protect the carotid artery. In addition, the modified pectoralis major myocutaneous flap can be adapted to different patients. For example, for female patients, the skin flap can be designed on the medial side of the breast and present as elongated longitudinal flap, and the breast tissue and breast skin are separated outward. Furthermore, only the pectoralis major muscle and its medial skin are harvested as the myocutaneous flap. After the myocutaneous flap is transferred to the cervical area, the lateral breast tissue can be sutured inward with the skin of the incision to basically retain the relatively normal position of the breast. If the skin flap for repair is larger, it can be designed as the half-moon flap on the medial side and the underneath of the breast tissue to retain the breast tissue. Then the myocutaneous flap is transferred, and the breast is returned to its original place, which can not only reduce the breast deformity at the affected side but also cover the skin defect in the inner lower part of the chest. After the surgeons familiarly master the microsurgical techniques, the free anterolateral thigh flap can be preferably used to repair the pharyngeal mucosa defects. The vascular pedicle of this skin flap is long, and the diameters of the blood vessels are larger. Thus the vascular anastomosis can be performed easily to achieve a successful repair; the donor site of the skin flap is relatively hidden, so as to avoid the disadvantages of chest donor site scar and deformity due to the harvesting of pectoralis major myocutaneous flap [16].

Case VII The patient, male, 46 years old, was admitted into the hospital because of recurrence of laryngeal cancerous ulceration for 2 months and difficulty eating at the sixth month after vertical partial laryngectomy. The examination showed a cauliflower-shaped mass in the laryngeal cavity, and the cervical mass reached 12 cm × 8 cm, and the ulcerated area reached 8 cm × 6 cm. Admission diagnosis: postoperative recurrence of laryngeal cancer $T_4N_1M_0$. The patient underwent total laryngectomy; resection of the cervical mass; bilateral cervical lymph node dissection in areas II, III, IV, and V; and repair of pharyngeal mucosa and cervical skin defects with free anterolateral thigh flap under the general anesthesia. The upper middle one third of the skin was folded after the removal of some epidermis, then one third was used to repair the hypopharyngeal mucosa defect, and two thirds was used to repair the cervical skin defect (Fig. 14.6). Postoperative pathological examination report: hypopharyngeal highly and moderately differentiated squamous cell carcinoma, and no cancer was observed in the incisal margins. The postoperative radiotherapy was carried out.

2.2.8 Repair of Complex Pharyngolaryngeal Defects and Cervical Esophageal Defects

For recurrent laryngeal cancer or hypopharyngeal cancer or complex pharyngolaryngeal cancers, after the removal of the lesion, in addition to the pharyngeal mucosa defect, some advanced patients usually have cervical skin defects and cervical esophageal defects, and the defects requiring repair involve not only the pharyngeal mucosa and cervical skin but also the cervical esophagus. We use the free jejunum to replace the esophagus, the free anterolateral thigh flap to repair the defects in the tongue root and pharyngeal mucosa, and the pectoralis major myocutaneous flap to repair the cervical skin defects. The pharyngolaryngeal cancer patients with pharyngeal and cervical ulceration and stink are rescued from extremely poor quality of life to relatively normal quality of life. Due to the improvement of medical technology and the strong desires to survive of the patients, there is a gradual increase in patients who undergo repair of pharyngeal, esophageal, and cervical skin defects with two or three composite tissue flaps.

Case IX The patient, male, 36 years old, was admitted into the hospital because of recurrence of laryngeal cancer for 2 months at the sixth month after total laryngectomy. The examination showed a cauliflower-shaped mass in the laryngeal cavity; the cervical mass above the stoma reached 8 cm × 4 cm, and the ulcerated area reached 3 cm × 2 cm. Admission diagnosis: postoperative recurrence of laryngeal cancer $T_4N_1M_0$. The patient underwent resection of recurrent cancer with anastomosis; bilateral cervical lymph node dissection in areas II, III, IV, and V; and the repair of pharyngeal and cervical esophageal defects with free jejunum and the repair of the cervical skin defect with pectoralis major myocutaneous flap under the general anesthesia (Fig. 14.7). Postoperative pathological examination report: hypopharyngeal highly and moderately

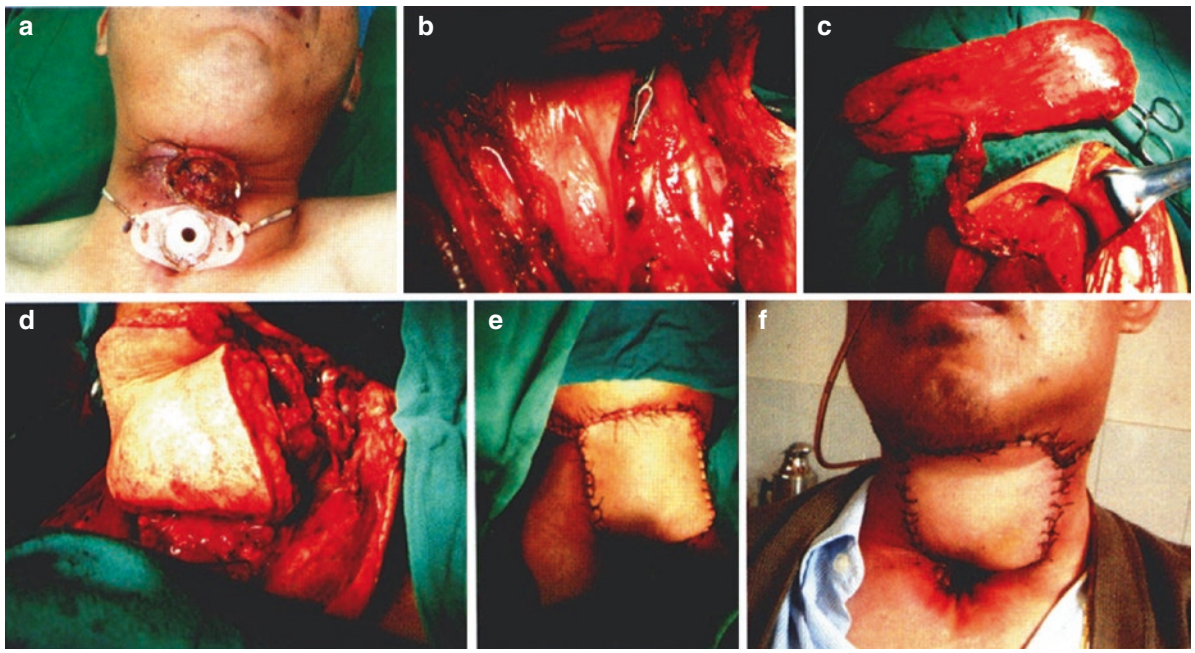

Fig. 14.6 Case VII. (**a**) Cervical mass and skin ulceration. (**b**) The pharyngeal and cervical soft tissue defects after resection of laryngeal cancers. (**c**) Preparation of free anterolateral thigh flap. (**d**) The free anterolateral thigh flap was folded to repair the defects in the pharyngeal mucosa and cervical skin. (**e**) The surgery was completed. (**f**) The wound healed well at the 2nd week after surgery

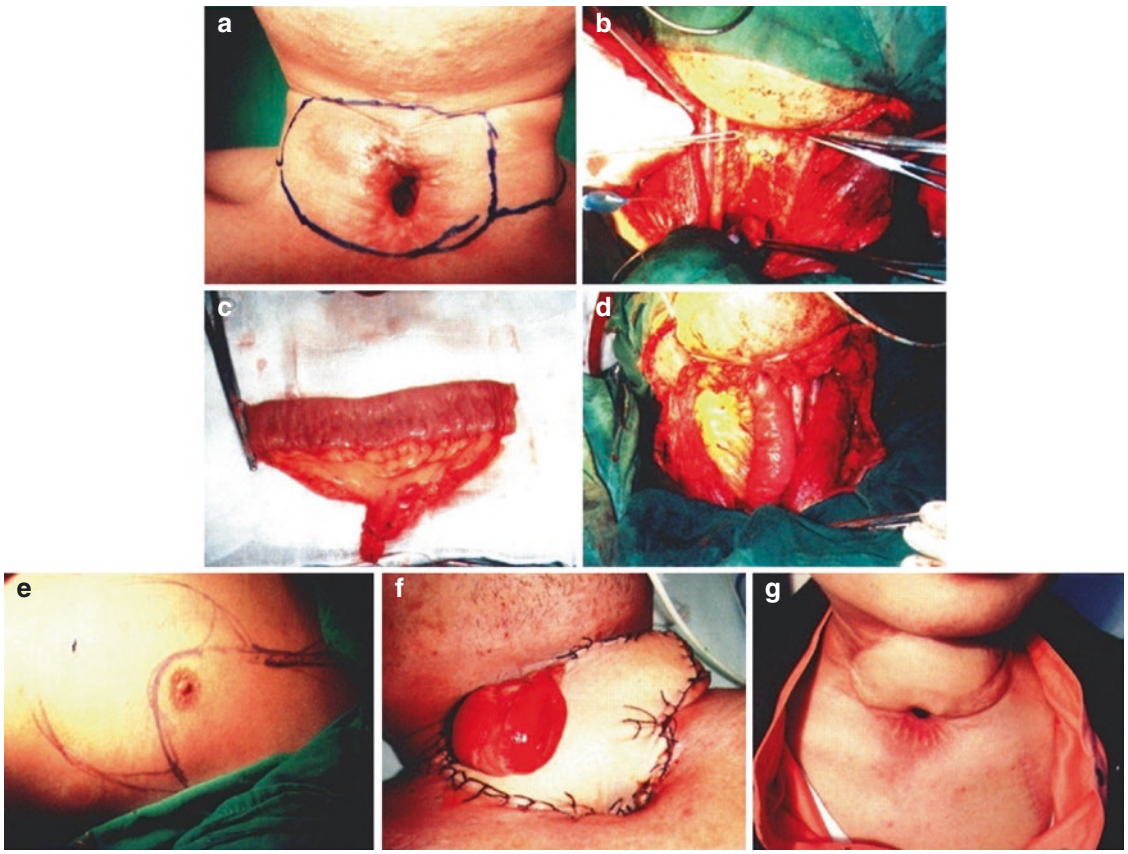

Fig. 14.7 Case IX. (**a**) Recurrent cancer and skin ulcers in tracheostomy stoma. (**b**) Hypopharyngeal mucosa and cervical skin defects. (**c**) Preparation of free jejunum. (**d**) The jejunum was used to repair the cervical esophageal and hypopharyngeal mucosa defects. (**e**) Preparation of pectoralis major myocutaneous flap. (**f**) The jejunum tube for observing the blood supply was placed externally and the pectoralis major myocutaneous flap was used to repair the cervical skin defect, and the surgery was finished. (**g**) The patient ate normally at the sixth month after surgery

differentiated squamous cell carcinoma, and no cancer was observed in the incisal margins. The postoperative radiotherapy was carried out.

Case X The patient, male, 67 years old, was admitted into the hospital because of laryngeal cancer recurrence after laryngeal vertical partial surgery and the uncontrolled condition after γ knife radiotherapy. The patient underwent total glossectomy, total resection of the oropharynx and hypopharynx, total laryngectomy, cervical esophageal resection, and cervical lymph node dissection under the general anesthesia. The jejunum was used to repair the cervical esophageal defects; the free anterolateral thigh flap was used to repair the pharyngeal mucosa defect and reconstruct the total tongue and a part of chin skin defect, and the pectoralis major myocutaneous flap was used to repair the cervical skin defect. The end-to-end anastomosis between the free jejunal mesenteric artery and the left facial artery, the end-to-side anastomosis between the mesenteric vein and the left internal jugular vein, the end-to-end anastomosis between the lateral femoral circumflex artery of free anterolateral thigh flap and the right lingual artery, and the end-to-side anastomosis between the vein and the internal jugular vein were performed successively, and all surgeries were successful (Fig. 14.8). Currently the patient can take the semiliquid diet and has survived for nearly 2 years.

All surgical photographs published in this chapter have been approved by the patients themselves.

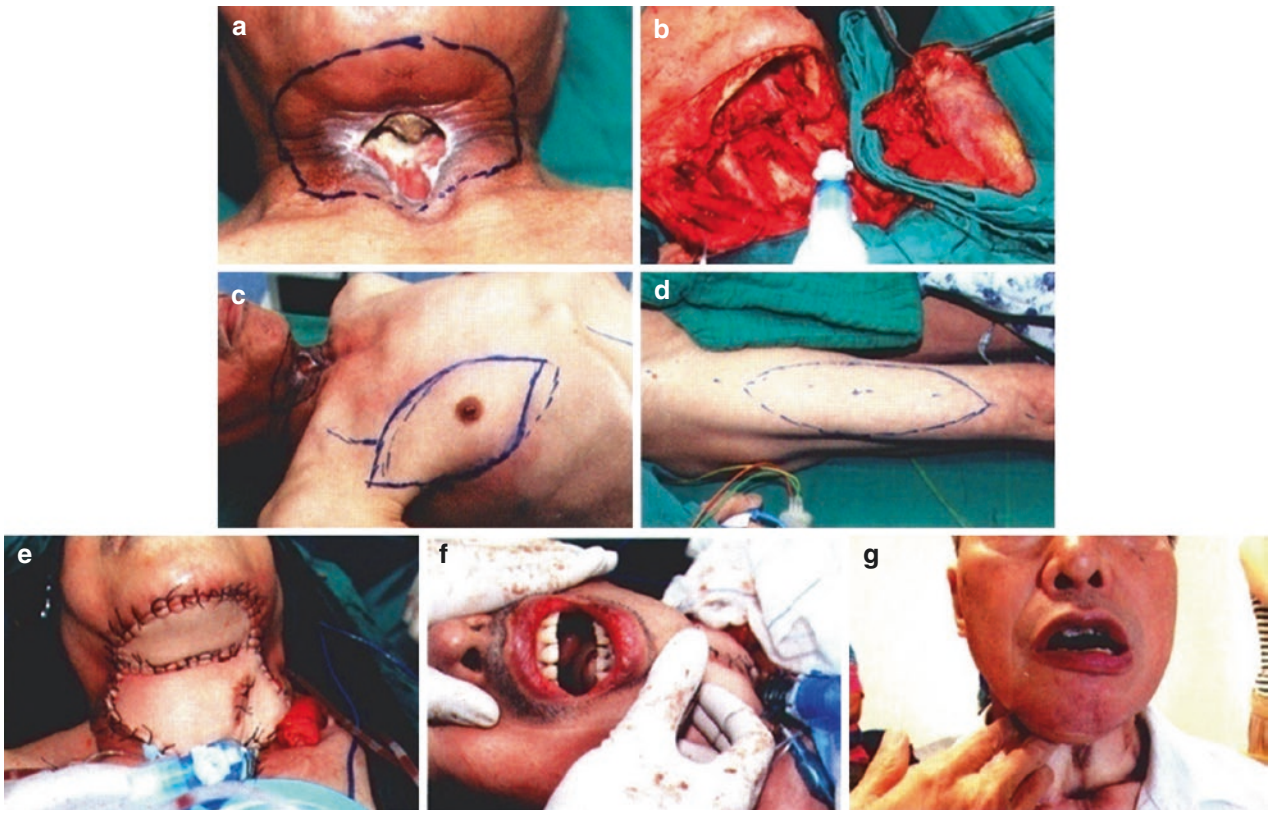

Fig. 14.8 Case X. (**a**) Preoperative cervical skin ulcers, pharyngeal fistula, and tongue base mass. (**b**) The tongue body mass specimen and cervical issue defects after primary focus resection. (**c**) Design of pectoralis major myocutaneous flap. (**d**) Design of free anterolateral thigh flap. (**e**) The chin skin defect was observed when the surgery was completed, and it is repaired with a portion of free anterolateral thigh flap; the cervical skin defect was repaired by the pectoralis major myocutaneous flap, and the window segment of the jejunum was pre-reserved in left cervical area to observe the blood supply. (**f**) The total tongue reconstruction with free anterolateral thigh flap was observed after opening the mouth. (**g**) The reexamination was performed one and a half years after surgery, and the patient could take liquid diet. Because the skin flap was relatively large, the patient usually needed to wear a tracheal tube. At this time the skin flap could be stretched open by hand for convenient inspection

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Defect Repair After Breast Cancer Surgery

15

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The breast cancer is the most common malignant tumor in women worldwide, and the incidence rate of breast cancer continues to increase in the past 20 years. It is estimated by World Health Organization (WHO) International Agency for Research on Cancer that in 2002 the patients with newly diagnosed breast cancers in women worldwide reach up to 1.15 million, accounting for 22.7% of total female malignant tumor incidence rate. The breast cancer is also one of the common tumors which damage the health of Chinese women. Some data shows that the breast cancer incidence rate in urban women of Shanghai has risen from 20.38/100000 in the 1970s to 69.22/100000 in 2007.

1 Breast Reconstruction After Breast Cancer Surgery

1.1 Overview

The breast is an important part of female body, is one of the landmark organs of secondary sex characteristic, and is the most important organ for female physical beauty. It has lactation and feeding functions and also has characteristics of the beauty. The absence of breast after breast cancer surgery not only affects the perfectness of the female body but also brings serious physical and psychological impacts on the patient, even affects the surrounding interpersonal relationship and the family stability, and causes a lot of inconvenience to social contact, work, and life of the patient. As people's living standards continue to improve and the breast reconstruction technology is improving, the breast reconstruction after breast cancer surgery is getting more and more attentions of people [1–9].

The breast reconstruction refers to the use of autologous tissue transplantation or breast prosthesis implantation to reconstruct the chest wall deformity and breast defect after mastectomy in patients suffering from breast diseases. Currently, the surgical methods for breast reconstruction include two categories of autologous tissue transplantation and breast prosthesis implantation, of which the transverse rectus abdominis myocutaneous flap in lower abdomen and the latissimus dorsi myocutaneous flap are most widely used.

The breast reconstruction aims to improve the quality of life (QOL) of the patients with breast cancers, but the breast reconstruction must be personalized, including assessment of the general condition of the patient, the choice of surgical approach for breast cancer resection, disease staging, and the symmetry of the contralateral breast [10–17]. A comprehensive examination in oncology should be carried out before breast reconstruction, the principles of oncology treatment are followed, and if the patients are found with systemic tumor metastasis or local recurrence, or vital organ dysfunction, they should not undergo breast reconstruction.

The timing of breast reconstruction is divided into immediate breast reconstruction and delayed breast reconstruction. The clinical practice has proved that it is safe and feasible to couple breast reconstruction (immediate breast reconstruction) with radical mastectomy, without significant differences in breast cancer recurrence and mortality rate compared to radical mastectomy alone. Therefore, the immediate breast

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reconstruction has become a trend in recent years. The advantages of the immediate breast reconstruction are that the patients have no psychological suffering due to breast defects, and the reconstructed inframammary folds are more natural; furthermore the local skin flap is more supple and smooth, and the total surgery cost and the total length of stay are less than those of the delayed breast reconstruction; the disadvantage is that the occurrence rate of the potential surgical complications is increased compared to the radical mastectomy alone.

The advantages of delayed breast reconstruction are that the patient has personal experience on breast defect and can make a rational judgment on whether to require breast reconstruction and the postoperative satisfaction is high. It is reported that the delayed breast reconstruction can reduce the incidence rate of upper limb lymphedema; the disadvantages are that two surgeries are required, and its cost is higher than that of the immediate breast reconstruction. It is considered traditionally that the patients who have no local recurrence and distant metastasis 1–2 years after breast cancer surgery can undergo breast reconstruction. Now it is generally considered that the delayed breast reconstruction can be performed at the third month after cessation of chemotherapy.

The choice of surgical approach for breast cancer resection should be determined based on the resection mode of breast cancer at the affected side and the situation of breast at the healthy side. The shape and direction of the scar after mastectomy at the affected side, the elasticity and texture of the skin, whether the pectoralis major muscle is retained, how is its quality, the statuses of tissue defects in infraclavicular and axillary areas, and whether the morphology of the anterior axillary folds are intact should be considered and examined at first. The fullness and the sagging degree of the breast at the healthy side as well as the patient's age, general physical condition, and previous surgical scars in the abdomen and back should be examined at the same time. Meanwhile it is taken into account that whether the patient has requirements for the breast at the healthy side to be enlarged or reduced as well as carrying out ptosis correction. In general, most patients refuse to receive any surgical operation on the breast at the healthy side.

TRAM flap breast reconstruction can nearly meet the requirements of all types of breast reconstruction, and its tissue volume is large. Moreover, the shape of the reconstructed breast is natural, with a certain degree of fullness and sagging degree, and can be symmetrical with the breast at the healthy side, especially when the requisite tissue volume is larger after radical mastectomy or extended radical surgery; the disadvantages are that the surgical trauma is larger and there is a possibility of appearance of abdominal hernia.

The latissimus dorsi myocutaneous flap and expanded latissimus dorsi myocutaneous flap are suitable for patients with benign breast tumor or partial breast defect after breast-conserving surgery and the patients with medium-sized breast at the healthy side after modified radical mastectomy with preservation of pectoralis major muscle or skin-sparing radical mastectomy. The prosthetic breast reconstruction may be combinedly used in some patients.

The breast reconstruction with breast prosthesis or breast prosthesis implantation after skin expansion is suitable for patients with medium-sized or smaller breasts which are not obviously sagging after modified radical mastectomy with preservation of pectoralis major muscle, particularly for patients who are unwilling or unable to accept the larger surgical trauma and the older patients.

1.2 Immediate Breast Reconstruction After Breast Cancer Surgery

The breast reconstruction can restore the morphology of the female breast, enhance the patient's physical and mental health, and improve the quality of life. For breast cancers detected in their early stages, the radical mastectomy and the breast reconstruction can be carried out at the same time. The immediate breast reconstruction after radical mastectomy consists of two parts of breast cancer resection and breast reconstruction. It requires the cooperation of breast surgeons and plastic surgeons. The surgeries can be divided into two groups of resection group and reconstruction groups and are carried out at the same time, and two groups of surgeries can also be carried out successively. In regard to the immediate breast reconstruction, attentions should be paid to factors in two aspects of oncological safety and cosmetic satisfaction. When the radical mastectomy is performed in department of surgical oncology, the key considerations are complete tumor resection, comprehensive treatment, and regular follow-up after surgery and timely detection of tumor recurrence, which prevent incomplete surgery effects caused by concerns on cosmetic effect; the tumor-free principle should be paid attention to during surgery to prevent tumor seeding and metastasis due to improper operation. In the department of plastic surgery, the key considerations are the cosmetic effect of the reconstructed breast, enhancing the blood supply of the skin flap and reducing the donor site complications.

1.3 Modified Radical Mastectomy and Immediate Breast Reconstruction

Halsted created and used the radical mastectomy in 1882, which requires removing the entire breast tissue including most of the breast skin, separating the thick chest skin flap, resecting the chest muscles, and thoroughly eliminating the axillary lymph nodes; this has become a standard surgical

mode for a long time. In the 1960s, the scope of partial resection gradually began to be narrowed, and the pectoralis major muscle was retained, whereafter some research data showed that there was no significant difference in survival rate between treatment methods of two groups. Thus the modified radical mastectomy gradually replaced the radical mastectomy and became the most commonly used treatment method for the breast cancer.

The surgical method of the modified radical mastectomy is largely identical but with minor differences, but it is different for each person, including all aspects such as the position, orientation and size of the incision, resection sequence, the scope of axillary lymph node dissection, drainage tube placement, and postoperative wound dressing. Just as what Silen has said: "the reason why it is called a modified radical mastectomy is that everyone has their own improvements on the basis of Halsted."

1.3.1 Breast Cancer Resection

For the patients with unclear diagnosis, a complete resection of breast mass is performed under local infiltration anesthesia, and the frozen section pathological examination is carried out. After the diagnosis is confirmed, the anesthesia, sterilization, and surgery are carried out again.

The breast skin resection is aimed to resect the skins which may be invaded by tumor cells at the same time of resecting the breast tissue. The spindle-shaped incision may be either traverse or longitudinal, and the appearance after traverse incision is better. The resection scope should include the biopsy incision, at least more than 1–2 cm away from the areola margin and the biopsy incision.

1. Mastectomy: After incising the skin along the marker line, the assistant pulls the skin flap with a skin retractor, and the surgeon oppresses and pulls the breast tissue with the left hand and holds an electric scalpel with the right hand for separation. The larger blood vessels are ligated or electrically coagulated for hemostasis at any time. The dissection scope of skin flap includes up from the clavicle and down to the area at 2–3 cm under inframammary fold which is close to the costal margin; the medial side is the sternum midline, and the lateral side is near to the anterior margin of the latissimus dorsi muscle. The skin flap should include the subcutaneous fatty tissue with a thickness of 0.5 cm to maintain the blood supply and prevent skin flap necrosis. The pectoralis major fascia is incised from the medial side, then the breast tissue together with the pectoralis major fascia is separated outward, and then the intercostal perforators of the internal thoracic vessel are carefully ligated. Meanwhile, attentions are paid to the prevention of the retraction of the vascular stump into the thoracic cavity. It has been reported that blindly finding the retracted vascular stumps in the intercostal space would damage the pleura to lead to pneumothorax. Stripping is carried out from inner to outer side to the lateral side of the pectoralis major muscle, as the Cooper ligament gradually disappears, the separated layers are more obvious, and the operation is relatively easy to carry out. For the patients with tumors in a deep location which is adhered to the pectoralis major fascia, it is required to remove a part of the pectoralis major muscle at the tumor site. The lateral margin of the pectoralis major muscle is dissociated to expose the pectoralis minor muscle, and the pectoralis minor fascia and the lymphoid tissue between two muscles are removed from inner to outer side. At this time, attentions should be paid to the medial anterior thoracic nerve which bypasses the pectoralis minor muscle to enter into the bottom of the pectoralis major muscle, and damaging this nerve can lead to atrophy of the lower one-third of the pectoralis major muscle. Both pectoralis major and minor muscles are retracted upward and inward to expose the axillary vein and axillary fat pad.
2. Axillary lymph node dissection: Along with the proposal of the concept of sentinel node, currently the scope of the axillary lymph node dissection is one of the focuses of debate within the field of breast surgery. Clinical data show that the dissection of anterior group and central group of the axillary lymph nodes and subscapular lymph nodes (grade 1 and 2 lymph node dissections) has been able to play the role of preventing axillary tumor recurrence and suggesting the prognosis; thus it is not necessary to carry out conventional dissection of the apical group of the axillary lymph nodes (grade 3 lymph node dissection). Among the breast cancer patients without distant metastasis, the patients with the involvement of the apical group of the axillary lymph nodes account for less than 4%, and grade 3 lymph node dissection will greatly increase the probability of the upper limb chronic lymphedema after surgery. Currently grade 1 and 2 lymph node dissections are mostly widely used in clinics.

   The dissection methods are as follows: The axillary fascia is opened to expose the axillary vein and ligate the vascular branches, and then its surrounding lymph nodes are dissected. Furthermore it is noted that the outer membrane of the axillary vein is not stripped. Dissection is performed downward and outward along the axillary vein and the lateral chest wall, and then the serratus anterior muscle fascia and the fascias of subscapular muscle and latissimus dorsi muscle in the armpit are separated. Meanwhile, attentions are paid to protecting the long thoracic nerve, thoracodorsal nerve, and intercostal nerve and protecting the subscapular blood vessels, and, finally, the breast together with the pectoralis major fascia, pectoralis minor fascia, interpectoral lymph nodes, the lymph nodes around the axillary vein, and the fascias of other muscles is removed. In the process of dissection, attention

should be paid to performing ligation with suture line at the same time of using the electric knife, which can reduce postoperative lymphatic fluid exudation.

After the axillary lymph node dissection is completed, the wound bleeding is carefully stopped. The wound is washed with normal saline or distilled water, then a port site is made at the lowest point of the axillary flap, and then the porous latex tube is placed; subsequently, postoperative negative pressure suction, dressing filling, and compression bandaging are carried out, and thus the attachment of the axillary flap is promoted to prevent hematoma formation.

1.3.2 Immediate Breast Reconstruction

It is applicable to the patients with reconstruction requirements, carcinoma in situ or stage 1 and 2 early breast cancers, and no general surgical contraindications such as serious heart and lung diseases and diabetes.

The methods for immediate breast reconstruction are the same as the methods for the second-stage breast reconstruction. Each reconstruction method has its own advantages and disadvantages, and it can be selected on the basis of the situation of the patient and the experience of the operator. The reconstruction methods include prosthesis implantation using dilator, extended latissimus dorsi myocutaneous flap, and TRAM flap. For oriental women with medium-sized breasts, the extended latissimus dorsi myocutaneous flap is one of good methods. When the autologous tissue is transplanted for breast reconstruction, we like to use the TRAM flap or the extended latissimus dorsi myocutaneous flap.

The modified radical surgery preserves the intact pectoralis major muscle and does not destroy the morphology of the anterior axillary folds, and it is not needed to fill the infraclavicular area; therefore, the required tissue volume is relatively small, and the single-pedicled TRAM flap with removal of area 4 and partial area 3 of the flap with poor blood supply can meet the requirements of reconstruction. It is found during surgery that there is venous flow obstruction, and the skin flap has extravasated blood with purple plague, which can be simply treated additionally with anastomosis of a vein. The severe complications in the donor site of the extended latissimus dorsi myocutaneous flap are lighter and less than those in donor site of the TRAM flap, and the tissue volume is sufficient; thus, it is especially suitable for medium and small breast reconstruction, and it is a good surgical method for oriental woman.

When the breast shaping is performed, the patient takes the semi-recumbent position, and the upper end of the skin flap is fixed to the subclavicular area. Since the morphology of the anterior axillary folds is preserved, it is not necessary to fix the skin flap to the medial side of the upper arm. When the volume of the skin flap is less, the caudate lobe cannot be shaped. When the inframammary fold is stripped off, the affected side should be symmetrical to the healthy side, and it is sutured and formed to form the new the inframammary fold.

1.3.3 Complications

1. Hematoma, subcutaneous effusion/hematoma, and subcutaneous effusion: They are the most common complications after breast cancer surgery. The incision hematoma formation is mostly due to intraoperative incomplete hemostasis, and the intraoperative complete hemostasis is the key to prevent hematoma. The negative pressure drainage tube is placed within the incision, and the local compression bandage is carried out reliably, which is conducive to preventing the incision hematoma formation. When the hematoma is larger, it is required to timely open the wound, remove the extravasated blood, stop bleeding again, and prevent infection. The subcutaneous effusion is pale yellow and is composed mixedly of serum exudation and lymph exudation, and it occurs mostly due to poor fixation of skin flap or obstructed drainage. The axillary subcutaneous fascia is sutured intraoperatively; the compression bandage in the armpit is performed; the unobstructed and continuous negative pressure drainage is maintained after surgery, and these are the keys to preventing subcutaneous effusion. The subcutaneous effusion is commonly seen in the axillary region and the lower end of the incision. When the negative pressure drainage tube is placed, the gas leakage should be prevented, and the effusion is drained out from the lowest point of the skin flap. When the subcutaneous effusion is found, if the volume is small, the puncture drainage and compression bandaging may be performed; if the volume is large, it is required to poke a hole and place the negative pressure drainage tube again or take out several stitches for incision open drainage, and the local compression bandaging is performed.
2. Injury of the axillary vein and phlebitis: The vein injury occurs during dissection of adipose tissue surrounding the axillary vein, usually due to the unclear anatomy or the fact that the operation is performed too closely to the axillary vein when cutting off the branches of the axillary vein. After the axillary vein is injured, it is compressed with gauze at first; it is avoided to clamp the vein with vascular clamp hurriedly to exacerbate the injury. When the axillary vein is slightly lacerated, the bleeding will be stopped after compressing for a certain period of time; when the axillary vein is seriously lacerated, it should be sutured and repaired. The axillary phlebitis occurs mostly after peeling of the outer membrane of the vein, and avoiding excessively peeling the outer membrane of the vein is the key point of prevention.
3. The flap margin necrosis is a common complication after surgery, and it is usually due to the fact that the skin flap

is separated too thinly and the skin suture tension is too large. Improving skin flap separation technology, reserving about 5 mm thick of subcutaneous fat layer, and carrying out skin transplantation when the skin defect is too much are the key points of prevention.

4. Injuries of the intercostobrachial nerve and long thoracic nerve: The injury of the intercostobrachial nerve will lead to numbness and hypesthesia in the posterolateral area of the armpit and the medial upper arm; thus, the emphasis should be laid on the prevention. The peripheral cutaneous nerve after injury can be partially compensated, but which requires a longer period of time. The injury of the long thoracic nerve will lead to paralysis of the serratus anterior muscle and cause deformity such as winglike shoulder. The deformity such as winglike shoulder is mostly temporary and usually disappears within 1–6 months.
5. The lifting up of the affected limb is limited, which is the common complication after surgery, and is usually due to subcutaneous scar contracture or the fact that the time of upper limb immobilization is too long, and the early postoperative functional exercise is the key point of prevention and treatment. Common exercise methods are as follows:
   (a) Finger climbing wall of the affected hand: The patient stands facing to the wall, and then the fingers of the affected hands climb upward along the wall; furthermore, the heights reached everyday are recorded.
   (b) Abduction exercise of the affected limb: The fingers are closed together, then the affected limb is raised and abducted forcefully, and then the hand is used to bypass the occipitoposterior region to touch the contralateral auricle; furthermore, the movement is trained repeatedly until the patient can touch the contralateral auricle.
6. Radiation-induced ulceration: With the progress of radiotherapy method, the incidence rate of radiation-induced ulceration has decreased significantly. The radiation-induced ulceration can affect the skin and subcutaneous tissue; thus, the treatment is required to remove the diseased tissue, and the chest wall defect is covered with a pedicled skin flap. The commonly used skin flaps include TRAM flap, latissimus dorsi myocutaneous flap, and contralateral breast flap.
7. Chronic lymphedema of the affected limb: It is the complication which is most difficult to treat after breast cancer surgery. It is generally believed that the occurrence of lymphedema is associated with the scope of the axillary lymph node dissection and the radiotherapy. The more complete the lymph node dissection is, the more likely to occur the lymphedema is; the radiotherapy can increase the probability of occurrence of lymphedema, but even the same surgeon uses the same surgical approach, a few limb lymphedemas will still occur. Now it is considered that the lymphatic system itself of the affected limb in the patients with upper limb lymphedema already has primary dysplasia or a kind of defect.

1.3.4 Oncological Factors After Immediate Breast Reconstruction

1. Oncological safety of immediate breast reconstruction: The breast reconstruction is traditionally performed 2–3 years after radical mastectomy and under the condition that there is no local recurrence and distant metastasis. With advances in breast cancer treatment, 5-year survival rate of early breast cancer has reached more than 80%. In addition, due to increased promotion of scientific knowledge, as well as the spread of community awareness about cancer prevention and the improvement of guided percutaneous biopsy technology, the early detection of breast cancer has become possible. In the late 1980s and early 1990s in countries such as Europe, Japan, and the United States, the immediate breast reconstruction has been carried out in succession. Webster reported 85 patients undergoing breast cancer resection and breast reconstruction at the same time and compared them with the patients undergoing radical resection of breast cancer alone. The results showed that the immediate breast reconstruction was safe and effective, not only did not increase complications and mortality but also maintained the shape of the breast, which is conducive to upper limb lymphatic drainage and wound healing; practice shows that the breast cancer resection and breast reconstruction can be performed at the same time.
2. Monitoring of tumor recurrence: Whether the monitoring and early detection of tumor recurrence are affected after breast reconstruction becomes one of the focuses of discussion. Practice has proved that the mammography and ultrasound can be used for early detection of tumors within the reconstructed breast, and selecting experienced breast surgeons and regular follow-up are the keys to early detect the tumor recurrence. After breast reconstruction with single-pedicled TRAM flap, 25–50% of patients have fatty degeneration due to unstable blood supply; thereby, the local lumps or nodules are formed; subsequently, they will be gradually absorbed over time, and the individual nodules can be removed when the nipple reconstruction is performed. The fat mass puncture is conducive to identifying the denatured fat nodules or recurrent tumors.
3. Chemotherapy and radiotherapy after breast reconstruction: The immediate breast reconstruction does not affect the implementation of postoperative chemotherapy. Hidalgo carried out immediate breast reconstruction with TRAM flap in 28 patients, and the postoperative pathological examination showed 8 patients had positive

axillary lymph nodes, of whom 4 patients had 3 or more positive axillary lymph nodes; 11 patients received postoperative chemotherapy, and one patient received radiotherapy, while 5 patients received chemotherapy and radiotherapy at the same time. The authors carried out immediate breast reconstruction with TRAM flap in 24 patients. The postoperative pathological examination showed that six patients had positive axillary lymph nodes, of whom one patient had three positive axillary lymph nodes; the conventional chemotherapy was carried out routinely after surgery, and one patient received chemotherapy and radiotherapy at the same time, while one patient started to receive chemotherapy one and half months after surgery due to delayed wound healing.

The immediate breast reconstruction is to remove the breast and create a new breast shape at the same time, so as to restore the female physical beauty and improve the quality of life of the patient. The patient only needs to undergo a surgery, which reduces the suffering and the economic burden of the patient. The immediate breast reconstruction has no significant relationship with prognosis of the patient, there is seldom local recurrence, and the distant metastasis is generally related to biological characteristics of the tumor. Even if there is local recurrence and distant metastasis, it can also be treated with the treatments which are the same as those given after radical mastectomy, including chemotherapy, radiotherapy, and hormone treatment. The immediate breast reconstruction is safe and feasible, can meet the requirements of two aspects of cancer treatment and physical beauty, and improve the quality of life of patients, and it is a treatment worthy of promotion.

1.4 Skin-Sparing Modified Radical Mastectomy and Immediate Breast Reconstruction

The surgical treatment of breast cancer has experienced the transitions such as Halsted radical mastectomy, extended radical mastectomy, and modified radical mastectomy and is developing toward the direction of breast-conserving surgery which is mass resection or quadrant resection combined with radiotherapy. The scope of local resection is increasingly narrowed. In China, due to the special caution of the oriental peoples and the fear of incomplete tumor removal, the breast-conserving therapy has not been universally accepted, and most patients still receive modified radical mastectomy. The conventional modified radical mastectomy removes the breast tissue. Meanwhile, it removes a chunk of oval breast skin including the nipple and areola. With the progress of treatment of breast cancer, there has been a qualitative change in the understanding of the breast skin. The breast cancer is a malignant tumor occurring in breasts, and it belongs to systemic disease in early phase, rarely involving the breast skin. For patients with early and midterm tumor without involvement of local skin, the removal of the breast skin has no effect on the survival rate. Thus, since the early 1990s, the skin-sparing mastectomy began to be gradually carried out, and currently the skin-sparing mastectomy has been widely carried out [15].

The postoperative local recurrence of breast cancer mainly comes from the remaining breast duct epithelium instead of the breast skin tissue. The skin-sparing mastectomy is defined as the removal of the mammary gland and areola duct epithelium and possibly involved local skin and the axillary lymph node dissection. The skin-sparing mastectomy has a small incision, but the scope of resection is the same as that of the traditional modified radical surgery.

The immediate breast reconstruction is an important part of skin-sparing mastectomy and is the significance of the surgical improvement. The breast reconstruction is not performed after skin-sparing mastectomy, while the excessive skin should be removed, and the simple nipple reconstruction should be performed or the incision is adjusted and sutured. Otherwise, the excessive skin can cause fluid retention, skin adhesion, or contracture.

Hidalgo defined the complete skin-sparing radical mastectomy as that the incision is located in the areola margin, while he defined the changes in the incision on this basis as near-complete skin-sparing radical mastectomy, for example, the incision is extended inwardly and outwardly with a certain distance away from the areola. In order to completely remove the breast ductal epithelium in areola area, some people consider that the incision should be 3 mm away from the areola margin, and some people recommend that the incision should be 5 mm away from the areola margin. We advocate that the incision should be 5 mm away from the areola margin. Therefore, on the one hand, it is endured to remove the breast ductal epithelial tissue in areola area; on the other hand, the reconstructed areola is slightly larger than that at the healthy side, so that there is a space to adjust the size of areola when the second-stage areola reconstruction is performed [17].

Jensen called the immediate breast reconstruction after skin-sparing radical mastectomy as the breast body replacement therapy and compared it with breast-conserving surgery. The local tumor recurrence rate after lumpectomy and radiotherapy was increased over time, and it was increased by about 1% per year. The results of a postoperative

follow-up of 10 years showed that the local tumor recurrence rate was 15–25%. In addition, 10% of patients had fibrosis, hardening, contracture, or pain in the breasts after radiotherapy; and the local recurrence rate after skin-sparing mastectomy was 1–5%. Jensen believed the implementation of the breast body replacement therapy would change the current treatment principles of breast cancer and would become the preferred method of treatment for the breast cancer [16].

The immediate breast reconstruction after skin-sparing mastectomy, just like the conventional modified radical mastectomy, completely removes the breast tissue and axillary lymph nodes, while the chest incision is small with a hidden location, similar to the nipple and areola, which greatly improves the morphological effect of the reconstructed breast. In addition to the nipple and areola, the skin of the reconstructed breast is the original breast skin, and it keeps the skin sensation, which contributes to the sensation recovery of the reconstructed breast.

1.4.1 Indications

It is mainly applied to early breast cancer patients with requirements for breast reconstruction and without general surgical contraindications, including tumors in stages 0, l, and 2 and 2a.

1.4.2 Incision Design

A circular incision around the areola is marked at 5 mm away from the areola margin (Fig. 15.1a). If there is a biopsy incision around the areola, the biopsy incision should be included. The incision can be extended toward the outside or inside of the breast according to the location of the mass (Fig. 15.1b, c), and it presents as a table tennis racket. If the location of the mass is superficial, a part of the skin on the surface of the mass should be removed (Fig. 15.1d). An additional axillary incision is made for axillary lymph node dissection. When the mass is located in the upper outer quadrant, the axillary lymph node dissection can also be performed through table tennis racket-shaped incision. If there is an incision for mass biopsy, the biopsy incision can be included into the "handle of the table tennis racket," and it can also be removed through making an additional incision.

For patients with huge and sagging breasts, especially those whose breast at the healthy side also needs to receive plastic surgery, it is necessary to perform breast plastic surgery at the same time of removing the breast and remove the excessive breast skin to achieve bilateral symmetry. Based on the vertical scar breast reduction method, the incision for partial resection of the skin below the breast can be used to the reduced breast skin. For particularly large breasts, when it is required to reduce the skins in both vertical and horizontal directions, it is recommended that the surgery is completed by several times. The vertical incision is used to reduce the horizontal skin at first (Fig. 15.2a), and the breast reconstruction is performed; the vertical skin is reduced 6 months later, and the incision is made in the inframammary fold, and then the "orecchiette" of breast reconstruction is removed and reconstructed (Fig. 15.2b). The advantages of the fractional resection are the same as the characteristics of the vertical breast reduction, and it can reduce the length of the incision in the inframammary fold and reduce the formation of scars.

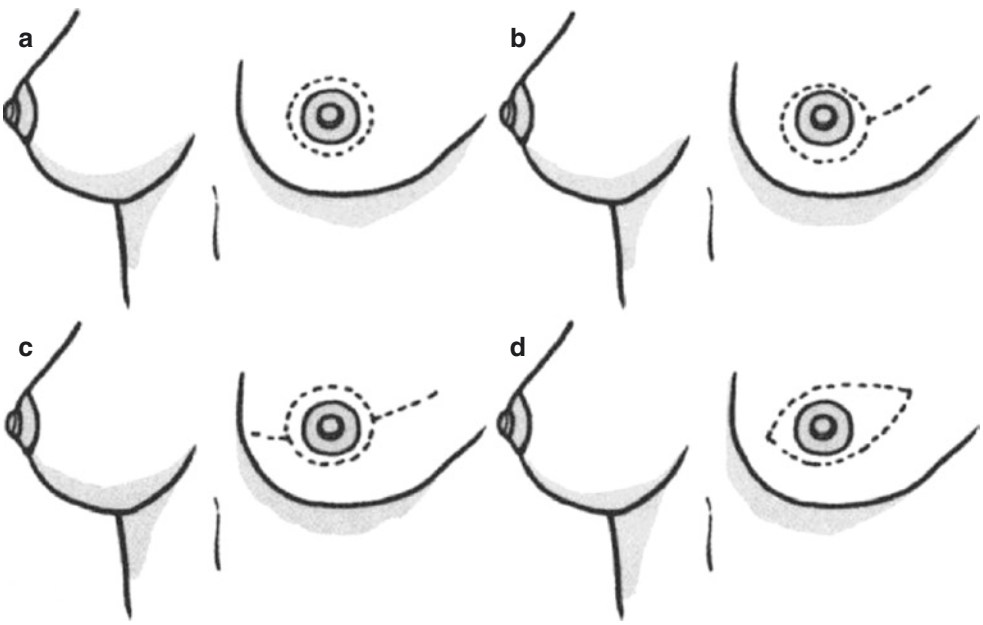

Fig. 15.1 The incision of skin-sparing modified radical mastectomy. (**a**) The circular incision 5 mm away from the areola margin. (**b**) The biopsy incision around the areola extended toward the outer side of the breast (the incision looked like a table tennis racket). (**c**) The biopsy incision around the areola extended toward the outside or inside of the breast. (**d**) The incision after removal of a part of the skin on the surface of the mass

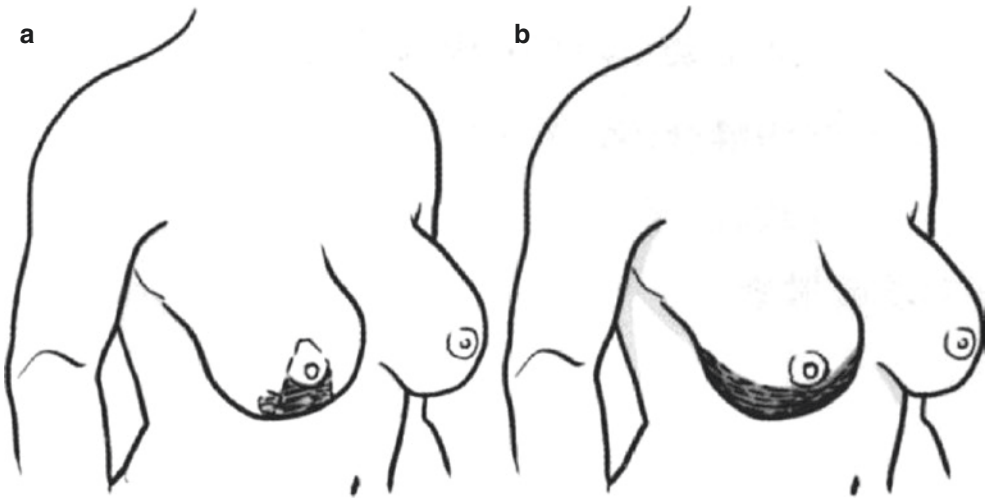

Fig. 15.2 The surgical incision in macromastia patient after sparing modified radical mastectomy. (**a**) The vertical incision for reducing the horizontal skin. (**b**) The incision in the inframammary fold for reducing the vertical skin

1.4.3 Surgical Methods

1. Mastectomy and axillary lymph node dissection: The surgeries are performed under general anesthesia. The breast flap is stripped at first, then the subcutaneous resection of mammary tissue is performed, and then the axillary lymph node dissection is performed. Two issues should be paid attention to during mastectomy, namely, the first one is to ensure the blood supply of the skin flap, and the second one is to maintain the intactness of thoracodorsal vessels. When the skin flap is dissected, it is required to not only remove all breast tissue but also ensure a certain thickness to avoid excessive tissue damage caused by the electric knife and maintain a good supply of the skin flap blood supply. Maintaining the intactness of thoracodorsal vessels can make preparations for carrying out vascular anastomosis, if necessary in the process of breast reconstruction, and can increase the safety of surgery. The axillary lymph node dissection can be performed referring to modified radical mastectomy.
2. Immediate breast reconstruction: The TRAM flap or extended latissimus dorsal myocutaneous flap can be selectively used for immediate breast reconstruction after skin-sparing mastectomy. The required skin tissue for immediate breast reconstruction after skin-sparing mastectomy is limited to the area of the nipple and areola. When the second-stage local flap nipple and areola reconstruction is performed, the circular areola skin has been slightly pulled and transformed; thus, it is necessary to make some adjustments. The areola skin should be slightly larger than that in the contralateral side during immediate reconstruction of breast body, and it can be adjusted to the size which is symmetrical to that of the healthy side when the second-stage nipple reconstruction is performed.
   (1) TRAM flap breast reconstruction: The skin-sparing radical mastectomy retains the pectoralis major muscle and breast skin on the basis of modified radical mastectomy, while the breast reconstruction only requires reconstructing the breast body, and it needs small tissue volume compared to tissue volume needed after radical mastectomy. The TRAM flap pedicled with superior epigastric vessels with removal of tissues in area 3 and 4 can meet the needs of breast reconstruction, and it is an effective and feasible surgical method. After the abdominal incision is sutured, the blood supply of the skin flap is intraoperatively examined; when there are signs of spotted skin and venous congestion, the epigastric inferior vessels and thoracodorsal vessels should be anastomosed to increase the safety of surgery. It is generally adequate to anastomose a vein.

   When the TRAM flap breast reconstruction is performed, the patient is placed in the supine position, the contralateral rectus abdominis muscle is taken as the pedicle to harvest TRAM flap, which is transferred to the chest through the subcutaneous tunnel, and the abdominal incision is closed. The following several points should be noted during harvesting of TRAM flap: ① after the epigastric inferior vessels are found with intramuscular separation techniques, the running directions of the blood vessels are confirmed behind the muscles, then the rectus abdominis muscle is separated, and then the muscle is brought into the skin flap minimally; ② in order to prepare for vascular anastomosis if necessary, the epigastric inferior vessels are separated to the femoral artery and vein, and they are harvested as long as possible for standby application; ③ the sputum is aspirated before the patient wakes, and the extubation is timely carried out to prevent the choking caused by respiratory irritation, which will lead to the burst apart of the area where the rectus abdominis muscle is sutured; ④ the

drainage tube should be drawn out through the middle of the lower abdomen, because the effusion easily occurs in this site to form the seroma, and the wound healing is delayed; and ⑤ attentions are paid to the repair of abdominal shape. The measures such as deepening the navel area, forming the depression on the middle of the abdomen, and highlighting the outline of the rectus abdominis muscle are adopted to simulate the abdominal morphology of the young woman [13, 14].

(2) Breast reconstruction with extended latissimus dorsal myocutaneous flap: The patient is placed into the lateral position to receive mastectomy, axillary lymph node dissection, and breast reconstruction. A crescent-shaped incision is made on the back corresponding to the area covered by the brassiere, and it is bent toward the head side. The flap width is about 7 cm. The latissimus dorsi myocutaneous flap and its surrounding fat tissue are harvested, and then the serratus anterior branch of the thoracodorsal artery is separated and protected and is transferred to the chest via subcutaneous tunnel. The areas of the shoulder and buttock are propped up with pillows after surgery to prevent flap necrosis caused by compression of the donor site, and the patient is encouraged to carry out early activities after recovery from anesthesia. Generally it is not needed to use the breast prosthesis in breast reconstruction with extended latissimus dorsal myocutaneous flap.

When combined with breast prosthesis for breast reconstruction, the muscle should cover breast prosthesis as far as possible, especially in the area around the areola incision, so as to prevent prosthesis exposure when the partial necrosis of original breast skin margin occurs after surgery. When the prosthesis is covered by the muscle, the necrotic tissue can be removed, and the incision is closed and sutured again, or the wound will be healed by dressing change.

(3) Breast shaping: The key of breast shaping is to keep the symmetry of the inframammary fold with that at the healthy side. If the inframammary fold is stripped off during mastectomy, the skin and the underlying tissue should be sutured and fixed to form the inframammary fold. When the inframammary fold is fixed, the distance between the areola to the inframammary fold should be equal to that at the healthy side. Otherwise it will easily lead to deviation of nipple position or the insufficient fullness of the lower half of the breast. During breast shaping, the upper and outer side of the skin flap are sutured and fixed onto the upper margin and outer upper side of the cavity gaps in the anterior part of the chest, and the areola area skin is preserved; meanwhile, the epidermis is removed, and the skin flap is folded and shaped; finally, the wound margin is sutured (Fig. 15.3).

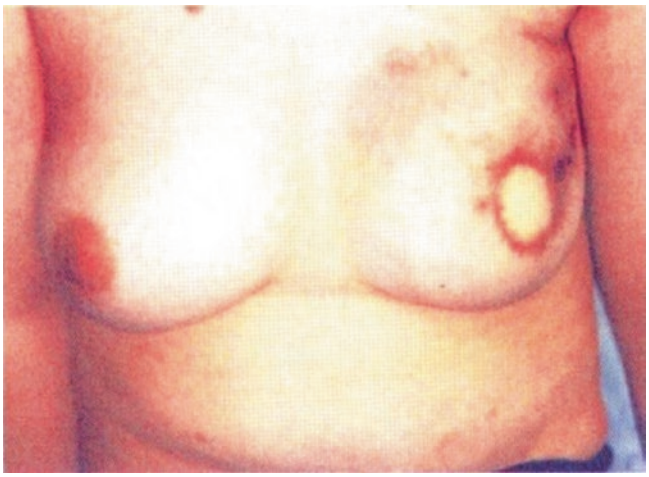

Fig. 15.3 After immediate breast reconstruction with the TRAM flap after modified skin-sparing mastectomy

(4) Nipple reconstruction and auxiliary operations: At the third month after surgery, the star-shaped flap is used for reconstruction of the nipple and areola after the flap swelling subsides and the condition is stable, and then the colored tattoo is made; thus, the entire process of breast reconstruction is completed. If there is local asymmetry, it is needed to be adjusted with syringe liposuction. In the immediate breast reconstruction after modified skin-sparing mastectomy, the position of the nipple and areola can be limited; in individual case, the nipple and areola reconstruction can be performed ahead of time about 2 weeks after reconstruction of the breast body.

1.4.4 Sensory Recovery

After immediate breast reconstruction combined with modified skin-sparing mastectomy, because of the extensive dissection between the skin flap and the base, the sense of the original breast skin disappears transiently. The sense of touch begins to recover firstly at the second week after surgery, and the sense of pain begins to recover at 4 weeks after surgery. At sixth month after surgery, in addition to slight poor two-point discrimination, the sense has been basically restored to the same level as that at the healthy side. A slight tactile and pain sense of the nipple and areola skin can only be restored at the sixth month after surgery.

1.4.5 Complications

The common complication of the skin-sparing modified radical mastectomy is the partial necrosis of the original chest skin. It is mainly due to the fact that the stripped skin is too thin or the electric knife damages the skin tissue. Slavin reported that the

incidence rate was as high as 21.6% in 51 cases of patients, while Hidalgo reported that the incidence rate was zero in a group of 28 cases of patients. In our group of patients, only one patient had chest skin congestion and redness after surgery, and there was only 1.5 cm of necrosis in the incisal margin skin, which healed after conservative treatment.

The axillary effusion is often caused by intraoperative incomplete hemostasis or poor drainage. The negative pressure drainage tube should be adjusted and replaced when the axillary effusion occurs to ensure smooth drainage and prevent air leakage, and the local pressure dressing is performed. One patient underwent drainage for 12 days after surgery, and then the wound was healed. The local small effusion in parasternal area may be treated by puncture and suction, and the pressure dressing is performed. When the prosthesis is used for breast reconstruction, the perforation of the prosthesis should be prevented.

1.5 The Modified Radical Mastectomy with Preservation of Nipple and Areola and the Immediate Breast Reconstruction

With the progress of the treatment of breast cancer, maintaining the perfect morphology of the female breast at the same time of radically curing the tumor has achieved broad consensus. Based on the Fisher's theory of breast cancer biology, the surgical treatment of breast cancer has experienced the transitions, such as Halsted radical mastectomy, extended radical mastectomy, and modified radical mastectomy, and is now developing toward the direction of breast-conserving surgery which combines the mass resection or quadrant resection with radiotherapy; thus, the scope of local resection is increasingly narrowed. Traditionally it is believed that the breast cancer surgery should completely remove the breast tissue and all ductal epithelial tissues including those in the area of the nipple and areola. Along with the progress of treatment of breast cancer, especially after carrying out of the breast-conserving treatment, there has been a qualitative change in the understanding of the breast cancer tumor characteristics. The treatment of breast cancer should be the same as the treatments of other tissue tumors, and the purpose is to remove the tumor tissue and the possibly involved surrounding tissues and lymph nodes. Therefore, some people are continuously exploring the methods for breast cancer treatment with preservation of the nipple and areola since a very early period at home and abroad. With the constant improvement of breast reconstruction technology in recent years, the modified radical mastectomy with preservation of the nipple and areola is attached with great importance again. Combined with immediate breast reconstruction, it has become the gland replacement therapy in its true sense.

The progresses of the modified radical mastectomy with preservation of the nipple and areola mainly focus on continuous improvement of surgical incision, and it is expected to reduce surgical scars and improve cosmetic results. The surgical incisions reported in the literatures include inframammary fold incision, U-shaped incision, anterior axillary fold incision, etc., and the methods for breast reconstruction include breast prosthesis implantation, TRAM flap, and latissimus dorsi myocutaneous flap. We used subaxillary longitudinal incision to simultaneously complete the breast cancer resection and the breast reconstruction with expanded latissimus dorsi myocutaneous flap, and the surgical results were improved significantly.

1.5.1 Indications

It is mainly applied to early breast cancer patients with requirements for breast reconstruction whose lesions are far away from the nipple and areola without general surgical contraindications, and it is not suitable for patients with advanced tumors.

1.5.2 The Use of Subaxillary Longitudinal Incision for Immediate Breast Reconstruction with the Expanded Latissimus Dorsi Muscular Flap After the Modified Radical Mastectomy

1. Incision design: A longitudinal incision is made at the midaxillary line under the armpit, and a length is about 10–15 cm; thus, the incision is completely covered when the upper limbs are sagging, and no surgical scars are left on the chest and back. The incision is near the anterior axillary fold, and it is easy to expose the incision scar when the upper limbs swing (Figs. 15.4 and 15.5).

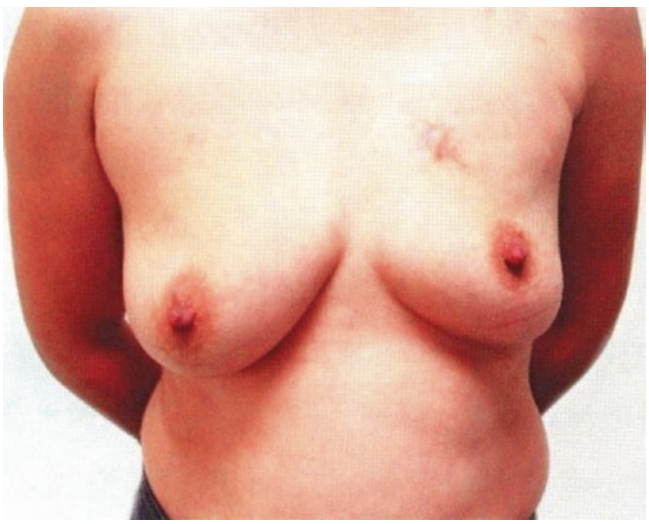

Fig. 15.4 After immediate breast reconstruction with the expanded latissimus dorsi muscular flap after the modified radical mastectomy with preservation of the nipple and areola

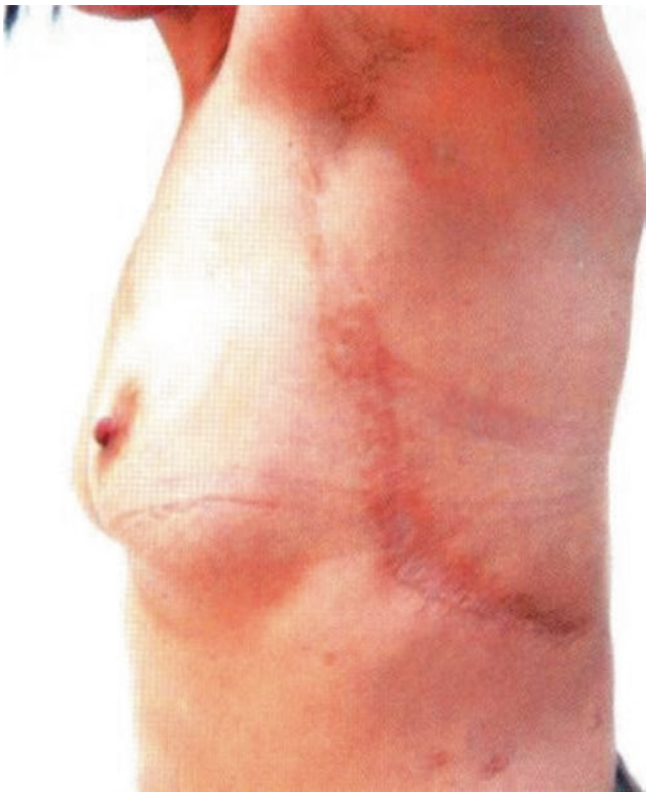

Fig. 15.5 The lateral chest wall incision of immediate breast reconstruction with the expanded latissimus dorsi muscular flap after the modified radical mastectomy with preservation of the nipple and areola

2. Surgical methods
   (1) Mastectomy and axillary lymph node dissection: The surgery is performed under general anesthesia. The patient is placed in the lateral position; the breast flap is separated and stripped at first and then is separated to the inframammary fold; subsequently, the subcutaneous resection of mammary tissue is performed; after that, the axillary lymph node dissection is performed. The subcutaneous injection of the saline solution containing a little adrenaline for vertical separation is conducive to surgical operation. When the breast is resected, it is required to not only remove all breast tissue but also ensure a certain thickness to avoid excessive tissue damage caused by the electric knife and maintain a good blood supply of the skin flap. Maintaining the intactness of thoracodorsal vessels is the premise of breast reconstruction with latissimus dorsal myocutaneous flap. The axillary lymph node dissection is completed through the same incision. When the tumor is near the breast skin, the skin with a width of 3 cm on the surface of the mass is removed, and the wound margin is directly sutured.
   (2) Breast reconstruction with extended latissimus dorsal myocutaneous flap: The saline solution containing a little adrenaline is subcutaneously injected through vertical axillary incision with epidural anesthesia needle, then the back flap is separated and stripped, and then the latissimus dorsal myocutaneous flap and its surrounding fat tissue are harvested; subsequently, the serratus anterior branch of the thoracodorsal artery is separated and protected and is transferred to the chest via subcutaneous tunnel. The negative pressure drainage tube is placed in the donor site. Generally it is not needed to use the breast prosthesis in breast reconstruction with extended latissimus dorsal myocutaneous flap (refer to relevant chapters for surgical methods).
   (3) Breast shaping: The key of breast shaping is to keep the symmetry of the inframammary folds with that at the healthy side. If the inframammary folds are stripped off during mastectomy, the skin and the underlying tissue should be sutured and fixed to form the inframammary fold. When the inframammary fold is fixed, the distance between the areola and the inframammary fold should be equal to that at the healthy side, and otherwise it will easily lead to deviation of nipple position or the insufficient fullness of the lower half of the breast. During breast shaping, the muscle surface of the myocutaneous flap is folded and sutured to form the breast body, and the lateral margin of the breast body is sutured and fixed to prevent tissue lateral displacement after surgery. After the shaping is completed, a negative pressure drainage tube should be placed along the inframammary fold. The negative pressure drainage tube is routinely placed in the site of axillary lymph node dissection, and the compression bandaging is performed moderately with the pectoral girdle.
3. Progress in the harvesting of expanded latissimus dorsi muscular flap: The use of subaxillary longitudinal incision for immediate breast reconstruction with the expanded latissimus dorsi muscular flap after the modified radical mastectomy with preservation of the nipple and areola avoids the surgical incision scar on the breast surface. At the same time, how to reduce the scars on the back donor site and shorten the axillary scar has become one of directions for the scholars to explore. With the popularity of endoscopy, the endoscopic harvesting of expanded latissimus dorsi muscular flap can avoid the surgical scar on the donor site, but because the body shows a certain curvature and lacks natural cavities, and the difficulty of surgical operation is increased, some scholars hold adverse opinions. United States Anderson Cancer Hospital reported the application of robot-assisted harvesting of expanded latissimus dorsi muscular flap in 2011, which is likely to be one of the future development directions.

1.5.3 The Use of Breast Incisions in Immediate Breast Reconstruction After the Modified Radical Mastectomy

The use of subaxillary longitudinal incision for immediate breast reconstruction with the expanded latissimus dorsi muscular flap has obvious advantages, but when the TRAM flap or breast prosthesis is used for reconstruction, this incision is not suitable. The incisions reported in the literatures include inframammary fold incision, U-shaped incision, and periareolar incision, of which the breast incision has excellent exposure, and the scar is not obvious; thus, the reconstruction effect is good.

The breast incisions of the modified radical mastectomy with preservation of the nipple, areola, and breast skin are roughly divided into three types:

1. The periareolar incision: If the areola circumference is small, if necessary, the incision can be extended toward the inside or the outside and even the inferior side according to the location of the tumor, which facilitates the exposure (Fig. 15.6a).
2. The incision at the lateral side of the breast, the incision along Langer's line above the breast, or the arc incision at the lateral side of the breast: All these incisions are located on the breast surface on the outside of the nipple, along the static tension line of the breast skin, which is conducive to reducing the scar formation (Fig. 15.6b).
3. The incision at the lower part of the breast: This incision is particularly useful for patients with huge and sagging breasts, and the breast skin can be reduced, and the breast can be shaped during mastectomy, especially in the patients with the breast at the healthy side requiring plastic surgery simultaneously (Fig. 15.6c).

The mastectomy and axillary lymph node dissection are carried out via abovementioned incisions, and it is necessary to retain a certain thickness of the tissue at the bottom of the nipple to prevent papillary necrosis. If necessary, an additional skin incision can be made in the armpit, which is conducive to axillary lymph node dissection. The reconstruction method selectively uses the first-stage prosthesis implantation, dilator-prosthesis implantation, or TRAM flap reconstruction according to the circumstances.

1.5.4 Complications

The common complication of the modified radical mastectomy with preservation of the nipple and areola is partial or total necrosis of the nipple and areola, and it is mainly due to the fact that the stripped skin is too thin or the electric knife damages the skin tissue.

The axillary effusion is often caused by intraoperative incomplete hemostasis or poor drainage. The negative pressure drainage tube should be adjusted and replaced when the axillary effusion occurs to ensure smooth drainage and prevent air leakage, and the local pressure dressing is performed.

1.6 Breast-Conserving Treatment and Immediate Breast Reconstruction

With the progress of breast cancer treatment, now it is considered that the early breast cancer belongs to the systemic

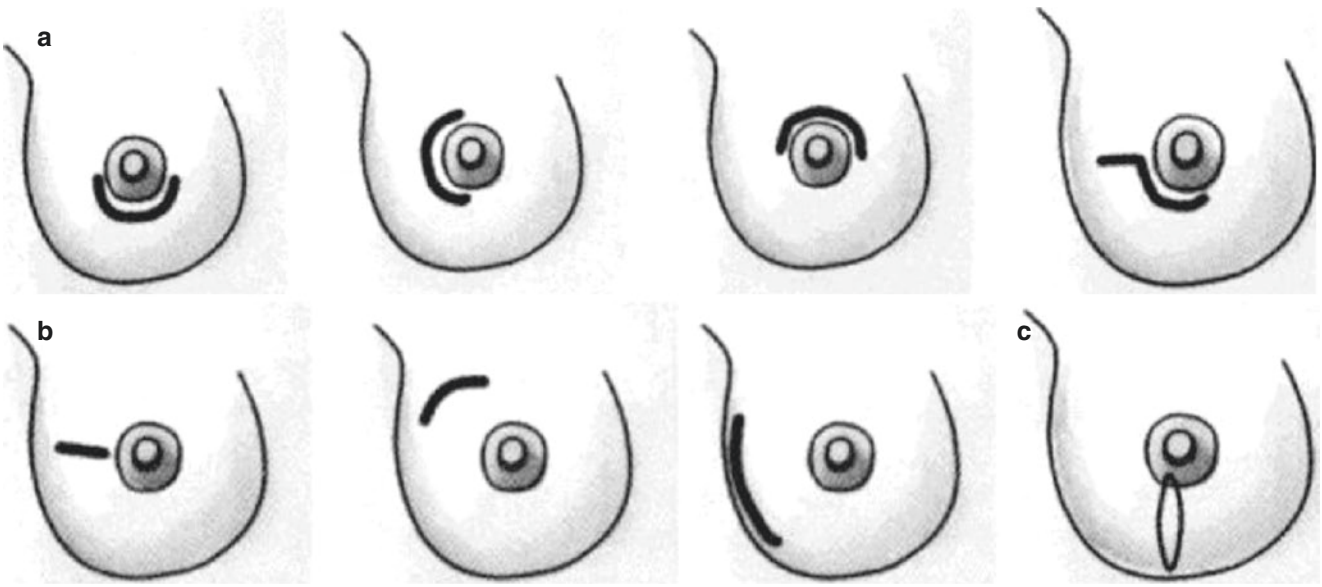

Fig. 15.6 Three types of incisions of the modified radical mastectomy with preservation of nipple, areola, and breast skin. (**a**) The periareolar incision. (**b**) The incision at the lateral side of the breast, the incision along Langer's line above the breast, or the arc incision at the lateral side of the breast. (**c**) The incision at the lower part of the breast

disease, and the distant metastasis is closely related to tumor biological characteristics, while the surgical removal of the breast tissue aims to remove the tumor tissue and control the local growth and recurrence of the tumor, and the scope of the surgical resection shows a narrowing trend. In recent years, the breast-conserving treatment mainly including partial breast resection combined with postoperative radiotherapy has been gradually popularized in oversea countries. The breast-conserving treatments in European and American countries have accounted for 70% of early breast cancers and account for only about 20% in Japan. The works in this aspect have been gradually carried out in areas such as Shanghai, Beijing, and Tianjin of China. However, due to factors such as the special caution of the oriental peoples, the fear of the tumor, poor tolerance to tumor recurrence, as well as insufficient popular science propaganda education on breast cancers and due to the fact that the tumors have developed into middle and advanced stage when the patients visit hospital, the breast-conserving therapy has not been popularized and applied in China. According to meeting data of the breast cancer branch of Shanghai Anti-cancer Association on December 25, 2010, the breast-conserving surgeries in Shanghai account for about 7–9% of breast cancer surgeries, and most patients still receive preferably the modified radical mastectomy. The breast-conserving treatment has three purposes: ① to completely remove the tumor tissue including the part of normal breast, ② to meet the requirements of female physical beauty, and ③ to maintain the sensation of the breast as far as possible.

So far, a lot of surgical methods for breast-conserving treatment have been reported, including names such as mass resection, segment resection, local lesion resection, quadrant resection, and partial breast resection. Except for the quadrant resection, other methods do not particularly limit the resection range of surrounding normal breast tissue. We hold the opinion that they are more appropriately to be called as partial breast resection, and its connotation is to remove the tumor tissue and part of the surrounding normal breast tissue. The breast-conserving treatment is defined as partial breast resection combined with local radiotherapy. If the tumor is located in the upper outer quadrant of the breast, the patient should also undergo axillary lymph node dissection simultaneously. After the early-stage breast cancer patients undergo quadrant resection with postoperative radiotherapy, the survival rate and local recurrence rate are the same as those of patients after undergoing mastectomy; but for some patients with smaller breasts, excessive tissues are removed in quadrant resection, which affects the appearance of breast. So far, the best volume of resection of normal tissue around the tumor still has no clear criteria, and further clinical studies are expected to be carried out.

1.6.1 Influence Factors on Breast-Conserving Treatment

1. Oncological factors
   (1) The frozen section examination of incisal margins should be carried out intraoperatively, but the pathological examination can only provide the approximate situation. Theoretically, the complete histological examination for incisal margins of the tumor with a diameter of 2 cm requires at least 2000 sections, but in the actual clinical work, a small number of sections can be only taken to reflect the local situation. Therefore, by contrast, the nature of the tumor can better determine the volume of resection of tissue and the prognosis.
   (2) The histological features of the tumors: 1 cm of breast tissues surrounding the tumor should be removed in patients with the sclerosing ductal carcinoma with clear boundaries; the volume of resection of tissues in the patients with invasive glandular carcinoma with unclear boundaries should be increased, and the examination of incisal margins is carefully performed; for the patients with invasive ductal carcinoma, which grows invasively along the ducts, the resection volume should be further extended, and the careful pathological examination is performed. It is reported in the literatures that the local recurrence rate of this type of tumors is higher, and it is considered unsuitable for breast-conserving treatment, and the mastectomy should be performed.
   (3) The breast-conserving treatment is not suitable for the multicenter breast cancer.
2. Cosmetology factors: The significance of breast-conserving treatment is to completely remove the tumor tissue but not destroy or destroy as little as possible the appearance of the female breasts. Therefore, the factors relating to cosmetology should be considered during the treatment process.
   (1) Relationship between the tissue resection volume and the breast size: For the patients with medium-sized or smaller-sized breast, the removal of excessive breast tissue volume can cause serious breast deformation, and the fiber contracture due to the postoperative radiotherapy will further aggravate the breast deformation in some patients. It is generally believed that the tissue resection volume in the patients with medium- and small-sized breasts does not exceed 25% of the total volume; the larger tissue resection volume can be removed in patients with larger breasts. If certain principles for breast reduction surgery in plastic surgery are adopted, a good appearance still can be maintained even though 50–60% of the breast is removed. In this type of patients, the appropriate local dissociation after

resection of bulk tissue can maintain good blood supply to the breast tissue, but also maintain the good appearance of the breast shape.

(2) The location of the tumor: The breast tissue volume in the upper part within the breast is less and the thickness is thin; thus, the removal of the tumor tissue in this part can cause deformities such as local depression or upper shift of the nipple; on the contrary, the breast tissue volume in upper outer part of the breast is more; thus, the deformation will not easily occur after the tumor in lateral or lower part of breast is resected, and the cosmetic effect is better.

(3) The direction of resection of the breast skin and breast: Any surgical incision of the breast should consider related cosmetic surgery principles. In general, the skin incision should be consistent with the skin tension lines, but the nipple will be easily shifted downward when the transverse incision in the lower half of the breast is made to resect a part of the skin. Therefore, the transverse incision should be made in upper half of the breast, and the radial incision should be made in the lower half of the breast. The glandular part is resected using radial wedge or fusiform resection, so as to reduce nipple displacement. The tumor located in the middle of the breast should be resected through areola margin incision or the transverse incision within the areola. The tumor near the areola should be resected together with the nipple and areola, and the nipple and areola can be reconstructed at a later stage.

(4) Scar contracture after surgery and radiotherapy: The surgery and radiotherapy may cause fibrosis, and the wound hematoma or seroma can further cause scar formation to lead to contractures and even lead to the nipple displacement. The induration can be palpated in local area in some patients, which is softened gradually and disappears over time. The surgical trauma should be reduced as far as possible during surgery; thus, the subcutaneous extensive dissection is avoided; meanwhile, the careful hemostasis is carried out, and the principles of noninvasive surgery are strictly adhered to.

1.6.2 Indications

It is mainly used in patients with early-stage breast cancers who require breast-conserving treatment, including tumors of stages l and 2 and 2a. The best indications are focal ductal carcinoma in situ and invasive carcinomas of stage $T_1N_0M_0$ and$T_1N_1M_0$.

There are more than two lesions in different quadrants for the same breast; the affected breast has diffuse calcifications; there is diffuse ductal carcinoma, and the treatment unit does not have conditions for radiotherapy. All of the above conditions should be considered as the surgical contraindications. The patients receiving breast-conserving treatment should be followed up regularly. If the breast-conserving treatment fails, the surgical resection will be performed at any time. Therefore, the breast-conserving treatment should also be used with caution in patients lacking regular follow-up.

1.6.3 Surgical Methods

1. Partial breast resection: Firstly, the methylene blue is used to mark the surgical skin incision and the resection range of the breast; if there is a biopsy incision, the biopsy incision scar should be removed together as far as possible. The skin flap is separated on both sides to fully expose the tumor, then en bloc resection of 1–2 cm of breast tissue surrounding the tumor is performed, and the depth reaches up to the pectoralis major muscle, including part of the pectoralis major muscle fascia. If the bottom is near the pectoralis major muscle, a part of pectoralis major muscle should be removed, and the resection depth is consistent with that of the modified radical mastectomy (see Fig. 15.6). The resection specimen is marked with suture lines. Although in theory, the frozen sections cannot fully reflect the situation in surgical margins; it is still necessary to carry out frozen pathological examination in clinical practice. If the surgical margins are invaded, the resection range should be expanded.
2. Effects of gravity action: After partial breast resection, the breast tissue defects can be aligned and closed by themselves with the help of gravity action; thus, most of them do not need to be sutured. Due to the gravity action, the incisions in middle upper and lower parts of the breast can't be closed, and furthermore the incision wound is ripped off. Therefore, the breast tissues in these parts need to be sutured. When the glandular tissue is selectively sutured, it is recommended to use the absorbable suture lines. When the alignment is performed, tight knots or distorted tissues should be avoided; otherwise, the local induration can be palpated after alignment. The patient is placed in the semi-recumbent position during surgery. Whether there is local depression or deformation is observed, and timely adjustments should be made when the deformation is found. Finally, the drainage tube is placed, and the skin is sutured with nylon threads.
3. Axillary lymph node dissection: In addition to the primary lesions located in the tail of the breast, an additional incision should be selected for the axillary lymph node dissection. S-shaped or axillary fold incision is often used, and specific methods are the same as those of axillary lymph node dissection.
4. The immediate breast reconstruction after breast-conserving surgery can be divided into two types: one type is the surgery to adjust the original breast tissue, and another type is the tissue augmentation surgery.

(1) The surgery to adjust the original breast tissue is suitable for patients with larger breasts, and the surgical method is determined based on the breast volume and the resection scope of the breast:
   (a) For the patients with larger breasts and small-sized resection scope, it is not needed to make special adjustments.
   (b) For the patients with larger breasts and medium-sized resection scope, the basal breast is slightly separated on both sides of the skin flap, and the breast body is sutured again. The breast tissue near the areola is thicker; thus, two-layer closure should be performed; the breast tissue near the outside of the breast becomes thin; thus, only a layer of closure needs to be performed.
   (c) For the patients with larger-sized resection scope, the principles for breast reduction surgery can be applied. The defect in lower half of the breast is repaired with inferior pedicle flap, and the defect in upper half of the breast is repaired with superior pedicle flap.

(2) The tissue augmentation surgery is suitable for patients with a smaller breast size and a relatively large tissue resection volume. Since the original tissue volume is less, and lacks the space for adjustment, it is necessary to carry out tissue transplantation and filling. The commonly used transplants include local subaxillary skin flap and latissimus dorsi myocutaneous flap. According to the size of skin defects, the epidermis of whole skin flap can be removed, and partial skin of the skin flap can also be retained (refer to related chapters and sections for the surgical methods). Most authors believe that TRAM flap should be used in the reconstruction after whole mastectomy, and the TRAM flap should not be used in the repair of partial breast defect. It is noteworthy that for the patients with smaller breasts, relatively large resected breast tissue volume, and severely distorted breast, the morphological effects of the skin-sparing modified radical mastectomy combined with breast reconstruction would be better.

1.7 Delayed Breast Reconstruction

1.7.1 TRAM Flap Breast Reconstruction

Hartrampf reported that there was a history of nearly 20 years since the use of TRAM flap for breast reconstruction, and it is currently the most commonly used surgical method for breast reconstruction and has been called as the standard surgery for breast reconstruction [12].

1. Applied anatomy: The rectus abdominis muscle is located on both sides of the abdominal midline, and the upper end is wider and the lower end is narrow. The upper end starts from the xiphoid and the areas of fifth to seventh costal cartilages, and the lower end terminates at the pubic symphysis and pubic crest. The rectus abdominis muscle is located within the sheath of rectus abdominis muscle, with three to four tendinous intersections, and Hunter's line is located between both left and right sheaths. The anterior sheath of the rectus abdominis muscle is intact, the posterior sheath forms into the semicircular line at 5.8 cm below the umbilicus, and there is no posterior sheath below this line.

   The blood supply of the TRAM flap mainly comes from the superior and inferior epigastric arteries and their accompanying veins. The upper one-third of the rectus abdominis muscle is supplied with blood by superior epigastric vessels. The middle and lower parts of the rectus abdominis muscle are supplied with blood by inferior epigastric vessels. There are very big individual differences between superior and inferior epigastric vessels. It is generally believed that there exist direct anastomosis branches between superior and inferior epigastric vessels within muscles.

   Single-pedicled TRAM flap is divided into four regions according to the status of the blood supply: region I is located on the surface of the abdominal rectus pedicle, and the blood supply is best; region II is located on the surface of the contralateral abdominal rectus muscle, and the status of blood supply takes second place; region III is located on the outside of the abdominal rectus pedicle, and on the same side of the muscle pedicle, the status of blood supply takes third place; and region IV is located on the outside of the contralateral abdominal rectus muscle of the pedicle and on the contralateral side of the muscle pedicle and is symmetrical to region III, and the blood supply is worst (Fig. 15.7).
2. Surgical method and indications: The safe blood supply range of TRAM flap pedicled with unilateral superior epigastric vessels is about 60% of the skin flap, namely, regions I and II and part of region III. For patients with scars in the center of the lower abdomen, the blood supply to the contralateral side of pedicle is affected. The appendectomy scar does not affect the blood supply of the skin flap; if there is a transverse incision scar of the rectus abdominis muscle, the pedicled transfer cannot be performed. Therefore, after the modified radical mastectomy with preservation of pectoralis major muscle, in addition to appendectomy incision, the patients without other abdominal scars are suitable for application of single-pedicled TRAM flap.

   After radical mastectomy or extended radical mastectomy, the required tissue volume is large, while the tissue

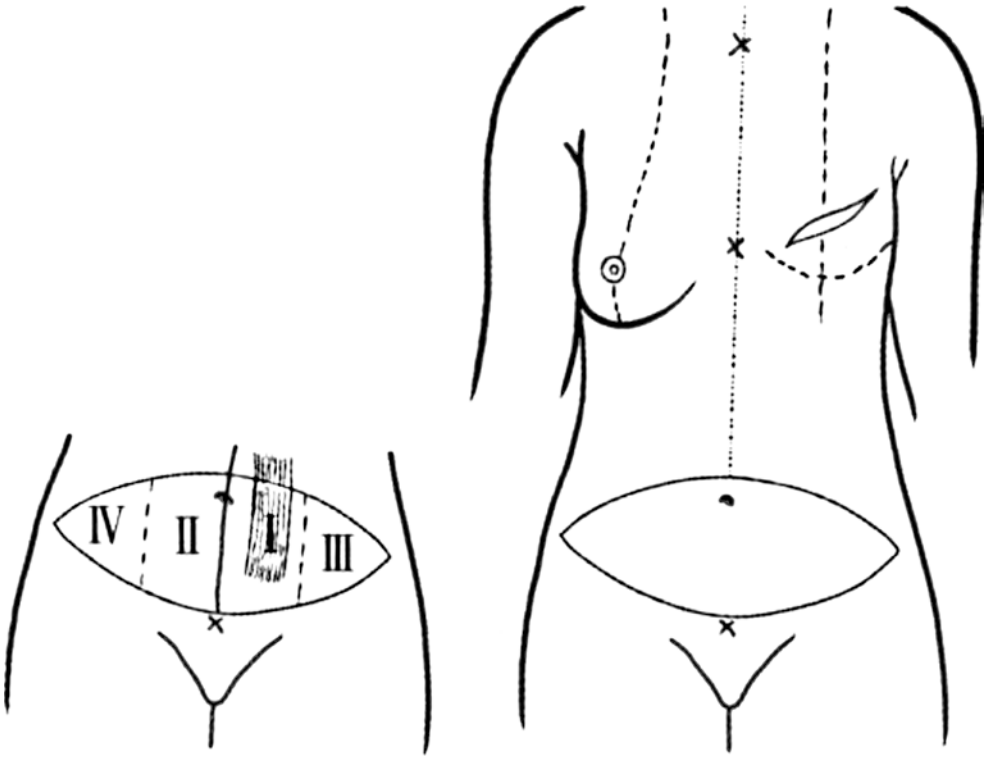

Fig. 15.7 Partitions of blood supply of pedicled TRAM flap

volume of the single-pedicled TRAM flap is inadequate; for patients with scars in the center of the lower abdomen, the contralateral blood supply of the single-pedicled TRAM flap is affected, and the surgical methods such as double-pedicled TRAM flap, vertical rectus abdominis myocutaneous flap or combined with additional vascular anastomosis, and free transplantation should be selected. The surgical method combined with additional vascular anastomosis is selected preferably.

3. Surgical design: The marker line is made in the patient in standing position before surgery – ① the range of tissue defect in the anterior part of chest, a wide range of tissue defects need to be filled from the infraclavicular area; ② the inframammary fold which is symmetrical to that at the contralateral side; ③ the midpoint of the xiphoid process; and ④ the midpoint of the upper pubic hair.

When TRAM flap is designed, it is required to determine the upper margin of the skin flap at first. Since the perforating branches of blood vessels around the navel are thickest and richest; the upper margin of TRAM flap is located at 0.5–1 cm above the navel; the upper margin passes through the slight upper side of the mons veneris, and it should be considered that the donor site can be sutured directly. Especially in younger patients, the abdominal skin is already strained and lacks of sagging; thus, the lower margin of the skin flap should be shifted upward moderately to prevent the donor site wound dehiscence or partial skin necrosis, while the incision in the pubic hair easily leads to necrosis of the middle part of the apron-like flap in upper abdomen. The skin flap presents as fusiform, and the range is limited between bilateral anterior superior spines that is limited within the blood supply range of the epigastric inferior vessels and the superficial inferior epigastric vessels. If exceeding this range, the blood supply area of the superficial circumflex iliac vessel will be brought into the skin flap, which becomes the cause of partial skin flap necrosis. In order to reduce the distortion of the pedicle when the skin flap is transferred, the contralateral rectus abdominis muscle of the reconstructed side is usually selected as the muscle pedicle. Recently, it is reported that the ipsilateral rectus abdominis muscle is also used as the muscle pedicle.

Part of rectus abdominis muscle and its sheath: The blood supply of the skin flap is ensured preferentially for the part above the navel, and the lateral one-third of the rectus abdominis muscle is only retained. A 2–3 cm-wide rectus abdominis anterior sheath in the middle part is harvested, and the medial two-thirds of the muscle is brought into the pedicle. The muscle pedicle is separated upward to the costal margin, then the superior epigastric artery and vein which enter into the body from underneath the costal cartilage are confirmed, and subsequently the skin flap is rotated and transplanted to the chest and is temporarily fixed. Only a part of the rectus abdominis muscle is harvested, and a part of the rectus abdominis muscle and its sheath are retained in the abdomen as much as possible, which is an important measure to prevent the

abdominal complications such as abdominal weakness and abdominal wall hernia.

4. Surgical method: The surgery is performed under general anesthesia; the urethral catheter is placed before surgery. The thoracic scar is removed at first. The skin flap in anterior part of the chest is separated, upward to the infraclavicular area, outward to midaxillary line, inward to the parasternal area, and downward to the inframammary folds. The subcutaneous tunnel is made from the center of the chest to the abdomen, and when the subcutaneous tunnel is made, it is supposed to prevent the excessive separation of inframammary fold at the affected side and the damage to the morphology of the intermammary groove.

   The area around the navel is incised, and the navel is separated from the skin flap. Then the upper margin of TRAM flap is incised and obliquely enters into and incises the fat layer toward the head side, which is conducive to bringing more adipose tissue and main periumbilical perforator vessels into the skin flap. The apron-like flap is separated toward the side of the head, the costal arch edge is crossed, and the subcutaneous tunnel in the chest wound is connected to. When the abdominal flap is separated, some adipose tissues are retained on the surface of the sheath of the rectus abdominis muscle, which is conducive to lymphatic drainage. The lower margin of TRAM flap is incised. At the contralateral side of the pedicle and starting from the outside, the separation is performed on the fascia surface to the center of the abdomen. At the ipsilateral side of the pedicle, the separation is performed from the outside to the inside to expose the myocutaneous perforator at the lateral side of the rectus abdominis muscle. The perforating branches of intercostal artery given off at the lateral margin of the rectus abdominis muscle are severed.

   At the junction of the middle and lower one-third of the skin flap, the sheath of the rectus abdominis muscle is incised at the outer side of the myocutaneous perforator, and then the rectus abdominis muscle is separated to find the inferior epigastric artery and vein and confirm the running directions of the blood vessels. It is noted that the muscle is brought into the skin flap minimally. In order to prepare vascular anastomosis if necessary, the inferior epigastric vessels are separated to the femoral artery and vein, and they are harvested as long as possible for standby application. The abdominal wall hernia occurs mostly in the lower abdomen; thus, the rectus abdominis muscle and its sheath should be retained on this site as much as possible to prevent the formation of postoperative abdominal wall hernia. Namely, 3 cm-wide rectus abdominis muscle and its sheath below the navel are harvested, and both inner and outer sides of the rectus abdominis muscle and its sheath are retained.

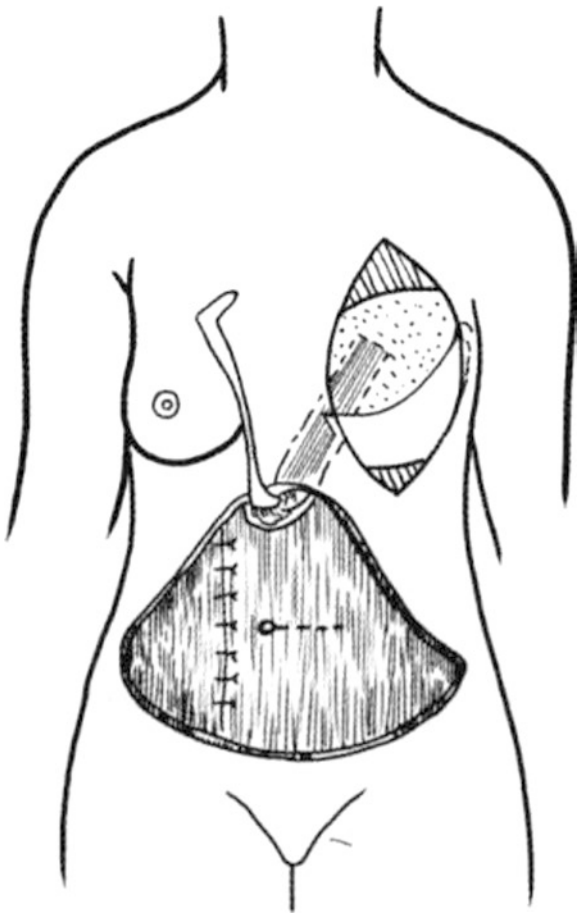

Fig. 15.8 Schematic diagram of TRAM flap breast reconstruction

The anterior sheath of rectus abdominis muscle is closed from top to bottom, and eight shaped two-layered sutures are performed using no. 2 silk suture line. The anterior sheath of the contralateral rectus abdominis muscle is also partially sutured, so as to maintain the symmetry of abdominal wall tension. The navel area is fixed with the anterior sheath of rectus abdominis muscle, so that the navel can be located in the center position; or the anterior sheath of the contralateral rectus abdominis muscle is partially incised, and the navel is fixed to the center position (Fig. 15.8). The patient is adjusted in a semi-sitting position. An opening is made in the center of the skin, and the fatty tissue surrounding the opening within the inner face of the skin is cut off, so that the newly formed navel can have deeper depression. A longitudinal incision is made in adipose tissue layer at the center of abdomen above the navel, and the skin flap is turned over, and then a portion of adipose tissue at the margin of the longitudinal incision is cut off to form a subcutaneous depression. The skin flap is put back to original place and is fixed with the anterior sheath by several stitches at the depression site in the center of the abdomen and the bilateral flanks,

so as to simulate the morphology of the abdomen in young females. The drainage tube is placed, then the suprapubic wound is adjusted and sutured from the outside to the inside to avoid the formation of "orecchiette" on both sides, and, finally, the periumbilical area is sutured.

At the same time of using TRAM flap to carry out breast reconstruction, the effect of abdominoplasty is also achieved for the donor site in the abdomen, especially for middle-aged women. Therefore, the treatment principles for the abdominal donor site are the same as those for the abdominoplasty. When the anterior sheath of the rectus abdominis muscle is closed, the anterior sheath of the contralateral rectus abdominis muscle is also partially sutured and closed to maintain the symmetry of abdominal wall tension, so that the navel can be located in the middle position. The navel is fixed with the anterior sheath of the rectus abdominis muscle during surgery, and a Y-shaped opening is made in the umbilical area at the middle line of the skin. The fatty tissue surrounding the opening within the inner face of the skin is cut off, so that the newly formed navel can have deeper depression. A portion of adipose tissue at the center of the upper abdomen is removed intraoperatively to form a subcutaneous depression, and the appropriate fixation with the anterior sheath is performed at the depression site in the center of the abdomen and the bilateral flanks, so as to simulate the morphology of the abdomen in young females.

According to methods for resection of breast cancer, the shaping methods of breast are slightly different. The design of skin flap is divided into transverse and longitudinal shape, and single-pedicled TRAM flap is designed mostly as longitudinal shape. Firstly, the upper outer one fourth of skin flap, namely, the region IV of the flap, is incised (see Fig. 15.7), and the upper end of skin flap is fixed and sutured to the upper margin of the lacuna in the anterior chest to simulate the caudate lobe of the breast and the anterior axillary fold; then the medial, lower, and lateral sides of the breast are fixed and the excessive skin is removed; furthermore, the folding and shaping are carried out and the wound margin is sutured. It is noted that the intermammary groove is made, and the breast shape with appropriate sagging and bulging which is symmetrical to that at the contralateral side is ensured. In the patients with modified radical mastectomy, the pectoralis major muscle and the pectoralis minor muscle are retained, and thus the morphology of anterior axillary folds is complete. The skin flap is placed by the inner on the upper part and the outer on the lower part, and the lateral curve of the reconstructed breast is highlighted. In the patients with radical mastectomy or extended radical mastectomy, the pectoralis major muscle is resected, and the tissue defects in the chest are severe. Therefore, it is required to fill the subclavicular and axillary dents and shape the breast ball for the breast reconstruction. The skin flap is placed by the inner on the upper part and the outer on the lower part, and the anterior axillary folds and breast curve are highlighted. In the patients with severe breast tissue defects, it is required to fix the skin flap to the medial upper arm to simulate the stop point and morphology of pectoralis major muscle.

The abdomen is bandaged with a bellyband after surgery, so that the skin flap of donor site is attached to the substrate, while the abdominal wall is strengthened and the formation of abdominal wall hernias is prevented. The pedicle passes through the area of the xiphoid process, and attention should be paid to preventing the local compression, which will affect the blood supply of the skin flap.

The anesthetic technique is particularly important. The aspiration of sputum should be performed before anesthetic awareness. The endotracheal tube is removed timely after anesthetic awareness, and when the extubation is performed, the assistant abdomen should press the abdomen to prevent choking during extubation, which can lead to the burst apart of abdominal wall sutures. The hospital where the authors work in has applied the technique of general anesthesia with laryngeal mask ventilation, namely, the laryngeal mask is used to cover the epiglottis and throat, and no tube is placed in the trachea; thus, the choking during extubation and the tracheal discomfort after surgery can be prevented. In addition, the general anesthesia with tracheal intubation plus the epidural anesthesia can greatly improve the safety of extubation and effectively prevent cracking of abdominal donor site.

The constipation and coughing should be prevented after surgery. The drainage tube is removed 4–5 days after surgery and then the patient can start walking. The stitches are taken out 10 days after surgery, and the patient can be discharged out of hospital if there are no special circumstances.

At the third month after surgery, after the flap swelling subsides and the condition is stable, the star-shaped flap is used to reconstruct the nipple and areola in outpatient clinic, and then, the tattoo coloring is carried out to complete the entire process of breast reconstruction.

5. TRAM flap: The free transplantation of TRAM flap pedicled with inferior epigastric artery and vein maintains the epigastric inferior vessels as the main supplying vessels of the lower abdominal skin and subcutaneous tissue, and TRAM flap has good blood supply and less fatty degeneration and induration compared to the pedicled transfer. Partial rectus abdominis muscle is merely harvested and included into the flap, which reduces the damage to the abdominal muscles. For surgeons mastering skilled

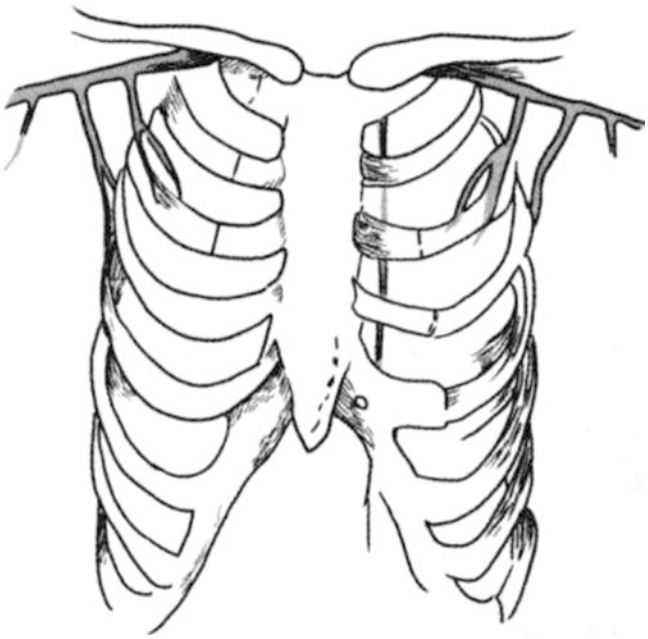

Fig. 15.9 The blood vessels in the receptor site which is available for vascular anastomosis

microsurgical techniques, the flap necrosis rate is 1–3%. In the 1990s, the free TRAM flap breast reconstruction had an increasing trend, and compared with pedicle transplantation, the disadvantages are that the operation time is prolonged by 1–2 h and the skilled microsurgical techniques are required, and the result of survival of skin flap is all or nothing.

The surgical operation is basically the same as that of the pedicled transfer. It is required to retain the epigastric inferior vessels as long as possible when the skin flap is separated. The branching blood vessels of the thoracodorsal vessels, the internal thoracic vessels, and the axillary artery and vein are generally selectively used as the blood vessels of the receptor site (Fig. 15.9). It is worth noting that although the required lengths of the inferior epigastric vessels are limited, it is recommended to separate and preserve the inferior epigastric vessels as long as possible for standby application when the internal thoracic vessels are selected for vascular anastomosis. Therefore, they can be anastomosed with the internal thoracic vessels or thoracodorsal vessels at the healthy side when the internal thoracic vessel at the affected side cannot be used due to anastomotic opening occlusion. The internal thoracic vessels are located at 1 cm beside the sternum, closely clinging to the subchondral area. When the internal thoracic vessels are exposed, firstly, the perichondrium in front of the costal cartilage is stripped off with the periosteal elevator, and the costicartilage is bitten off with rongeur forceps, and then the ophthalmology small scissors are used to cut open the costal perichondrium at the underside of the costal cartilage. If the perichondrium around the costal cartilage is stripped and then the costal cartilage is removed according to the general method, this will easily damage the thoracic artery and vein. When the internal thoracic vein is too small and cannot be used, it is required to harvest the saphenous vein of the lower limb to be bridged with the thoracic dorsal vein, or the cephalic vein of the upper limb is reversed and translocated and is anastomosed with the vein of the skin flap.

The blood circulation status of the skin flap is closely observed within 1 week after surgery. The surgical exploration should be timely performed when it is suspected that the anastomotic thrombosis is formed. The embolism area is removed, and the anastomosis should be carried out again.

6. Inferior epigastric perforator flap: Koshima and Soeda (1989) firstly reported the inferior epigastric perforator flap completely without the rectus abdominis muscle. [18] took the lead in using this flap in breast reconstruction. The inferior epigastric perforator flap is the hypogastric skin flap which takes the inferior epigastric vessels as the vascular pedicle and takes its major vascular branch in periomphalic area as the nourishing blood vessels. Before surgery, the ultrasound or CTA is used to locate the perforating vessels; the shape and design of the skin flap are the same as those of TRAM flap. The major perforator vessels of the inferior epigastric vessels are found at the surface of the rectus abdominis muscle during surgery, and then the rectus abdominis muscle is separated along their traveling direction to look for the main trunk blood vessel. To protect the supplying perforator vessels, a little muscle tissue can be retained around the blood vessels. After the skin flap is formed, the supplying perforator vessels are anastomosed with the blood vessels in chest receptor site under a microscope.

   The advantages of this method are that the morphology and function of the rectus abdominis are maximumly retained and the damage degree of the abdominal wall is reduced to a minimum level. The disadvantages are that the surgical operation is relatively cumbersome and the operation time is prolonged. It is easy to damage the perforator vessels during separation of blood vessels, especially when the pectus abdominis muscle is not included completely, and the probability of failure of the skin flap is increased.
7. The hypogastric skin flap pedicled with superficial inferior epigastric vessels: The hypogastric skin flap pedicled with superficial inferior epigastric vessels refers to that the superficial inferior epigastric vessels are taken as the pedicle during the transfer and the skin flap is located on the surface of the rectus abdominis muscle; thus, the rectus abdominis muscle is not damaged at all, and the

abdominal wall function is preserved to the greatest degree. However, the superficial epigastric vessels have more variation. Only about 20% of patients can use this method.

The flap design is the same as that of TRAM flap. Firstly, the lower margin of the skin flap is incised to look for the superficial epigastric vessels carefully. If the vessel diameter is larger than 1.5 mm, the surgery with superficial epigastric vessel flap can be performed; if there are no superficial epigastric vessels of suitable diameter, the inferior epigastric perforator flap can be used as replacement.

8. Double-pedicled TRAM flap: Double-pedicled TRAM flap is a feasible treatment for the patients with scars in the middle of the abdomen and the need of undergoing reconstruction with the whole TRAM flap after radical mastectomy. Since the double-pedicled TRAM flap needs to harvest bilateral rectus abdominis muscle and the impact on the abdominal wall function is greater, it is particularly important to harvest a part of the sheath of rectus abdominis muscle and use the intramuscular separation techniques during surgery. Attentions are paid to the operation method, and it is not required to synthesize the artificial patch to strengthen the abdominal wall under normal circumstances. For patients with excessive removal of the rectus abdominis muscle and its sheath, it is required to use intraoperatively the autologous fascia, dermal tissues, or artificial patch (polyester mesh) to strengthen the abdominal wall.

The preoperative design and surgical operation are basically the same as those of the single-pedicled TRAM flap. The separation is carried out inward from both sides of the skin flap until the lateral blood vessels are exposed. Then a tunnel on the deep fascia is made at Hunter's line in the middle of the navel and the lower margin of the skin flap; attention is paid to preventing damage to the perforator vessels at the medial side of rectus abdominis muscle. The anterior sheath of rectus abdominis muscle is incised at the outer side of the perforator vessels. Firstly, the inferior epigastric artery and vein are found. After the running directions of the blood vessels are confirmed, the lateral rectus abdominis muscle and the medial rectus abdominis muscle are splitted off, and then the sheath of the medial rectus abdominis muscle is cut off and gradually separated toward to the head side. Similar to single-pedicled TRAM flap, for the part above the navel, only 2–3 cm-wide anterior sheath of rectus abdominis muscle in the middle part and two-thirds of medial rectus abdominis muscle are harvested, and the lateral one-third is retained; for the part under the navel, only a part of the rectus abdominis in the middle part is harvested, and a portion of the sheath and muscle on both inner and outer sides are retained.

The skin flap is mostly designed as transverse shape after being transferred to the chest. The excessive skin is removed, and the clavicle depression is filled; subsequently, the morphology of anterior axillary fold and the mammary contour are reconstructed (Fig. 15.10).

9. Complications: The most common complications after TRAM flap breast reconstruction are flap necrosis and abdominal wall hernia formation in donor site. The complications after breast prosthesis reconstruction depend on the biological characteristics of the prosthesis itself, but the complications after TRAM flap breast reconstruction depend on the patient selection and the operation method and experience of the surgeon. We should be fully aware that the vast majority of complications after TRAM flap breast reconstruction can be avoided.

In earlier application of TRAM flap, the incidence rate of surgical complications was between 20% and 30% [19, 20]. Analyzed the complications in 346 cases of TRAM flap breast reconstruction, and the simple abdominal complication rate was 16% from 1981 to 1984. With the accumulation of surgical experience, the incidence

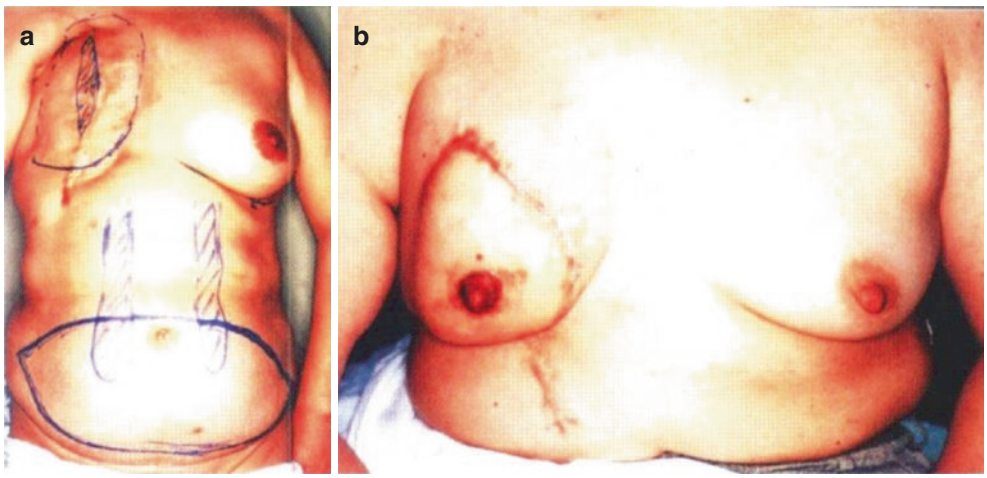

Fig. 15.10 Double-pedicled TRAM flap breast reconstruction. (**a**) Before reconstruction. (**b**) After reconstruction

rate of abdominal complications was decreased to 4% from 1985 to 1990. Hartrampf (1987) reported surgical complication rate in more than 300 patients: the partial skin flap necrosis rate was 6%, and the complete necrosis rate was 0.3%, and the abdominal wall hernia rate was 0.3%; in 1991, he reported that the incidence rate of partial skin flap necrosis was 3%, and the complete necrosis rate was 0. The reduction of complications is due to the accumulation of surgical experiences and the full understanding of the risk factors. According to the data from European and American countries, the risk factors related to the complications include obesity, smoking, previously treated with radiotherapy, hypertension, severe systemic disease, etc., with special emphasis on obesity factor. Kroll [21] divided the degree of obesity into four levels: emaciated, standard, obese, and severely obese. Their complication rates of TRAM flap breast reconstruction were 15.4%, 22.7%, 31.4%, and 41.7%, respectively.

(1) Skin flap necrosis: The best way to deal with skin flap necrosis is to avoid the occurrence of the skin flap necrosis. Clinical practice has proved that the safe area which can be carried by the single-pedicled TRAM flap accounts for about 60% of the total skin flap; when single-pedicled TRAM flap is selectively used, the region 4 and part of region 3 of the skin flap should be removed. If the skin flap necrosis is expected to occur during surgery, the inferior epigastric vessels should be anastomosed with the axillary vessels. The blood supply disorder of TRAM flap in earlier stage shows only poor venous return, congestion, and piebaldness in flap, and the microsurgical vascular anastomosis should be performed during surgery. If the venous congestion is found at the next day after surgery, it is required to open the incision again in the operating room and anastomose the epigastric inferior vessels with the axillary vessels.

After the occurrence of skin flap necrosis, when the necrotic boundaries are obvious, the thorough debridement is performed to remove necrotic tissue, and the reshaping is performed. It is noteworthy that the skin flap should be stretched again during debridement, and the reshaping of the breast after removal of necrotic tissue is carried out. If the necrotic tissue is removed during shaping, the debridement is incomplete often due to misgiving that the pedicle is damaged, and the wound cannot heal for a long time.

After debridement and shaping, the breast volume after reconstruction is slightly reduced, and most patients can accept it. For patients with a large range of necrotic tissue and too small breast volume after reconstruction and shaping, the breast prosthesis can be implanted under the skin flap at the second stage.

When the necrosis boundaries are not confirmed, the debridement should be performed after the necrosis boundaries are confirmed, and the antibiotic ointments such as chlortetracycline ointment and SD-Ag cream are topically applied during the waiting period, so as to prevent aggravation of the tissue necrosis due to secondary infection or the effusion under the scab.

(2) Abdominal wall weakness and abdominal wall hernia: The abdominal wall weakness is demonstrated as the distension of whole abdominal wall; the abdominal wall hernia is due to the fact that the local abdominal wall tension is too small and the intra-abdominal tissues herniate through this site. In early application of TRAM flap, it is emphasized that attentions should be paid to the blood supply of the skin flap. If excessive muscle and sheath tissue are brought into the skin flap, the incidence rate of abdominal wall hernia is higher. With the improvement of the study on blood supply of the skin flap and the operating techniques, the incidence rate is significantly reduced. We carried out (1999) a group of 34 cases of TRAM flap breast reconstruction; the abdominal wall hernia only occurred in one case. Attentions are paid to that the intramuscular separation techniques are used. More anterior sheath of rectus abdominis muscle is retained, and the sheath is doubly stitched. The sputum is aspirated before the patient wakes, and the endotracheal tube is removed timely to prevent the burst apart of muscle sutures due to choking. The sharp increase of intra-abdominal pressure caused by constipation and cough is prevented after operation, and the abdominal compression bandaging is performed. Furthermore, the patient wears elastic stretch tight pants within 3–6 months. These measures are conducive to prevent the occurrence of abdominal wall weakness and abdominal wall hernia.

In order to prevent the occurrence of abdominal wall hernia, some authors advocate using the artificial patch (including polyester mesh, nylon mesh, etc.), autologous fascia, and dermal tissue to strengthen the abdominal wall. Hein (1998) transplanted the skin tissue which was removed during skin shaping and then was de-epithelialized to the anterior sheath of the rectus abdominis muscle, so as to strengthen the abdominal wall and make good use of waste materials, which had achieved good results. For selection of reconstruction method, the single-pedicled TRAM flap or free transplantation should be selectively used, and double-pedicled TRAM flap is avoided as far as possible.

After the abdominal wall weakness or abdominal wall hernia occurs, the patient should wear reinforced elastic stretch tight pants until the surgical correction at the

second stage is performed. The repair of abdominal wall hernia can be carried out together with other local adjustment surgeries. The area of abdominal wall weakness or abdominal wall hernia is separated through original abdominal surgical incision, and the herniated tissues are put back, and then the tissue patch is used for repair and is fixed onto the surrounding healthy anterior sheath and muscles of rectus abdominis muscle or fixed onto bilateral iliac crests. The patient should wear strictly the elastic stretch tight pants within 3 months after surgery and avoid strenuous exercise abdomen.

(3) Liquidation of fatty scleroma: The TRAM flap carries a lot of fat tissue, and the fat tissue is fragile and has a poor blood supply; thus, the ischemic degeneration or necrosis liquefaction easily occurs due to poor blood supply or tissue injury. When there is a large amount of liquefied fat, there will be a palpable undulating sensation. It is required to extract it out with a syringe, and the pressure dressing is carried out. The operation often needs to be repeated for multiple times; a small amount of liquefied fat can be self-absorbed. Most fat degeneration and induration can be absorbed with the passage of time, and some of them form into isolated fat indurations in individual cases, which can be removed during implementation of other plastic surgery.

Sometimes the isolated fat induration is easily confused with tumor recurrence, and the local biopsy examination is useful in differential diagnosis.

(4) Incision disruption: The sites with incision disruption are mostly located in the margin of the skin flap in receptor site and in the donor site with too large tension during suture. When the skin flap in donor site is designed, it should be considered that it is appropriate as long as the donor site can be directly closed and sutured. The margins of the scar tissue should be removed as far as possible. When there is partial margin necrosis, the suture line should be retained, and the premature removal is avoided, since the suture line can play the role of closing the wound and preventing the expansion of the wound. After the incision disruption, the wound dressing is performed, and the wound heals at the second stage; the large wound after the granulation tissue has grown is repaired with skin transplantation, and the scar tissue can also be removed under the circumstances to make fresh wound, which is sutured directly.

(5) Other complications: Other rare complications include:

(a) Local effusion under the skin flap: The puncture suction or local drainage can be performed.

(b) Scar hyperplasia in donor site: It is common in vertical rectus abdominis myocutaneous flap and rarely occurs in TRAM flap. The treatment is the same as the scar treatment. The scars are removed at the second stage, and the corticosteroid is injected into the scar, and then the silicone gel patch is applied externally.

(c) The shape of the reconstructed breast is poor, and it is mainly due to improper method for flap shaping. Different abnormalities should be appropriately adjusted at the second stage.

1.7.2 Breast Reconstruction with Expanded Latissimus Dorsi Myocutaneous Flap

The traditional latissimus dorsi myocutaneous flap does not carry surrounding adipose tissues and has a small tissue volume; thus, it requires the combined application with breast prosthesis for breast reconstruction, so as to achieve the purpose of being symmetrical to the contralateral breast. The breast prosthesis, as a foreign substance, has complications such as rupture and leakage of the prosthesis and capsular contracture, which have become the focus of attention or discussion. In order to avoid the use of breast prosthesis, Bohme and Hockin proposed the simple application of the latissimus dorsi myocutaneous flap, without the use of breast prosthesis for breast reconstruction, which is adopted by more and more people through continuous improvement. The breast reconstruction with expanded latissimus dorsi myocutaneous flap traditionally refers to carrying the fatty tissue surrounding the latissimus dorsi muscle to be transferred together for reconstruction, and some scholars have recently carried parts of the serratus anterior muscle on this basis, in order to increase the tissue volume for breast reconstruction. The breast reconstruction with expanded latissimus dorsi myocutaneous flap is a good surgical method for medium-sized breasts, especially for oriental females.

1. Partition of the fatty tissue surrounding the latissimus dorsi muscle: Delay (1998) divided the available fatty tissue surrounding the latissimus dorsi into five regions (Fig. 15.11):

(1) Region I: It is the tissue located between the skin part of the skin flap and the latissimus dorsi muscle. Any form of latissimus dorsi myocutaneous flap includes this part of the fatty tissue, and blood is supplied by the myocutaneous perforator vessels.

(2) Region II: It is the fatty tissue on surface of the latissimus dorsi myocutaneous flap after removal of the skin. Similar to region I, blood is supplied by the myocutaneous, muscle, and fat perforator vessels. The area of this region is large, and the available adipose tissue seems to be thin. In fact, the cumulative tissue volume is very considerable. It is

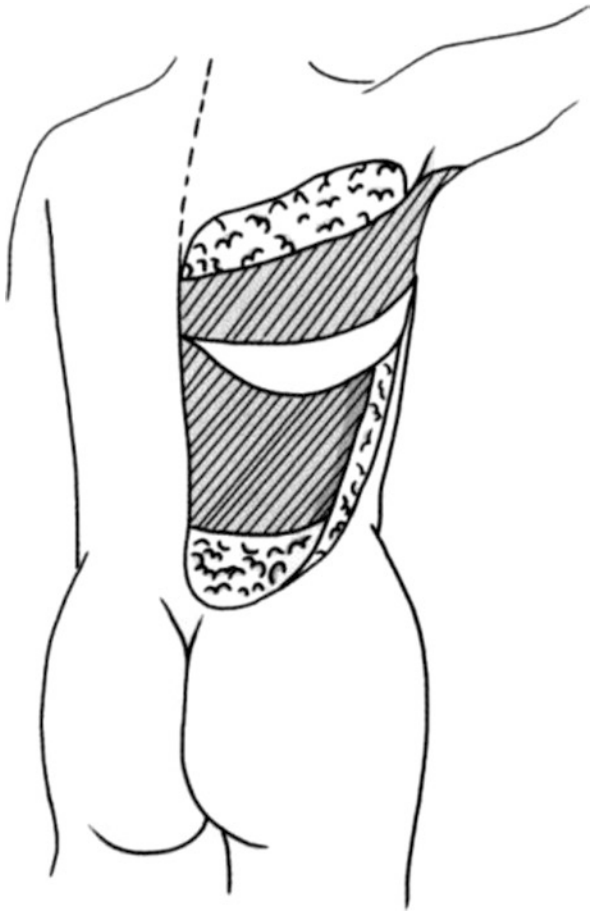

Fig. 15.11 Partition of the fat around the latissimus dorsi muscle

presumed that the area of unilateral latissimus dorsi muscle is 450 cm^2, and there is 0.5 cm-thick fat on the muscle surface, the total fat volume can reach up to 225 ml.

(3) Region III: It is the scapular fat area and is located on the medial upper margin of the latissimus dorsi muscle. As a continuation of the muscle flap, it can be folded to use, so as to increase the volume of myocutaneous flap. The region travels toward the head side along the medial upper margin of the latissimus dorsi muscle, and blood is supplied by small perforator vessels given off from the latissimus dorsi muscle.

(4) Region IV: It is the fat area in the anterior margin of the latissimus dorsi muscle, it is located at 3–4 cm in front of the lateral margin of the latissimus dorsi tissue, and blood is supplied by small perforator vessels given off from the latissimus dorsi muscle.

(5) Region V: It is the upper iliac fat area and is located above the iliac crest, also known as love handle, it is a continuation of the lower margin of the latissimus dorsi muscle, and blood is supplied by the muscle and fat perforator vessels of the latissimus dorsi muscle. This region is located in the far end of the skin flap, and the latissimus dorsi muscle is transmigrated into the fascia part in this region, and therefore, the blood supply of this region is weakest.

2. Preoperative examination and skin flap design: In addition to conventional examinations on systemic recurrence of the tumor, the situations of the breast at the healthy side and the donor site are the examination key points.

(1) Estimation of available back tissues: The index finger and thumb are placed on the anterior margin of the latissimus dorsi muscle, and the skin is nipped up to estimate the thickness of the fat which can be taken advantage of. Attentions are paid to observe the thickness and range of the fat above the iliac crest. The patient with thin back can only provide tissues to reconstruct a smaller breast; the patient with medium-sized body can provide tissues to reconstruct a medium-sized breast, and the patient with hypertrophic back fat can provide tissues to reconstruct a larger breast.

(2) Measurement of the function of the latissimus dorsi muscle: The affected upper limb is abducted, and then the examiner holds the affected upper limb with hands and asks the patient to adduct the limb to observe the contraction situation of the belly of the latissimus dorsi muscle. The loss of the contraction function of the latissimus dorsi muscle indicates the thoracodorsal nerve damage, and it also means that the thoracodorsal vessels are damaged. The thoracodorsal vessels are damaged during breast cancer radical surgery; meanwhile, the latissimus dorsi muscle is denervated and atrophic, and the tissue volume of latissimus dorsi myocutaneous flap is reduced; thus, other methods such as TRAM flap should be used for breast reconstruction. The latissimus dorsi muscle with good function means that the thoracodorsal vessels and nerves are intact and undamaged.

There are three methods for skin flap design, namely, the transverse shape, the oblique shape with the outer on the upper part and the inner on the lower part, as well as the oblique shape with the inner on the upper part and the outer on the lower part. The scar of transverse skin flap is covered by bras and the scar is not obvious; thus, the transverse skin flap is more commonly used. The oblique skin flap with the outer on the upper part and the inner on the lower part leads to the longitudinal scar in the back, which impedes the appearance, but is convenient for surgical operations, especially for easy harvesting of the fat in region V. The skin flap design with the inner on the upper part and the outer on the lower part is in accordance with the direction of the dermatoglyph in the back, which is not only convenient for the harvesting of the skin flap but also conducive to the appearance of postoperative scar.

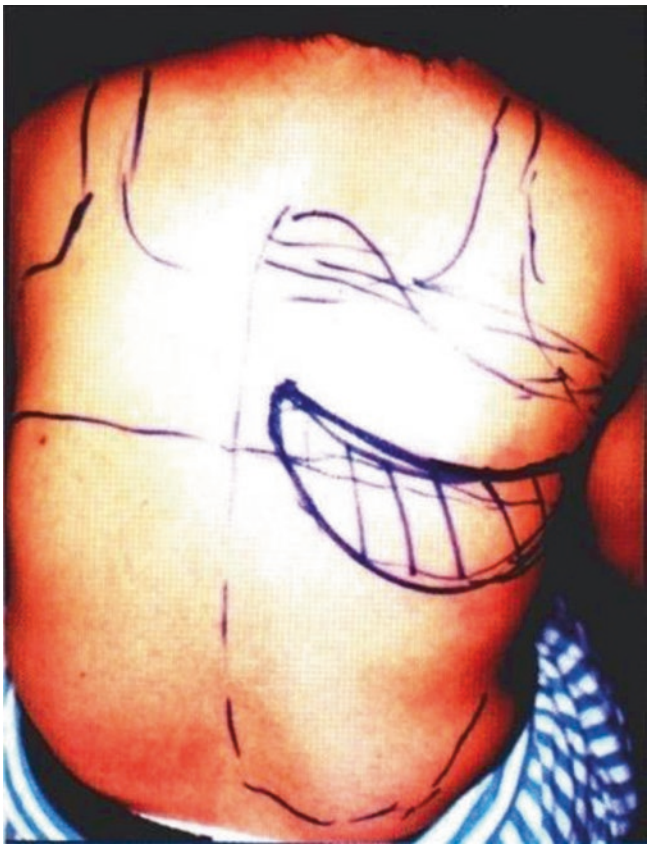

Fig. 15.12 The lacunas in separation range of the chest and the harvesting range of fat flap in the back are marked in the patient in standing or sitting position

The patient takes a standing or sitting position, and then the lacunas in separation range of the chest and the harvesting range of the fat flap in the back are marked (Fig. 15.12). The flap part presents as crescent shaped and is bent toward the head side. The medial side of the crescent-shaped flap is 3 cm from the midline of the back, and the lateral side reaches the anterior axillary line. The width of the skin flap is about 7 cm, which is appropriate as long as the donor site can be directly closed and sutured. Too wide skin flap has limited increase in fat tissue volume. On the contrary, it will cause serious complications in donor site.

The patients take a sitting or standing position, and the preoperative marker lines are made: ① the inframammary fold which is symmetrical to that at the healthy side, ② the contour of latissimus dorsi muscle at the operation side, and ③ design of myocutaneous flap. Firstly, the contour of the bra is roughly marked out on the back, and the oval skin flap is designed at the lower margin of the bra. The skin flap is located in the sarcoplasmic parts at the upper margin of the latissimus dorsi muscle and presents as transverse or oblique shape. The size of the skin flap should meet the requirements for breast reconstruction, and the donor site can be closed and sutured directly. If the skin-sparing radical mastectomy is applied, only a little skin is needed.

3. Surgical methods: The patient takes the lateral position with the affected side on top, and the chest scar removal and skin flap separation can be carried out in this position. After disinfecting and draping in surgical area, the affected upper limb is bandaged with a sterile sheet, which facilitates the movement during surgery.

   The chest scar is removed, and the lacuna is separated within the preoperative marked range on the surface of the pectoralis major muscle under the skin flap. After the bleeding is stopped, the lacuna is filled with saline gauzes for standby application.

   The flap incision is made along the back marking line. After the skin is incised, 0.5 cm-thick subcutaneous fat is retained, and the remaining fat is retained on the surface of the muscle; meanwhile, the undermining dissection of the harvesting area of the muscle and the fat flap are performed. In the process of undermining dissection, a certain thickness of subcutaneous fat should be maintained, and the subdermal vascular network is protected to prevent partial skin necrosis in donor site. Separation is performed on the surface of the muscular fascia at the anterior margin of the skin flap to expose the anterior margin of the latissimus dorsi muscle. The running directions of the blood vessels are confirmed at the anterior margin of the skin flap, and the starting point of the latissimus dorsi muscle is cut off according to the required muscle volume. The skin flap is harvested using the method of from far and near. The separation is carried out in deep layer of the muscle, and the thoracodorsal vessels are included. The myocutaneous flap is lifted up and separated toward the direction of the armpit. The thoracodorsal vessels give off a branch to enter into serratus anterior muscle before entering into the latissimus dorsi muscle. Under special circumstances, when the subscapular vessels are destructed, the latissimus dorsi myocutaneous flap relies on the branch to maintain the blood supply. Therefore, it is required to retain the vascular branch of the serratus anterior muscle as far as possible. Under normal circumstances, retaining the branch does not affect the transfer of the latissimus dorsi myocutaneous flap; if necessary, the surrounding tissues of the vascular branch are appropriately dissociated to increase the length of the branch. On the other hand, even if the subscapular vessels are good, retaining the vascular branch of the serratus anterior muscle is also conducive to the blood supply of the latissimus dorsi muscle. The end point of the latissimus dorsi muscle can be kept intact, partially cut off, or cut off to reconstruct the anterior axillary folds. In general case, it should be cut off completely, so as to prevent deformation of the reconstructed breast due to muscle contractions.

Between two incisions before and after the chest, a subcutaneous tunnel near the armpit is made, and the latissimus dorsi myocutaneous flap is transferred to the chest through this subcutaneous tunnel and is temporarily fixed. The negative pressure drainage tube is placed after both sides of the wound margin of donor site are dissociated, and the direct closure and suture are performed in sequence of the subcutaneous area, intradermal area, and skin.

The patient is adjusted in the supine semi-sitting position, and the flap shaping is performed. The latissimus dorsi muscle is placed in separated lacuna in the front chest, and the skin flap is folded, and then the fat flap is placed under the skin flap. Firstly, the myocutaneous flap is placed near the lower part as far as possible and is fixed with chest muscle, costal perichondrium, and inframammary fold flap, and then the end point of the latissimus dorsi muscle is fixed, respectively, with the medial clavicle and the parasternal line. The muscle flap is fixed with lateral chest wall at the anterior axillary line and is sutured on the fascia of the serratus anterior muscle. When there is partial absence of the pectoralis major muscle, the muscle flap is sutured and fixed with the pectoralis major muscle. The adjustment is made to achieve symmetry with the healthy side. The excessive epidermis is removed, and the drainage tube is placed along the inframammary fold, and then the skin incision is sutured. The protection of thoracodorsal nerve during surgery can reduce the denervation atrophy of muscle in a later period. The volume of the reconstructed breast right after surgery should be slightly larger than that at the healthy side. The pedicle compression is prevented during wound dressing. The upper limb is immobilized for 72–96 h after surgery (Fig. 15.13).

4. Complications: The major complications are donor site hematoma and seroma, and the incidence rate is as high as 30–50%. Careful intraoperative hemostasis is performed; the negative pressure drainage tube is placed in the lowest point, and maintaining unobstructed drainage is the key of prevention. Other complications include partial skin flap necrosis in donor site, poor healing, and partial necrosis of stripped skin flap margin in the chest. The artificial breast prosthesis-related complications are reduced compared with the breast reconstruction with the combined use of traditional latissimus dorsi myocutaneous flap and breast prosthesis. Because the separation range in donor site is wider, the possibility of donor site hematoma, seroma, and partial necrosis of donor site is relatively increased.

The refractory seroma lasts longer, and it doesn't heal after repeated treatments. Furthermore, it doesn't heal within 1–2 years after surgery in the individual patients. Therefore, it brings a huge psychological burden to patients. Repeated puncture aspirations are required in early stage after the occurrence of seroma, and an opening is made in the lowest position to place the negative pressure drainage tube again, and the pressure dressing is performed if necessary. The pseudomembrane has been formed around the seroma with longer duration, which can heal only after the pseudomembrane is treated, and the specific operation is as follows:

1. After the release of serum liquid, the cyst cavity is washed with10–15 ml ethanol. After the pseudomembranous is corroded to form a fresh wound surface, a negative pressure drainage tube is placed, and the pressure dressing is performed. The repetitive operation is carried out if necessary.
2. The incision is reopened, and the cyst wall is removed to form a fresh wound, and then a negative pressure drainage tube is placed, and, finally, the incision is sutured again. The method requires carrying out anesthesia again, and the trauma is increased.
3. The skin incision is opened under local anesthesia. The cyst wall is scraped with a curette, and the cyst is packed with iodoform gauzes, and then the open wound drainage is performed. The wound heals at the second stage, or the debridement and suture are performed after the wound surface is reduced and the granulation tissue has grown.

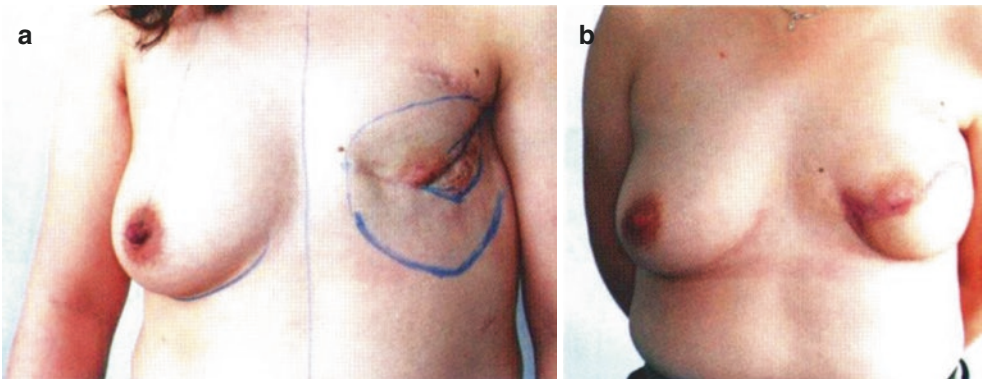

Fig. 15.13 Delayed breast reconstruction with expanded latissimus dorsi myocutaneous flap. (**a**) Before reconstruction. (**b**) After reconstruction

1.7.3 Breast Reconstruction with Gluteal Myocutaneous Flap

There are two methods for breast reconstruction with gluteal myocutaneous flap: One method is to take the superior gluteal vessels as the pedicle and carry a part of the upper gluteus maximus muscle and the adipose and skin tissues to carry out free transplantation for breast reconstruction; another method is to take the inferior gluteal vessels as the pedicle and carry a part of the lower gluteus maximus muscle and the adipose and skin tissues to carry out free transplantation for breast reconstruction. The composite tissue flap has large tissue volume; thus, the breast prosthesis is not required. The donor site scar is hidden compared to those of TRAM flap and latissimus dorsi myocutaneous flap. Therefore, it is a practical method of breast reconstruction. But it may be due to the causes such as changing position during surgery, and it has not been widely applied compared to TRAM flap scar and latissimus dorsi myocutaneous flap.

1. Breast reconstruction with gluteal myocutaneous flap pedicled with superior gluteal vessels
   (1) Preoperative and skin flap design: The patient takes the standing position, and bilateral inframammary folds and chest separation range are marked out. The ipsilateral gluteal myocutaneous flap is harvested for transplantation. Doppler flowmetry is used to detect the running directions of the superior gluteal vessels; the superior gluteal vessels are taken as the axis to mark and draw the upper gluteal myocutaneous flap. The myocutaneous flap looks like a spindle, and the long axis is located on the connection line between the upper margin of the sacral bone and the iliac crest. The solid line is used to mark the range of the skin flap, and the dotted line is used to mark the harvesting range of the subcutaneous fat (Fig. 15.14). The harvesting range of the subcutaneous fat is greater than that of the skin, in order to facilitate filling the chest subcutaneous tissue defects.
   (2) Surgical methods: The patient takes the lateral position, and the affected side faces upward. Firstly, the upper margin and lateral margin of the skin flap are incised, and the gluteus maximus muscle is bluntly separated above the femoral great trochanter at lateral side of the gluteus maximus muscle, and then the blunt separation is performed between the gluteus maximus muscle and gluteus medius muscle toward the direction of the sacral bone. The running directions of the superior gluteal vessels are confirmed between the gluteus medius muscle and the piriformis muscle, and then the skin is completely incised to dissociate the myocutaneous flap. There is usually an artery and two veins. The myocutaneous flap is harvested, and the donor site is sutured. The patient is adjusted into a supine position, and the skin flap is transferred to receptor site in the chest, and then the artery and vein are anastomosed under a microscope. The flap shaping is carried out, and the excessive skin is removed.

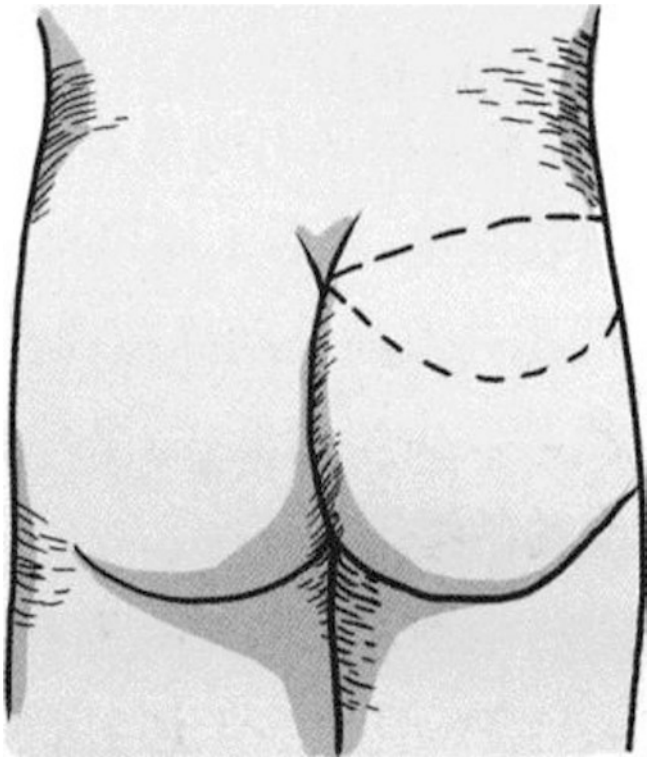

Fig. 15.14 Design of breast reconstruction with gluteal myocutaneous flap pedicled with superior gluteal vessels

The blood vessels available for anastomosis in receptor site include the internal thoracic vessels, thoracoacromial vessels, and the branches of other axillary vessels, and the internal thoracic artery and vein are the most commonly used vessels. The internal thoracic vessels are about 1 cm away from the parasternal line, closely clinging to the costal perichondrium. When the blood vessels are exposed, firstly, the costal cartilage in front of the fifth costal cartilage is stripped off with the periosteal detacher, and the costal cartilage is bitten off with a rongeur, and then the posterior costal perichondrium is cut off using a small pair of scissors, and subsequently the internal thoracic artery and vein are exposed. It should not be the same as the general removal of costal cartilage. The surrounding costal perichondrium is stripped off at first, and then the entire length of the costal cartilage is resected; otherwise, it is easy to damage the blood vessels. Sometimes when the internal thoracic vein is thinner, and is not suitable for vascular anastomosis, the saphenous vein of the lower limb should be harvested and transferred to the axillary vein, or the cephalic vein of the upper limb

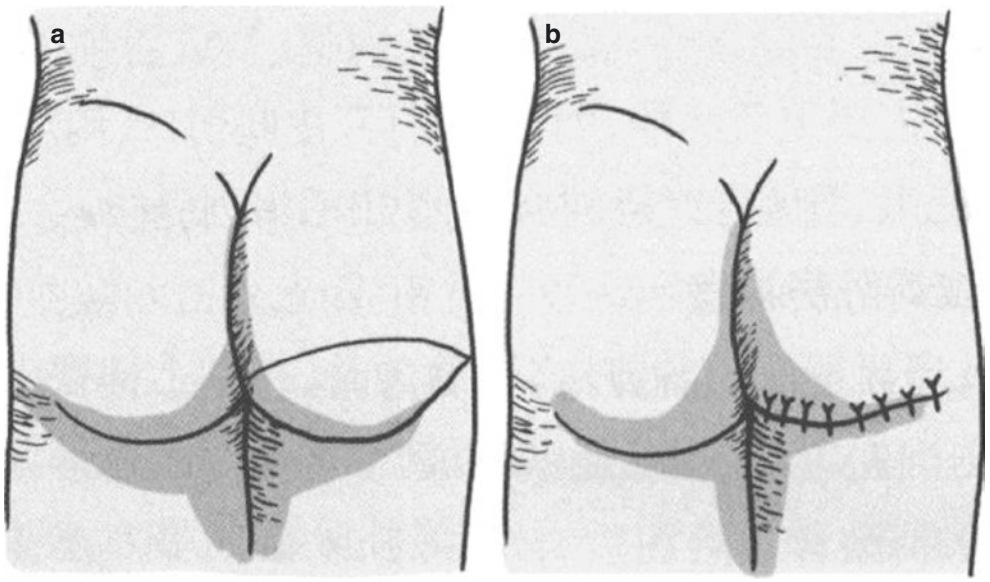

Fig. 15.15 Design of breast reconstruction with gluteal myocutaneous flap pedicled with inferior gluteal vessels

is harvested and transferred to be anastomosed with the blood vessel of the skin flap.

2. Breast reconstruction with gluteal myocutaneous flap pedicled with inferior gluteal vessels
   (1) Skin flap design: The range of the gluteal myocutaneous flap is marked. The lower margin of the skin flap is located at the gluteal groove, and the upper margin is located at the surface of the gluteus maximus muscle with a width of about 10 cm and is demonstrated as fusiform or crescent shaped. The lower margin of the skin flap is longer than the upper margin, so that when the donor site is sutured the scar is demonstrated as arc shaped and is consistent with the gluteal groove (Fig. 15.15).
   (2) Surgical methods: The patient takes a prone position. The lower margin of the skin flap is incised, and a part of the gluteus maximus muscle is harvested. The excessive harvesting of gluteus maximus muscle which can cause dysfunction is prevented. The skin flap is separated from far and near, and attention is paid to preventing damaging the sciatic nerve. After the skin flap is harvested, the donor site is closed and sutured. Subsequently, the patient is adjusted into the supine position, and the disinfection and draping are performed again. The myocutaneous flap is transferred to the receptor site in the chest, and the arteries and veins are anastomosed under the microscope. The thoracoacromial blood vessels, thoracodorsal blood vessels, and internal thoracic blood can be selected as the blood vessels in receptor site; if necessary, the cephalic vein of the upper limb is transferred to be anastomosed with the blood vessel of the skin flap.
3. Postoperative treatment: The blood supply of the skin flap is closely observed, and the blood supply disorder is timely treated when it occurs. The treatment method is the same as that of the general microsurgery, and the anastomotic thrombus is cleared, and the anastomosis is performed again when necessary.

   The patient takes the horizontal position, and the donor site in hip is compressed. The drainage tube is removed in 48–72 h according to the amount of drainage volume after surgery. The patient can take a sitting position 5 days after surgery under the condition of good bandaging, and the hip is elevated with soft seat cushion. The patient can move freely without restriction at 1 week after surgery.
4. Complications: The most serious complication of free transplantation is arteriovenous anastomotic thrombosis, which leads to the flap blood supply disorders; if it is not treated, it can lead to necrosis of the entire skin flap. Although its incidence rate is low, the consequences will lead to the failure of the reconstructive surgery. Correct skin flap design and skilled anastomotic technique under the microscope are the keys to successful operation.

   After the transplantation of the gluteal myocutaneous flap, the lower extremity movement disorder occurs in individual patients in the early period of postoperation, which will disappear in most cases after functional training.

1.7.4 Breast Reconstruction with Gracilis Myocutaneous Flap

The breast reconstruction with gracilis myocutaneous flap is a new method reported in recent years. The gracilis muscle is located under the skin in the medial thigh, and it is a flat and long strap muscle. The main nutrient artery is a branch of the deep femoral artery, and it enters into the muscle from the deep surface at about 8 cm under the pubic tubercle and at

the junction of the upper and middle one third of the muscle. The deep femoral artery has less variation and appears constantly, and it is easy to harvest. The breast reconstruction with gracilis myocutaneous flap mostly uses the transverse design on the upper medial thigh and the location is hidden; thus, the scar after harvesting is not obvious with little effect on the function. The harvesting of the gracilis muscle can be carried out simultaneously with the thoracic surgery in the same position subgroup, and it is not necessary to change the position; thus, the operation time is shortened.

This method is suitable for patients with more adipose tissue in the upper thigh, especially in the elderly or the people with increased weight who need to lost weight. Before surgery, the patient is in a standing position; the lifting-pinching manipulation is used to estimate the available tissue volume and the width of the skin flap which can be harvested, and the width of the skin flap is appropriate as long as the donor site can be sutured directly.

1. Skin flap design
   (1) The patient takes a standing position. Firstly, the connection line between the pubic tubercle and the medial knee semitendinosus is marked with a sign, and the connection line is the anterior margin of the gracilis muscle, and the gracilis muscle is located behind the connection line.
   (2) The location of the vascular pedicle of the skin flap is marked at 8 cm under the pubic tubercle.
   (3) The harvesting range of the skin flap is marked. The upper boundary of the skin flap is located at the junction of the thigh, the perineum, and the hip, and the lower boundary is located at the upper medial thigh. The width of the skin flap is about 7–10 cm, and the length is about 12 cm. The rear boundary does not exceed the midline of posterior side of the thigh that the scar can't be seen when the patient stands taken as the limit.
2. Surgical method: Both surgeries at the upper and lower parts are performed simultaneously, and the chest group separates the chest flap and the blood vessels for vascular anastomosis in donor site. The patient takes the lithotomy position. The routine disinfection and draping are carried out, and the margin of the skin flap is incised, and then the separation is performed from front to rear along the surface of the muscle; subsequently, the anterior margin of the musculus gracilis muscle is exposed, and the muscle is pulled to find the nutrition blood vessels and retrogradely trace the blood vessels, and the length of the vascular pedicle is increased as far as possible. After the harvesting of the skin flap, the donor site is closed and sutured directly.
3. Selection of blood vessels in receptor site: In general, the internal thoracic is selectively used. The third or fourth costal cartilage is bitten off with a rongeur, and a small pair of scissors is used to cut off the perichondrium at the rear side of the costal cartilage, and then the blood vessels in receptor site are exposed, and, finally, the vascular anastomosis is performed under a microscope. The subscapular blood vessels are not selectively used as the blood vessels in receptor site as far as possible. Although they have been used by some scholars, the subscapular blood vessels are the nutritional blood vessels of the latissimus dorsi myocutaneous flap. Therefore, we generally take the latissimus dorsi myocutaneous flap as the remedial measure after the failure of microsurgical reconstruction, and the flap is used as "life-saving flap."
4. Advantages and disadvantages: The advantages of the breast reconstruction with gracilis myocutaneous flap are that the scar is hidden and there is little effect on the function of donor site; the disadvantages are that the skin color is deeper in some patients and there is a certain color difference compared with the receptor site. The hair growth occurs in the upper thigh in the individual patients, and the laser hair removal treatment can be carried out after the survival of the skin flap. In young skinny patients, the available tissue volume on upper thigh is limited, and the prosthesis reconstruction can be combinedly used.

2 The Breast Reconstruction with Breast Prosthesis

Fazhi Qi and Peizhi Fan

The breast reconstruction refers to the use of autologous tissue transplantation or breast prosthesis to reconstruct the chest wall deformity and breast defect after mammectomy in patients suffering from breast diseases. The most common breast defect is found after breast resection of breast cancer. Currently, the surgical methods of breast reconstruction include two types such as breast prosthesis implantation and autologous tissue transplantation. The breast prosthesis can be used for immediate breast reconstruction or delayed breast reconstruction; it can be directly implanted, and it can also be implanted after tissue expansion. The breast reconstruction with breast prosthesis has small trauma and simple operation, and it is especially suitable for patients with complex systemic conditions which are not suitable for surgery; the disadvantage is that reconstructed breast lacks a certain degree of prolapse, especially for middle- and old-aged women with obvious sagging breast at the healthy side. If the necessary adjustments are not made, it is difficult to achieve the full symmetry on both sides.

The breast reconstruction with breast prosthesis is suitable for patients who have good covering tissue and light and moderate sagging breast at the healthy side, otherwise

it needs to be combinedly used with the latissimus dorsi myocutaneous flap to provide extra covering tissue. Under normal circumstances, since the chest skin in patients undergoing breast reconstruction is poorer than that in patients undergoing breast augmentation, the teardrop-shaped textured silicon gel breast prostheses are firstly selected as the used prostheses, and the circular textured breast prostheses can also be used. The size of the prosthesis is generally 300–450 ml, and it is larger compared with that for breast augmentation. When the breast prosthesis is used for reconstruction, there are three surgical methods for selection according to the statuses of the breast tissues of the patients: ① for patients with local skin defects after breast cancer surgery, generally, it is required to expand the skin with expander at first, and then the breast prosthesis is implanted; ② for patients after skin-sparing modified radical mastectomy or patients after subcutaneous mammectomy, since the chest skin is retained completely or mostly, the breast prosthesis can be directly implanted; and ③ for patients with infraclavicular tissue defects or patients unwilling to undergo tissue expansion, the combined use of the transfer of latissimus dorsi myocutaneous flap and the prosthesis implantation can be performed for breast reconstruction.

When the prosthesis is used for breast reconstruction, it is needed to confirm the complications which may appear after surgery and their treatment methods. The problem which is most difficult to predict and deal with during application of the prosthesis is the periprosthetic capsular contracture. For patients with severe capsular contracture, through several surgical resections or incisions, after prosthesis replacement, sometimes the occurrence of capsular contracture still cannot be avoided, and, finally, the autologous tissue transplantation must be carried out again for breast reconstruction. The patient should be informed of this possibility to prevent unnecessary disputes.

The patients who have received the radiotherapy and need to receive the radiotherapy after reconstruction are relatively contraindicated to undergo prosthetic breast reconstruction. Although it is reported in literatures that the prosthetic breast reconstruction is performed successfully, it should be carefully chosen. The autologous tissue breast reconstruction is more appropriate for these patients.

Any artificial tissue substitute implanted into the body requires to be covered by certain healthy tissues. The deeper the implantation layer is, the safer the substitute is, and the less it is prone to complications. On the contrary, if the implantation layer is thin, the complications such as prosthesis exposure easily occur. In order to increase the tissues to cover the prosthesis, recently, some scholars cover the prosthesis surface with acellular artificial dermis, which makes up the shortcomings that the muscle tissue cannot completely cover the prosthesis surface and improves the safety of operation and the effect of reconstruction, which has become one of the main developments for prosthetic breast reconstruction.

2.1 Breast Reconstruction with Direct Prosthesis Implantation

Without skin and soft tissue expansion, the indications of the breast reconstruction with direct prosthesis implantation should consider two factors: one factor is the quality and volume of the breast covering tissues, mainly the skin volume; another factor is the size and shape of the contralateral breast. The patients with small- and medium-sized breasts and unapparent prolapse are good indications for this surgery or including patients undergoing transformation surgeries such as contralateral breast reduction.

The breast reconstruction with direct prosthesis implantation is applicable to patients with a relatively small skin resection volume and adequate chest skin texture and tissue volume after modified radical mastectomy or skin-sparing modified radical mastectomy, as well as patients undergoing immediate reconstruction after breast prophylactic subcutaneous mammectomy; for a very few patients with delayed breast reconstruction, if there is a sufficient amount of chest skin, the breast reconstruction with direct prosthesis implantation can also be performed. For most patients undergoing modified radical mastectomy, it is often required to carry out skin expansion at first, and the breast prosthesis implantation is performed at the second stage. On the other hand, for patients with original huge breasts, hyperplasia, and prolapse which are often accompanied by excessive breast skin after subcutaneous mastectomy, the prosthesis is out of proportion to excessive breast skin, and thus it is required to reduce the excessive skin at the same time of removing the breast.

The advantages of the breast reconstruction with direct prosthesis implantation are short surgery time and simple operations. The second surgery is not required, and no new surgical scars are additionally increased; meanwhile, the chest skin color is good and there is no damage to flap donor site.

After breast cancer surgery, the blood supply status of the skin flap should be examined at first. Any area in the margin of the skin flap with suspected poor blood supply should be completely removed. The surgical approach is changed if necessary, and the dilator/prosthesis implantation can be applied. There are two layers for prosthesis implantation: one layer is that the prosthesis is implanted into the layer completely under the muscles, that is, the spaces under the pectoralis major muscle and serratus anterior muscle are separated, and the prosthesis after implantation is completely covered by the muscles. The advantages are that the prosthesis exposure due to postoperative partial necrosis of flap margins or poor incision healing is prevented that the prosthesis

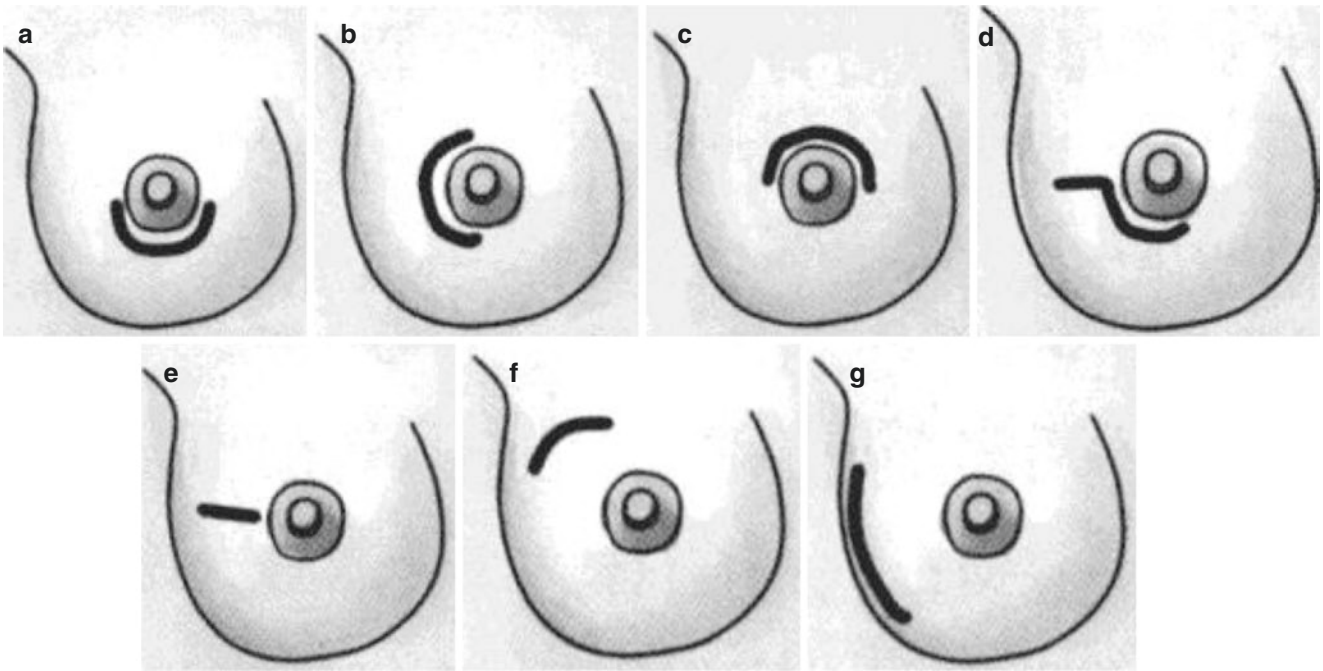

Fig. 15.16 The incision in the areola margin or breast skin

is placed under the muscles can reduce the probability of capsular contracture; the disadvantages are that the bulge of the prosthesis is limited to a certain extent. The second layer is that the prosthesis is implanted under the pectoralis major muscle. The medial lower starting point of pectoralis major muscle is separated off, and the part of the prosthesis where can be completely covered by the muscles is covered with acellular dermal matrix.

There are two methods according to the size of the original breast and whether it is needed to reduce the skin.

2.1.1 Direct Prosthesis Implantation After Subcutaneous Mammectomy

The incision in the areola margin or breast skin is used (Fig. 15.16). After subcutaneous mammectomy, the separation is performed under the pectoralis major muscle to the mark range, and the layers to be dissected are located on the deep surfaces of the muscles, namely, the deep surfaces of pectoralis major muscle, serratus anterior muscle, obliquus externus abdominis muscle, and the anterior sheath of the rectus abdominis muscle. The dissection scope reaches upward to the second intercostal space, innerward to the parasternal line, outward to the anterior axillary line, and downward to the inframammary fold. The medial lower starting point of pectoralis major muscle often needs to be cut off or stripped off. After it is inspected that no fibrous band is left in the cavity, the careful hemostasis is performed, and the wound is washed with normal saline, and then the breast prosthesis is implanted. The body position is adjusted into semi-sitting position. After the bilateral symmetry is examined, the drainage tube is placed, and the separated muscle fibers and the skin incision are sutured. A part of the prosthesis which cannot be covered by the pectoralis major muscle can also be covered with acellular dermal matrix or de-epithelialized autogeneic dermis. It is worth noting that if the inframammary fold is dissociated during breast cancer resection, it is required to suture and fix the inframammary fold to the chest wall to reconstruct the inframammary fold.

2.1.2 Reduction of Breast Skin and Direct Prosthesis Implantation After Mammectomy

Based on the principle of vertical scar mammoplasty, the spindle-shaped incision below the nipple and areola is selected (Fig. 15.17), and the subcutaneous mammectomy and the longitudinal resection of excessive skin are carried out simultaneously. If there is transverse excessive skin in the inframammary fold 3 months later, it can be removed through small inframammary fold incision. One author used Wise incision to simultaneously remove the transverse and longitudinal excessive breast skins, and the inverted T-shaped surgical scar was left after surgery. After the vertical scar mammoplasty has been popularized, this method has been used less.

After subcutaneous mammectomy, the separation is performed under the pectoralis major muscle to the mark range; the layers to be dissected are located on the deep surfaces of the muscles, namely, the deep surfaces of pectoralis major muscle, serratus anterior muscle, obliquus externus abdominis muscle, and the anterior sheath of the rectus abdominis

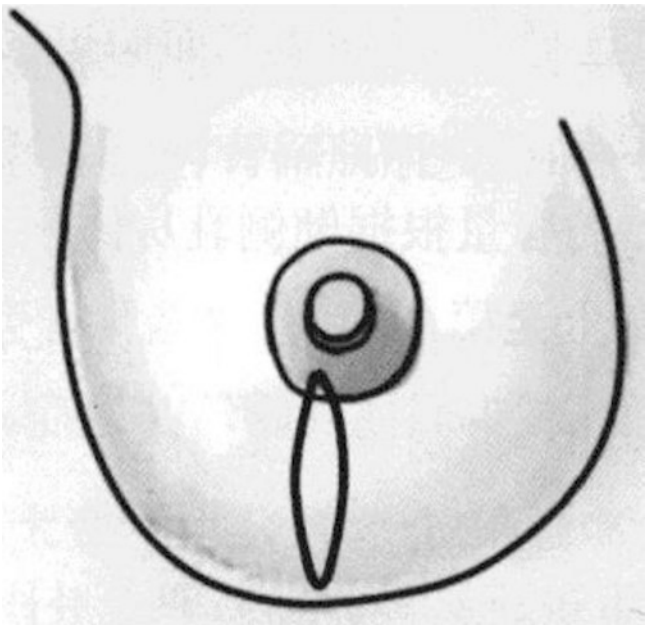

Fig. 15.17 The subcutaneous mammectomy and the longitudinal resection of excessive skin are carried out simultaneously

muscle. The dissection scope reaches upward to the second intercostal space, innerward to parasternal line, outward to the anterior axillary line, and downward to the inframammary fold. The medial lower starting point of pectoralis major muscle often needs to be cut off or stripped off, and the breast prosthesis is implanted behind the muscles.

The complications of breast reconstruction with direct prosthesis implantation mainly include prosthesis exposure and severe capsular contracture in addition to general surgical complications such as active bleeding, seroma, and infection. The cause of prosthesis exposure is the rupture of incision, in addition to the infection factor, more due to poor blood supply of the incision of skin flap, or higher tension born by the incision caused by oversize prosthesis. To prevent the prosthesis exposure, it is required to examine the blood supply of the skin flap and remove the suspected area with poor blood supply, avoid the oversize prosthesis, and place the drainage tube intraoperatively.

If the prosthesis is placed directly under the skin, the severe capsular contracture will easily occur, which is demonstrated as hard texture, breast deformation, and obvious skin folds. The classification of capsular contracture uses the Beckett grading after breast augmentation surgery. According to our experiences, when the subcutaneous lacuna is too large and the prosthesis is too small, severe capsular contracture will occur very easily. When the tissue lacuna is not perfectly matched with the prosthesis, the dilator placement is a good method. The dilator can be used as a temporary instrument to play roles in adaptation and shaping for the skin at surface of the prosthesis, while it can adjust the tension born by the incision and alleviate the complications such as severe capsular contracture and prosthesis exposure.

Another common complication after application of breast prosthesis is the appearance of the prosthetic wrinkles; in severe case, they are seen through the skin by naked eye and can be touched by the hand. The happening reasons are periprosthetic capsular contracture and the thin tissues covering on the prosthesis surface. The prosthetic wrinkles can be corrected by the methods such as release of capsular contracture, replacing the prosthesis with high viscosity contents, and increasing the tissue thickness with acellular dermal matrix, in severe case, and it is required to carry out autologous tissue breast reconstruction in severe cases.

2.2 Breast Reconstruction with Prosthesis Implantation After Tissue Expansion

2.2.1 Overview

The reconstruction process is divided into two phases. The soft tissue expander is implanted in the first phase. After the tissue volume is sufficient through expansion of a certain time, the dilator is taken out at second phase, and the permanent breast prosthesis is implanted. The surgical trauma is small, and the patient recovers quickly. The surgery may be performed under local anesthesia or general anesthesia. The breast reconstruction can be immediately performed at the time of mastectomy and can also be performed at a later stage. Implanting the dilator at the same time of performing mastectomy can adjust the tension of the chest skin flap, increase the adaptability of the skin flap to facilitate symmetry of bilateral breasts, and reduce the probability of capsular contracture.

With the development of the dilator, the adjustable dilator is in combination with permanent prosthesis. After the expansion is completed, the expander capsule can be adjusted to a certain volume, and a small skin incision is made in the distant area, and then the injection pot of the dilator is taken out directly, and, finally, the expander capsule as a permanent prosthesis is implanted into the body to complete reconstruction. But this dilator is adapted to saline-filled breast prosthesis, with new understanding of the silicon gel-filled breast prosthesis, and the expansion technology in the traditional sense is still the mainstream.

In the past, the dilator is placed behind the pectoralis major muscle, due to limitation of the medial lower starting point of the pectoralis major muscle; the muscle tension is larger in this site, which easily leads to upper shift of the dilator during expansion, resulting in excessive expansion of the upper chest skin and insufficient expansion of medial lower chest skin. To prevent this deformity, there are two important developments: one is that the surface of the dilator is designed as textured surface instead of smooth surface,

and thus the shifting during expansion is reduced; the second is that the medial lower starting point of the pectoralis major muscle is partially cut off to reduce the muscle tension in this site, and the area with the lack of muscle overage is covered with artificial dermis. On the other hand, if there are no textured dilators available for selection, when the smooth dilator must be used, the placement location should be appropriately lowered, and the dissection scope below the breast should be 1–2 cm lower than the inframammary fold at the healthy side.

The circular dilator is selectively used. The capacity of the dilator is determined according to the size of the breast at the healthy side and should be 150 ml greater than the permanent breast prosthesis. The range of lacuna to be dissected in the chest is marked before surgery. The range reaches upward to the second intercostal space, innerward to parasternal line, outward to the anterior axillary line, and downward to 2 cm below the inframammary fold. The dilator should be implanted to the deep surface of the chest muscles to reduce the complications such as prosthesis exposure, which is conducive to the delayed reconstruction of the nipple and areola.

2.2.2 Surgical Operation

The surgery is performed under local anesthesia and epidural or general anesthesia. The patient is placed in a supine position, and bilateral upper limbs are fixed on both sides of the body. If bilateral upper limbs are abducted by 90° and fixed to the supporting plate, this will lead to the pectoralis major muscle tension, which is not conducive to the placement of the dilator. The position should be correct and should be not twisted; otherwise, it is easy to cause the asymmetry of both sides. If the surgical approach chooses the original chest scar incision due to mastectomy, it is only needed to incise 4–5 cm at the lateral side, and it is not necessary to incise the whole length of the scar. For patients with wider scars, under the premise that the incision tension is not affected, the original scar can be removed together.

The skin incision is incised, and the separation is performed toward the deep layers within the incision to expose the pectoralis major muscle. The lacuna is separated at the bottom of the pectoralis major muscle passing through the lateral margin of the pectoralis major muscle, and the separation is performed from the preoperative marked separation range to the site at 2 cm under inframammary fold. After the separation of lacuna is completed, the wound is washed and careful hemostasis is performed, and then the dilator is implanted. A certain distance should be kept between the expander capsule and the injection pot to prevent damage to the expander capsule during expansion with water injection. The expander capsule should be unfolded when being placed to avoid angular deformity and prevent skin dehiscence in expansion process. The negative pressure drainage tube is placed, and then the dermal layer and skin are sutured, and, finally, the local pressure dressing is carried out.

When the dilator is implanted, it is injected with a certain amount of saline, about 100–150 ml. After the dilator is immediately implanted during skin-sparing modified radical mastectomy, it should be expanded to the same volume of the breast at the healthy side. The water injection expansion is performed for the first time 2–4 weeks after surgery. The injected water volume at a time is determined according to the degree of skin expansion, and it is usually 30–50 ml. Eventually, the expanded volume should be >50–75% of the prosthesis. When the water injection is performed, the left hand is used to touch the injection pot, and touching up and down about the margin of the injection pot is used to determine the center position of the injection pot. The fine needle is used to pierce vertically into the metal sheet within pot to pot bottom, and then the needle is slightly retreated and the water injection starts to be carried out. The water injection expansion is performed 1–2 times weekly, and after being expanded to final volume, the expansion is maintained as long as possible for a period of time. The longer the maintained expansion time is, the lower the probability of postoperative capsular contracture is. Under normal circumstances, the second surgery is completed 4–6 weeks after water injection expansion, and the permanent breast prosthesis is implanted after the dilator is taken out.

2.2.3 Adjusting the Expander Capsule

The dilator is taken out at second phase, and the permanent breast prosthesis is implanted. The patient takes a standing position, and the inframammary fold is marked. The incision is made along the original surgical scar, and the dilator is taken out. Generally it is not required to remove the capsular membrane around the expander capsule, and the well-expanded capsular cavities mostly do not require a big adjustment. It is worth noting that the lower margin of expanded skin is inconsistent with the inframammary fold, and it is required to reconstruct the inframammary fold before implantation of permanent breast prosthesis. For patients with short expansion time of usually no more than 3 months, the inframammary fold is reconstructed in the corresponding position, and the buried suture can be used for direct suture and fixation; but for patients with a long expansion time, it is required to remove the envelope under the inframammary fold and then suture and fix the skin with the chest wall at the site symmetrical to the inframammary fold at the healthy side to form the new inframammary fold; otherwise, the formed pseudomembrane is not easy to heal. In the area where it cannot be expanded, the capsular membrane is incised, and the separation is performed under the muscle, and then the prosthesis is implanted through the incision; subsequently, the negative pressure drainage tube is placed, and, finally, the pressure dressing is carried out. The

nipple and areola reconstruction is performed at the third month after surgery.

2.3 Breast Reconstruction with Latissimus Dorsi Myocutaneous Flap and Breast Prosthesis

For the patients with partial or complete absence of pectoralis major muscle after mastectomy who have chest hypertrophic scar, too tight and thin skin, sunken subclavian region, and disappearance of the morphology of anterior axillary fold, prior to implantation of breast prosthesis, it is required to repair the chest tissue defect. The latissimus dorsi myocutaneous flap can carry the fan-shaped muscle tissue and provide good chest covering tissues. But the latissimus dorsi myocutaneous flap has a larger area and a small volume. In addition to patients with partial absence of breast tissue or moderate and small breast at the healthy side, when the latissimus dorsi myocutaneous flap is simply used for breast reconstruction, the tissue volume is insufficient; thus, it is difficult to achieve the bilateral symmetry, and it is required to implant the breast prosthesis under the breast prosthesis to replenish the volume of reconstructed breast.

2.3.1 Indications

It is applied to patients with too tight chest skin, serious scar contracture, and lack of good tissue coverage in whom the breast prosthesis or dilator cannot be placed directly and the patients who are inappropriate or reluctant to adopt TRAM flap breast reconstruction. The function of latissimus dorsi muscle should be examined before surgery. The affected upper limb is abducted, and the examiner holds the affected upper limb with hands and asks the patient to adduct the limb to observe the contraction situation of the belly of the latissimus dorsi muscle. In individual cases, if the thoracodorsal nerves and thoracodorsal vessels are injured during breast cancer radical surgery, and the atrophy of denervated latissimus dorsi muscle occurs, the tissue volume of the latissimus dorsi myocutaneous flap will be further reduced at this time, and the blood supply should be affected, and therefore, other methods should be used for breast reconstruction as far as possible.

2.3.2 Preoperative Design

1. The patient takes a standing position. The preoperative marking lines are made, and the inframammary fold symmetrical to that at the healthy side and the contour of the latissimus dorsi muscle at the operated side are marked, respectively.
2. When the myocutaneous flap is designed, the outline of the bra is roughly marked, and the oval skin flap is designed at the lower margin of the bra. The skin flap is located on the muscular part of upper margin of the latissimus dorsi muscle and is transverse or crescent shaped. It is required that the size of the skin flap cannot only meet the requirement for breast reconstruction but also allow that the donor site can be closed and sutured directly. If the skin-sparing radical mastectomy is applied, only a little skin is needed.

2.3.3 Surgical Methods

The patient takes the lateral position with the affected side on the top, and both the mastectomy and skin flap separation can be carried out in this position. After the disinfection and draping are performed in surgical area, the upper limb at the affected side is bandaged with a sterile sheet, which facilitates the intraoperative movement.

The chest scar is removed, and a lacuna is separated under the pectoralis major muscle for standby application. The incision of the skin flap is made along the marker line, and the separation is performed forward on the surface of the fascia of the latissimus dorsi muscle at the anterior margin of the skin flap, and then the anterior margin of the latissimus dorsi muscle is exposed. The running directions of blood vessels at the anterior margin of the latissimus dorsi muscle are confirmed, and a part of the starting point of this muscle is cut off downward from the anterior margin of the latissimus dorsi muscle. The undermined dissection of the upper side and posterior side of the skin flap is performed at the superficial surface of the fascia of the latissimus dorsi muscle, and the starting point of the latissimus dorsi muscle is cut off according to the required muscle volume. The muscle fibers are splitted off on the upper margin of the required muscle range, and the separation is performed at the deep layer using the flap harvesting method of from far and near, and then the myocutaneous flap is lifted up and separated toward the direction of the armpit. The thoracodorsal vessels give off a branch to enter into serratus anterior muscle before entering into the latissimus dorsi muscle. After the branch is found, it is temporarily blocked at first and then is ligated when it is confirmed that the blood supply of thoracodorsal vessels is not affected. The starting point of the latissimus dorsi muscle can be kept intact, cut off, or cut off to reconstruct the anterior axillary folds.

Between two incisions before and after the chest, a subcutaneous tunnel near the armpit is made, and the latissimus dorsi myocutaneous flap is transferred to the chest through this subcutaneous tunnel and is temporarily fixed. The negative pressure drainage tube is placed in donor site in the back, which is directly closed and sutured.

The patient is adjusted in the horizontal position, and the disinfection and draping are performed again. The latissimus dorsi muscle is placed in separated lacuna in the chest; firstly, the myocutaneous flap is placed near the lower part as far as possible and is fixed with chest muscle, costal perichondrium,

and inframammary fold flap, and then the starting point of the latissimus dorsi muscle is fixed respectively with the medial clavicle and the parasternal line. The muscle flap is fixed with lateral chest wall at the anterior axillary line and is sutured on the fascia of the serratus anterior muscle, so as to prevent the retraction of the muscle flap and limit the shifting outward of the breast prosthesis. When there is partial absence of pectoralis major muscle, the muscle flap is sutured and fixed with the pectoralis major muscle. After most of the skin flap is sutured, the lateral incision is retained, so that the breast prosthesis can be placed in through this incision. The patient is adjusted in the semi-sitting position, and the breast prosthesis is implanted behind the muscle flap. After bilateral sides are adjusted to be symmetrical, the negative pressure drainage tube is placed, and the incision is closed. The upper limb is immobilized for 72–96 h after surgery. In order to achieve the symmetry of bilateral breasts, the dilator can be placed at first, and the size of the required prosthesis for reconstruction is confirmed, which facilitates correct selection and application of the breast prosthesis.

2.3.4 Complications

The combined use of latissimus dorsi myocutaneous flap and artificial breast prosthesis has the disadvantages of two aspects of autologous tissue transplantation and the foreign body such as breast prostheses. The complications related to breast prosthesis are the same as those in breast augmentation, which mainly include the periprosthetic capsular contracture and the prosthesis exposure due to the partial flap necrosis. Other rare complications include prosthesis rupture, prosthesis displacement, infection, exposure, and excessive worry of the prosthesis. The donor site hematoma and seroma are the most common complications, and performing intraoperative careful hemostasis, placing a negative pressure drainage tube at the lowest point, and maintaining unobstructed drainage are the keys to prevention. After the occurrence of seroma, multiple puncture aspirations are required to remove the hemorrhage, and the pressure dressing is carried out; in individual cases, it is required to make an opening in the lowest position to place the negative pressure drainage tube. The donor site scar is located under the bra, and it can be covered by the bra. The scar hyperplasia may appear in individual cases.

The cause of high hardening rate after prosthesis-based breast reconstruction is the high incidence of hematoma, and the organization of hematoma causes periprosthetic capsular contracture; the tissue covering the prosthesis is limited; thus, the chest skin tension is large, and the skin flap is thin, which restricts the activities of the prosthesis and facilitates the formation and thickening of periprosthetic capsule. Its prevention methods are that the textured breast prosthesis is selected, and data indicate that the degree of capsular contracture of the textured breast prosthesis is significantly lower than that of the smooth breast prosthesis; the breast tissue volume is increased; for patients with lack of tissue volume, the breast reconstruction should be carried out after combined use of muscle flap transfer or soft tissue expansion.

In order to prevent the surgical failure resulted from prosthesis exposure due to partial necrosis of skin flap margin, the prosthesis should be implanted behind the chest muscle tissue. Especially for patients with immediate reconstruction, the prosthesis should be implanted completely behind the muscle tissue, and at least the incision site should be covered by the muscle tissue.

Another common complication after application of breast prosthesis is the appearance of the prosthetic wrinkles; in severe case, they are seen through the skin by naked eye and can be touched by the hands. The happening reasons are periprosthetic capsular contracture and the thin tissues covering on the prosthesis surface. The prosthetic wrinkles can be corrected by the methods such as release of capsular contracture, replacing the prosthesis with high viscosity contents, and increasing the tissue thickness with acellular dermal matrix. In severe cases, it is required to carry out autologous tissue breast reconstruction.

The performance of the prosthesis after prosthetic breast reconstruction is different with that of the autologous tissue; with the growth of age, the prosthesis cannot gradually prolapse just like the normal breast, while the breast at the healthy side will prolapse seriously. On the other hand, when the surrounding environment temperature is too low and the heat preservation measures are poor, some patients will feel a cool prosthesis, but most patients do not consider it a problem.

3 The First-Stage Breast Reconstruction for Women at High Risk of Breast Cancer After Prophylactic Mastectomy

Wei Wang, Lizhi Ouyang, and Bo Zhou

3.1 Overview

Since the late 1970s, the first-stage immediate breast reconstruction after prophylactic mastectomy in women at high risk of breast cancer has become an issue in the western society and the medical profession. After decades of practice, this surgery has become an acceptable option for women at high risk of breast cancer and the surgeons of surgical oncology and plastic surgery in more countries. The authors believe that in our country, the plastic and reconstructive surgeons will give more attention to this issue together with the

surgeons in oncology and general surgery; in the coming years, the first-stage immediate breast reconstruction after prophylactic mastectomy in women at high risk of breast cancer will become an acceptable option for women at high risk of breast cancer and the surgeons of surgical oncology and plastic surgery in our country.

The prophylactic mastectomy was controversial when it was initially proposed, because the effectiveness of the use of surgical approach to prevent breast cancer has not been confirmed by a large sample and multicenter clinical study at that time. As a constituent element of female physical beauty, the breasts are very important for body curve. If the mastectomy is implemented in young women without a child, how to make trade-off decisions between the unconfirmed cancer risk and the physical aesthetics and the resulted psychosocial problems are certainly worthy of in-depth research and exploring by many scholars. With advances in genetic testing instruments and cancer risk assessment model as well as with the deepening of research on woman group at high risk of breast cancer, combined with the recent development and progress of breast reconstruction technique and material science, people begin to gradually gain an in-depth understanding of this kind of surgery. This surgery has gained identification of more and more surgeons and patients, and the researches on this kind of surgery have gradually become popular in the fields of breast plastic surgery and breast tumor surgery.

3.2 Breast Cancer Risk Factors and High-Risk Groups

3.2.1 General Risk Factors for Breast Cancer

The breast cancer is the number one killer threating the health of the women, and its incidence rate accounts for highest percentage among female malignant tumors. The regional differences in the incidence of breast cancer in the world are relatively larger, and European and American areas are usually considered as the high-incidence areas. The foreign data show that in the United States, the average probability of developing breast cancer is 13% in women's life, and in women older than 60 years later, the probability will be increased significantly; the incidence of breast cancer in women in Asia is relatively low, which may have a great relationship with lifestyle, environmental, and genetic backgrounds. In China, there is still a lack of nationwide joint investigations on prevalence of female breast cancer, but in recent years the results of regional general survey showed that the prevalence of breast cancer in China showed an upward trend, and the incidence showed a trend of younger age, which may be related to that the breast tissues in Asian female are relatively compact and the morbidity peak age is relatively young [1]; meanwhile, more early breast cancers can be detected due to the wide development of general surveys on female disease.

Variety of factors in vivo and in vitro commonly lead to the high incidence of breast cancers, and different research institutions have different screening criteria and classifications for all kinds of risk factors which may increase the risk of breast cancer. At present some factors which have not been revealed and may have important relationships with the occurrence and prognosis of breast cancers still need to be studied further. Currently recognized risk factors which are definitely related to the breast cancer incidence rate include family history of tumor, menarche and menopause ages, history of pregnancy and breastfeeding, history of benign breast disease, the density of the breast tissue, smoking, alcohol consumption, and use of contraceptives. Among the numerous factors, the family history of tumor is often related to the genetic background of the patient and is currently one of the most confirmed risk factors for breast cancers. The assessment of the various types of risk factors contributes to the prevention of breast cancer and screening of high-risk groups; therefore, the researchers have carried out a lot of researches on all kinds of risk factors and their impact on the incidence of breast cancers. Through comparing the research results of assessment of multiple breast cancer risks, Nelson et al. found that the risk factors which lead to the fact that the average breast cancer incidence rate in women with 40–49 years of age is twice higher than that in normal persons include extremely dense breast tissue and history of breast cancer in immediate family members, and the risk factors which lead to the fact that the breast cancer incidence rate is 1.5 to 2 times higher than that in normal persons include history of breast cancer biopsies and history of breast cancer in nonlineal relatives; in addition, the risk factors which lead to the fact that the breast cancer incidence rate is 1.0–1.5 times higher than that in normal persons include recent use of oral contraceptives, unbearing, or women of more than 30 years old giving birth to the first child [2]. Of all the risk factors, the family history of breast cancer, especially the immediate family history of breast cancer before menopause, leads to a sudden increase in the risk of breast cancer; if a family member has bilateral breast cancer before menopause occurs, or there are more than one patient with breast cancer or combined with ovarian cancer in family members, this risk will be doubled and highly indicates the possibility of hereditary breast cancer.

3.2.2 The Risk Factors for Breast Cancer

Current research indicates that about 10% of breast cancers are associated with genetic mutations, of which, people are mostly familiar with BRCA1 and BRCA2 mutations. For patients with BRCA1 mutations, the risk of breast cancer before the age of 65 is up to 50–80%. A remarkable feature of breast cancers which are related to BRCA1 and BRCA2

mutations is estrogen receptor negative. Therefore, they are not susceptible to tamoxifen therapy, and the curative effect of chemotherapy is poorer. The tumor cell differentiation is lower, and the pathological characteristics indicate that the atypia of the cells is more obvious than that in sporadic breast cancers and the medullary carcinoma is more common. This type of breast cancers mostly involves the young women due to the early age of onset. More importantly, the imaging screening window phase of breast cancers which is related to BRCAl/BRCA2 mutations is only 1 year, and the imaging screening window phase of sporadic breast cancers is as long as 3 years; in this case, it is not more conducive to the early detection of breast cancers which is related to BRCAl/BRCA2 mutations [3]. Another factor associated with the incidence rate of hereditary breast cancer is the mutation of the antioncogene p53. After mutation of antioncogene p53, the person is susceptible to intracranial and adrenocortical tumors in childhood. This genetic syndrome is known as Li-Fraumeni syndrome, and young women suffering from this syndrome have a very high incidence rate of breast cancer.

In addition to the high incidence rate of breast cancer due to a single or multiple mutations, some breast lesions such as atypical hyperplastic disease and lobular carcinoma in situ also highly suggest the possibility of the occurrence or recurrence of breast cancer. Although the lobular carcinoma in situ can be cured by surgery due to the fact that it has not invaded and infiltrated surrounding tissue, some studies have found early that the possibility of occurrence of bilateral invasive breast cancers in patients with lobular carcinoma in situ is up to 30–40% within 15 years after surgery [4]; furthermore, about 50% of the patients with unilateral invasive breast cancer also have the lobular carcinoma in situ occurring in the contralateral breast, and about 5% of the patients undergoing resection of lobular carcinoma in situ have cancerous infiltration in the resected breast tissue.

3.2.3 The Scope of High-Risk Groups

A lot of researches on risk factors and high-risk groups for breast cancer are carried out in China, while a lot of achievements have also been made, but so far there is still a lack of precise definition of risk factors. The definition of the scope of high-risk groups has not yet reached a consensus, and many domestic treatment criteria for breast cancer often refer to some foreign conference consensus or treatment guidelines. According to the surgery guidelines for prophylactic mastectomy updated by American Society of Surgical Oncology in 2007, the high-risk groups of breast cancer should at least include the following two types of people:

1. The women without personal history of breast cancer but with a family history of breast cancer and/or ovarian cancer, in whom the genetic tests clearly detect BRCA1/BRCA2 or other gene mutations which are highly correlated with breast cancer.
2. There is a high incidence rate of breast cancer in the contralateral breast in the patients with a clear history of unilateral breast cancer or precancerous lesions such as lobular and duct atypical hyperplastic lesions or lobular carcinoma in situ.

3.2.4 Genetic Tests of High-Risk Groups

Given that the groups with breast cancer-related gene mutation has such a high incidence of breast cancer, the genetic test has become a necessary test item for women with a family history of breast cancer.

1. National Comprehensive Cancer Network (NCCN) guidelines: American NCCN guidelines recommend that the patients with one of the following circumstances should undergo genetic test – ① the patients with an age of ≤40 years have early breast cancer; ② the patients have multiple breast cancers or combined with ovarian cancer or history of this disease in immediate family members; ③ more family members have histories of male breast cancer, thyroid cancer, sarcoma, or other diseases; and ④there are patients with clear BRCA1/BRCA2 mutations or other suspicious genetic mutations which are associated with breast cancer among the family members.
2. Studies of American Society of Clinical oncology (ASCO): According to the studies of ASCO, the patients with one of the following circumstances have significant increase in risk index of genetic hereditary breast cancer: ① there are more than two breast cancer patients or one to two patients with history of ovarian cancer in family members, regardless of the onset of age; ② there are more than three patients in family members who have been diagnosed with breast cancer before age 50; and ③ there are sisters who have bilateral breast cancers, bilateral ovarian cancers, or unilateral breast cancer combined with unilateral ovarian cancer before age 50.

It is important to note that the differences in genetic backgrounds and constitutions of the patient groups at home and abroad and the differences in social life environment and even cultural background have a certain influence on therapeutic effect; therefore, in reference to foreign standards, attentions should also be paid to different situations at home and abroad, or some criteria should be correspondingly amended to conform to the actual situation of the patient group at home.

Current research on hereditary breast cancer is still not very incisive, and the known types of BRCA1/BRCA2 mutations include more than 500 types. Furthermore, new mutation types are still being discovered, which lack the so-called hot spot region, and the mutation occurs throughout

the entire gene, which brings difficulty to the detection of mutation and the prediction of incidence rate. In addition, there is also a large discrepancy in statistics of various research centers on incidence of breast cancer after BRCAl/BRCA2 mutation; except BRCA, the gene mutations such as P53, ATM, PTEN, STK11, MLH1, MSH2, and CHK2 can also cause breast cancer [5]; and the incidence of breast cancer is not only closely related to the genetic background but also closely related to the patient's living habits, environmental factors, and drug use. These factors make it very difficult to accurately predict the incidence rate of breast cancer and can also make the definition and screening of high-risk group become more complicated. Since there is still a lack of large sample survey on the incidence rate of breast cancer in high-risk groups in China, the definition and screening criteria of high-risk group are also a topic worth further study and discussion for surgical oncologist.

3.3 The Necessity and Efficiency of Prophylactic Mastectomy

3.3.1 Prophylactic Mastectomy

In the foreign countries, the study on prophylactic mastectomy started early, and there are more cases; thus, a wealth of experience has been accumulated; the domestic research in this area is still in its infancy; the surgical concept of prophylactic mastectomy surgery still cannot be accepted by most of the patients and surgeons. The total mastectomy is implemented for the breast which has not been affected, whether this surgery belongs to excessive medical treatment. This has become the focus of controversy within a period of time. Some scholars have suggested that it is better to treat the women in high-risk groups with effective monitoring and chemotherapy than to carry out the preventive surgery due to limited social medical resources; but subsequent researches have also found that younger women undergo preventive mastectomy and reconstruction, which can save more social medical resources compared with the many years of monitoring. In 1999, Hartmann in Mayo Clinic and his work team launched a study comparing and observing the effect of prophylactic mastectomy on the incidence rate of breast cancer in high-risk groups and published a landmark paper, which exactly proved the effectiveness of prophylactic mastectomy. This retrospective study found that after the implementation of bilateral prophylactic mastectomy, the breast cancer risk in high-risk groups can be reduced by 90%. Another similar study also found that patients with personal and family history of breast cancer may benefit from prophylactic mastectomy; in addition to the radical mastectomy at the affected side, the prophylactic mastectomy is performed at the contralateral side, so that the incidence rate of breast cancer for the contralateral breast can be reduced by of 94.4% (before menopause) or 96% (after menopause); for patients with BRCA1/BRCA2 mutation, the implementation of bilateral prophylactic mastectomy can reduce the incidence rate of breast cancer by 85–100%. Since then more studies show that prophylactic mastectomy is an effective preventive measure against breast cancer in high-risk women. What the attention needs here is, although the prophylactic mastectomy may significantly reduce the incidence rate or recurrence rate of breast cancer, there is still no conclusive evidence to indicate that this surgery can effectively improve the survival rate of patients with unilateral breast cancer.

3.3.2 Conservative Monitoring and Drug Treatment

In addition to surgical approach, some conservative preventive measures can also play a certain role. These measures include close monitoring and preventive medication. Nonsurgical monitoring contents should include monthly breast self-examination, annual mammography, and a clinical breast examination every 4–6 months. The preventive medicine researches mostly focus on nonsteroidal antiestrogen drugs such as tamoxifen. The study results of US NSAB-PI have demonstrated that in the women with a high risk of breast cancer who have taken orally tamoxifen for 5 years, the incidence rate of invasive breast cancer within 7 years is lower than that in the control group by 50%. But whether it is monitoring or drug prevention, the overall effects are not as good as that of the prophylactic mastectomy.

3.3.3 Advantages of Prophylactic Mastectomy

Prophylactic mastectomy and reconstruction have following significant advantages compared with conservative treatment [6]:

1. The risk of breast cancer is comprehensively reduced.
2. The risk of psychological problems is reduced, and the confidences of the patients in their own health statuses are enhanced, and the emotional burden of the occurrence or recurrence of breast cancer is reduced.
3. There is a good aesthetic effect and body image.

It should be noted that the patients still require close monitoring and follow-up after surgery.

Thanks to improved means of genetic tests and risk assessment model, progress of surgical techniques, and development of prosthetic material, the oncology plastic surgeons can more accurately grasp the distribution of high-risk groups and develop individualized surgery and postoperative reconstruction programs, and a higher postoperative satisfaction has been achieved. Therefore, the prophylactic mastectomy and reconstruction have been

increased continually in foreign countries in recent years. In addition, people have a continuously improved understanding of the risk of hereditary breast cancer. As a consequence, more patients tend to choose the prophylactic mastectomy as the means to prevent breast cancer.

Due to differences in social and cultural backgrounds between domestic and foreign countries, it is difficult to generally carry out the prophylactic mastectomy in short time in domestic country, and the effectiveness of the surgery has not been confirmed by a large sample of cases in domestic country. The initial research draws on foreign experience and should simultaneously combine with the domestic situation, carry out in-depth research on the effectiveness of prophylactic mastectomy, and draw its own conclusions on the basis of practice.

3.4 Prophylactic Mastectomy and Breast Reconstruction

3.4.1 Indications of Prophylactic Mastectomy

The oncology plastic surgeons should strictly grasp the indications of the prophylactic mastectomy. The domestic research on this type of surgery is still in its infancy; therefore, there is also a lack of uniform regulations on the surgical indication; there is a more stringent selection criteria and complete preoperative preparation at abroad for carrying out this type of surgery; the indications of prophylactic mastectomy established by the American Society of Surgical Oncology are shown in Table 15.1.

Table 15.1 Indications of prophylactic mastectomy

Classification	Indication
Women without a previous history of breast cancer (bilateral prophylactic mastectomy)	Atypical hyperplasia
	There are bilateral breast cancer patients before the menopause in the family
	There is a family history of atypical hyperplasia and/or bilateral breast cancer, combined with dense and nodular breast
Women with a previous history of unilateral breast cancer (contralateral prophylactic mastectomy)	Dispersed and tiny calcification foci
	Lobular carcinoma in situ
	The larger breasts which are difficult to be evaluated
	The unilateral breast cancer which occurs after lobular carcinoma in situ
	There are other risk factors, such as atypical hyperplasia, the history of breast cancer in immediate family, age < 40 years

3.4.2 Preoperative Preparation

The prophylactic mastectomy includes bilateral prophylactic mastectomy and contralateral prophylactic mastectomy. The former is mainly for pathogenic BRCA1/BRCA2 mutation carriers confirmed by genetic test or the patients with highly suspected hereditary breast cancer; the latter is for patients with unilateral breast cancer and/or atypical hyperplasia and lobular carcinoma in situ definitely diagnosed by pathology. As a nontherapeutic surgery, the prophylactic mastectomy may not be accepted by all of the patients; thus, the preoperative full communication with the patient is crucial, which is directly related to postoperative patient satisfaction. According to the recommendations of Eldor et al., the medical staff in the treatment team should include genetic specialist, oncology specialist, breast surgery specialist, and plastic surgeons; trained nurses, psychiatrists and gynecologists, and the entire medical team can provide detailed information consultation to patient before surgery, so that patients have a full understanding of this surgery.

3.4.3 Preoperative Conversation

Before surgery, the following issues need to be communicated to the patients in detail:

1. The timing of surgical breast reconstruction.
2. The pros and cons of autologous tissue and prosthesis reconstructions.
3. The autologous reconstruction method is selected according to the physical characteristics of the patient.
4. The prostheses available for selection.
5. The reconstruction of the nipple and areola may be required; the sensory deprivation may occur after surgery.
6. It is required to carry out strict oncological monitoring and follow-up after surgery.
7. The estimated postoperative recovery time and rehabilitation exercise steps.
8. The scars in breast and donor site.
9. Possibility of postoperative complications in breast and donor site.
10. The possibility of reoperation, including the replacement of the prosthesis and aesthetic plastic surgery.
11. The acceptance degree of the spouse.

3.4.4 Preoperative Preparation and Surgical Procedures

The self-contained medical team and adequate preoperative preparation are necessary for a successful operation. According to the experience abroad accumulated in carrying out such operations, some medical centers have created a set of standard procedures, such as the full preoperative preparation and operation process recommended by Wickman et al. (Fig. 15.18).

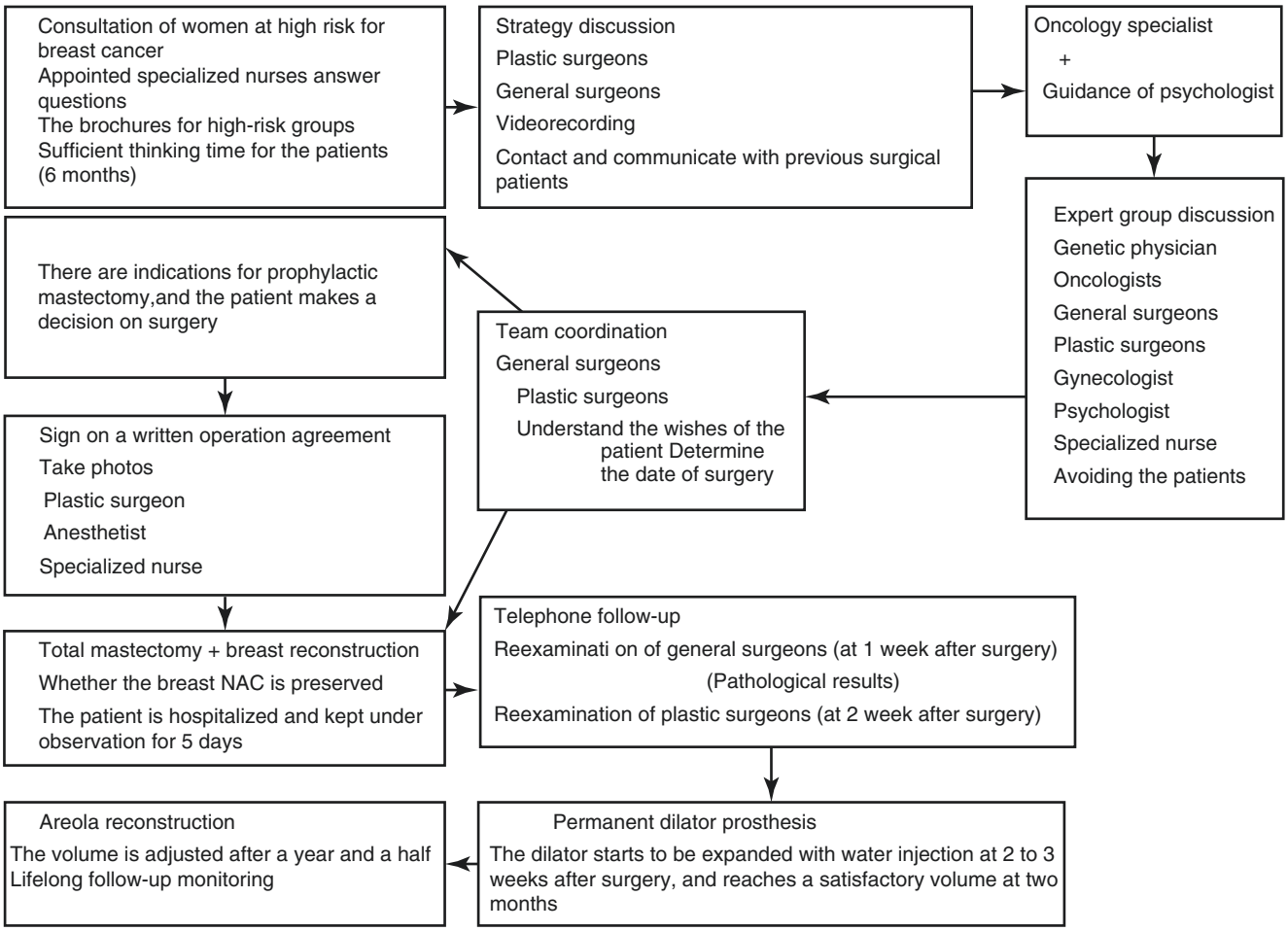

Fig. 15.18 The complete surgical process recommended by Wickman et al.

Whether it is the bilateral prophylactic mastectomy or contralateral prophylactic mastectomy, it is a precautionary measure. After all, the normal organ of the patient is resected by the surgery. Even if the first-stage reconstruction is taken as a remedial measure, it is still a larger devastating surgery. It has a huge impact on physical beauty of the patient and also tends to be an aggressive preventive measure relative to the conservative treatment. In view of the irreversible consequences of the surgery, the oncology plastic surgeons should fully weigh the pros and cons together with multi-department experts and prudently make a selection of the surgical methods.

3.4.5 Surgical Methods

1. Mastectomy method: The surgical methods for prophylactic mastectomy include simple total mastectomy and the mastectomy with preservation of nipple-areola complex (NAG).
   (1) Simple total mastectomy: The primary goal of the prophylactic mastectomy is to remove all breast tissue as thoroughly as possible (but the facts show that any kind of surgical method cannot remove all breast tissues by 100%), and all surgical methods preserve the pectoralis major and minor muscles and don't carry out axillary lymph node dissection. As early as in 1984, Syderman proposed that the prophylactic mastectomy should include the nipple-areola complex, while the surgical method with preservation of the nipple and areola is not enough. According to earlier studies of Hartmann et al., among 575 patients undergoing total mastectomy with preservation of nipple-areola complex, seven patients still had breast cancers during an average follow-up period of 17 years; and among the patients undergoing simple total mastectomy, no breast cancers occurred; thus, it is concluded that, for the very high-risk groups, the total mastectomy with preservation of nipple-areola complex should be implemented.
1. Surgical steps: An oval incision including nipple-areola complex is designed, and the entire breast

is resected through the incision. The dissection plane of the skin flap is the same as that of the modified radical mastectomy, with preservation of pectoralis major and minor muscles and without axillary lymph node dissection. The prosthesis implanted under the pectoralis major muscle for breast reconstruction or autologous tissue reconstruction and nipple and areola reconstruction are selected according to the patient's condition.

2. Advantages and disadvantages:
   Advantages:

   - It can remove the breast tissue more thoroughly.
   - The surgical steps are simple.
   - The surgical field is exposed clearly.
   - There are fewer complications, and theoretically there is a lower incidence rate of postoperative breast cancer.

   Disadvantages:

   - It is required to carry out nipple-areola complex reconstruction.
   - The appearance, color, position, symmetry, and sensation of breasts are unsatisfying to a certain extent.

(2) Total mastectomy with preservation of nipple-areola complex: It is required to try to achieve a closer fidelity in the process of breast reconstruction. Therefore, the total mastectomy with preservation of nipple-areola complex (NAC) starts to increase. The classic surgical method for prophylactic total mastectomy does not retain NAC. NAC reconstruction methods include local skin flap, skin transplantation, composite transplantation, temporary storage transplantation, and partial preservation of the nipple. But the degree of satisfaction of NAC reconstruction is not high; studies have shown that 36% of patients are not satisfied with the reconstructed NAC after surgery, in particular, the lack of uplift with good appearance in the reconstructed nipple, the colors do not match, and various factors such as shape, size, texture, and location are unsatisfactory [7]. Another great defect is the lack of sensation in the reconstructed nipple sensation, so that more surgeons start to select total mastectomy with preservation of NAC.

1. Surgical steps: The surgical steps and requirements are similar to those of the simple mastectomy, and the difference is the selection of the incision (Fig. 15.19). For females with smaller breasts and patients with breasts which don't droop or slightly droop, the incision beside the areola or the inframammary fold incision can be selected. In addition to that, the skin flap below the nipple-areola complex is retained with a thickness of several millimeters; all breast tissues in the other areas should be removed as thoroughly as possible, and the pathological examination of the area below the NAC should be taken as the key examination and is carried out independently and separately. And for those patients with larger breasts or patients with severe sagging breasts, in addition to implementation of mastectomy, usually it is also required to remove some residual skin. The females with less full breasts can also select the inframammary fold incision, so that the surgical scars can be better hidden, but the surgical method will make it more difficult to remove the upper quadrant of the breast. The females with full breasts can select the Ω-shaped incision beside the areola; this facilitates the removal of some excessive skin when preserving the NAC.
2. Advantages and disadvantages: The surgery with preservation NAC is compared with NAC reconstruction; in theory, the former can retain the natural shape, size, color, and sensation of the nipple and areola, can significantly improve the aesthetic effect after breast reconstruction, and thus achieve a higher patient satisfaction, but this surgical method inevitably increases the residual breast volume and thus increases the risk of postoperative breast cancer. When the inframammary fold incision is selected, the difficulty of resection of upper quadrant of the breast is also increased greatly. These factors lead to that some patients still have breast cancers after surgery. Recently a number of studies have shown that the risk of occurrence or recurrence of breast cancer due to preservation of NAC in prophylactic mastectomy or even the mastectomy for peripheral small breast cancer is still within the acceptable range.

2. Breast reconstruction method: The breast reconstruction methods include autologous tissue reconstruction, prosthesis reconstruction, or autologous tissue reconstruction combined with prosthesis reconstruction.

(1) Autologous tissue reconstruction: The autologous tissue reconstruction refers to the use of a variety of pedicled or free skin flap and myocutaneous flap to repair the defects after mastectomy. Studies have shown that the autologous tissue breast reconstruction can obtain a breast with good appearance after surgery, can prevent the occurrence of situations such as prosthesis capsular contracture to achieve a better long-term curative effect compared with the prosthesis reconstruction, and thus get the favor of surgeons.

The commonly used tissue flaps include pedicled transverse rectus abdominis myocutaneous flap (TRAM flap), free TRAM flap, deep inferior epigastric perforator (DIEP) flap, pedicled latissimus dorsi

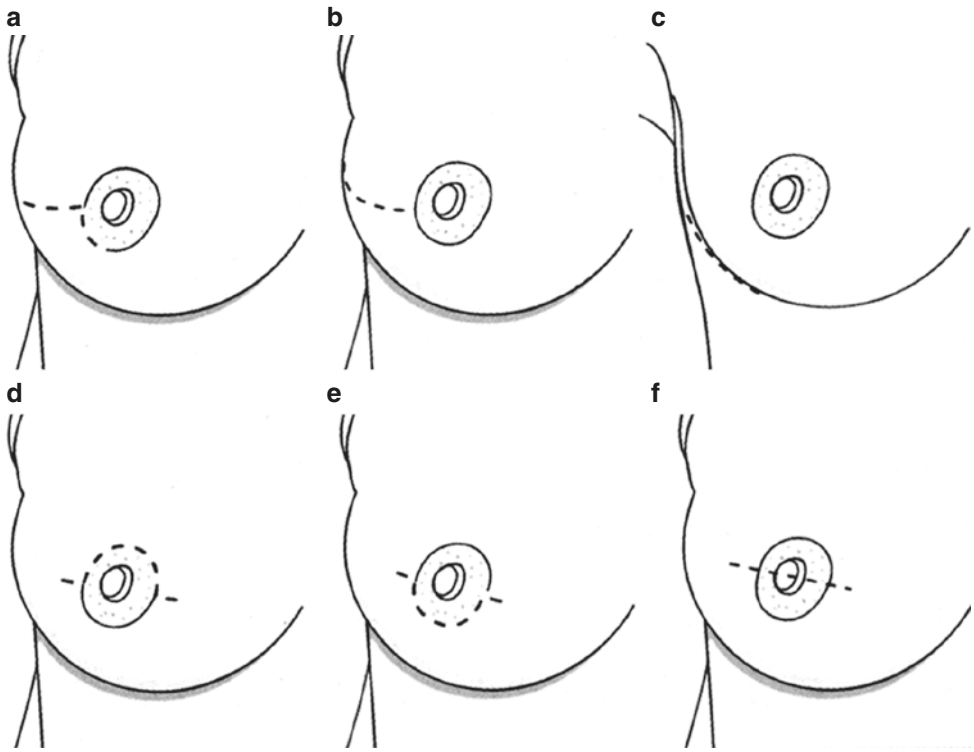

Fig. 15.19 Several incisions for total mastectomy with preservation of nipple-areola complex. (**a**) Unilateral incision beside the areola. (**b**) The incision in lateral side of the breast. (**c**) The inframammary fold incision. (**d**, **e**) Ω shaped incision. (**f**) The incision across NAC

myocutaneous flap, superior gluteal artery perforator flap, inferior gluteal artery perforator flap, and transverse myocutaneous gracilis flap.

The applications of various types of skin flaps in breast reconstruction, surgical steps, and the advantages of various kinds of skin flap are described in relevant contents of the first section in this chapter.

At present, the gold standard of breast reconstruction still uses the autologous tissue reconstruction and takes the TRAM flap as the first choice, and the reconstruction methods include the use of TRAM flap and DIEP flap. Because the patients undergoing prophylactic mastectomy are mostly young women, most of them have a relatively slender body and have no excessive abdominal fat tissue; in this case, the latissimus dorsi myocutaneous flap or free skin flaps in hips and thighs can also be available for selection.

The disadvantages of autologous tissue breast reconstruction include the injury of donor site of the skin flap, postoperative deformity, more early postoperative complications and more complex surgical steps, a longer operative time, and higher surgical technical requirements.

(2) Prosthesis reconstruction: Relative to autologous tissue reconstruction, the prosthesis reconstruction has clear advantages. Especially for patients undergoing bilateral prophylactic mastectomy with preservation of nipple- areola complex, the permanent or temporary prosthesis implantation under the pectoralis major muscle can better restore the appearance of the breast and achieve a higher postoperative satisfaction. Spear et al. comprehensively compared the satisfactory degrees, the incidence rate of postoperative complications, reoperation rate, and aesthetic score among patients with different breast reconstruction methods (prosthesis reconstruction, TRAM flap reconstruction, and the latissimus dorsi myocutaneous flap reconstruction). It was found that the prosthesis reconstruction can achieve maximum postoperative patient satisfaction and the lowest incidence rate of postoperative complications; although its aesthetic effect is worse than that of TRAM flap reconstruction and has a higher reoperation rate, the patients undergoing prosthesis reconstruction have a higher quality of life after surgery [8], and the surgical operation requirements are relatively low, and the postoperative complications are less, so that more surgeons tend to also choose the prosthesis reconstruction. According to investigation of plastic surgery in the United States in 2010, 82.7% of plastic surgeons tend to choose the prosthesis implantation breast reconstruction, while only 14% of surgeons choose the autologous tissue reconstruction. The study also found that, in relation to the academic institutions, the plastic surgery team is more willing to use prosthesis reconstruction. Relative to autologous tissue reconstruction, the prosthesis reconstruction is also considered to be a less invasive surgery. Due to its advantages such as short

operation time, simple surgical procedure, faster postoperative recovery, no damage to the flap donor site, and no postoperative deformity, it is praised highly by most scholars.

The disadvantages of prosthesis reconstruction include long-term postoperative instability and capsular contracture of the implant. Although the recent complications after prosthesis reconstruction are less, the observation on long-term effects (>5 years) shows that its prosthesis loss rate and reoperation rate are higher; for younger women undergoing bilateral prophylactic mastectomy, these disadvantages can't be ignored apparently.

(3) Reconstruction with autologous tissue and prosthesis: The reconstruction with autologous tissue and prosthesis is more used in the case that the tissue volume in autologous tissue reconstruction is insufficient to recover the appearance of the breast, and the prosthesis or dilator is embedded under the pectoralis major muscle to restore the volume of the breast. It is mostly used in reconstruction after simple mastectomy (without preservation of NAC).

The selection of reconstruction method after prophylactic mastectomy should be determined according to the specific circumstances of the patient; through the research, it is recommended by the Spear et al. that those younger patients with busy daily work, smaller breasts, light body weight, and implementation of bilateral breast reconstruction tend to choose prosthesis implantation, and those older patients with more relaxed work, too large breast size, high body weight, and unilateral breast reconstruction tend to choose autologous tissue reconstruction. The oncology plastic surgeons should comprehensively weigh the pros and cons and make the choice mostly suitable for the patient combined with the patient's own subjective requirements, economy bearing capacity, and medical technical condition of the team.

3. The timing of breast reconstruction: According to the relationship of the time interval between breast reconstruction and mastectomy, the breast reconstruction can be divided into the first-stage reconstruction and the second-stage reconstruction [9]:

(1) The first-stage reconstruction: The first-stage reconstruction refers to carrying out breast reconstruction at the same time of performing a mastectomy. It can be divided into two kinds of immediate reconstruction and delayed primary reconstruction. The immediate reconstruction means the mastectomy and reconstruction are completed at one time, that is, to carry out breast reconstruction through myocutaneous flap transfer after implementation of simple mastectomy or implant the breast prosthesis under the pectoralis major muscle at the same time of preserving the nipple-areola complex. The surgery retains the skin on the surface of the breast and the inframammary fold to avoid scars around the reconstructed breast, so that the appearance and skin sensation of the reconstructed breast are closer to nature. The delayed primary reconstruction means that firstly the dilator is embedded under the pectoralis major muscle after mastectomy, and then the dilator is taken out and replaced with silicon prosthesis 4–6 months later. The advantages of this surgery are ① it can maximize the use of the remaining breast skin, and it can adjust the tissue volume and adjust the position of the nipple and areola to the best position at the same time of replacing the silicon prosthesis; ② in the early postoperative period, the injected water volume of the dilator can be controlled to avoid the effect of the excessive tension at the surface of skin flap on the blood supply and reduce the incidence rate of ischemic complications in skin flap and nipple-areola complex; and ③ the surgeons and patients can choose a silicon prosthesis with a suitable size according to specific statuses of skin expansion after surgery.

(2) The second-stage breast reconstruction: It is mainly used for patients who don't have local recurrence and distant metastasis following adjuvant therapies such as systematic radiotherapy and chemotherapy more than 2 years after radical mastectomy. The patients undergoing bilateral or unilateral prophylactic mastectomy often choose the second-stage breast reconstruction, because the breast at the operation side doesn't require radiotherapy.

(3) The selection of the timing of reconstruction: Some surgeons believe that the patients undergoing the first-stage reconstruction have not experienced all the pains due to the absence of the breast and would easily produce dissatisfaction for the reconstructed breast, thus affecting the postoperative patient satisfaction; there is a certain incidence of breast cancer even in patients undergoing prophylactic mastectomy: thus, it is necessary to fully communicate with the patients and inform them before surgery that after the first-stage reconstruction performed in this situation, it may be required to carry out radiation or chemotherapy which will seriously affect the postoperative aesthetic effect. But most of surgical patients have opted for the first-stage reconstruction.

Compared to the second-stage breast reconstruction, the first-stage breast reconstruction has the following advantages: ① it can alleviate the psychological suffering of the patient caused by the absence of the breast and reduce the incidence rate of psychological disorders; ② it can reduce the number of operations, shorten the treatment time, and lower the treatment costs; and ③ the remaining

tissues after mastectomy are not affected by the scars, the texture is soft, and the appearance of reconstructed breast is better than that after second breast reconstruction.

3.5 Limitations of the First-Stage Reconstruction After Prophylactic Mastectomy and Its Current Situation in China

In the early 1960s, the patients with a clear family history of breast cancer in foreign country were treated with prophylactic mastectomy; after years of practice and analytical research, it is found that this surgery is the most effective means of prevention of breast cancer; with the continuous improvement of breast reconstruction techniques, more and more high-risk groups have chosen the method of the first-stage reconstruction after prophylactic mastectomy to reduce the risk of breast cancer.

However, it is noteworthy that although the prophylactic mastectomy may significantly reduce the incidence rate of breast cancer, there is no enough evidence to indicate that the surgery can reduce breast cancer mortality. The prophylactic mastectomy in the United States shows an increasing trend in recent years, which has attracted the concerns of some scholars. Studies have shown that most patients choose this surgery because of the surgeon's recommendation, and the surgeons overestimate the incidence rate of breast cancer in patients. Wood et al. considered that a considerable proportion of patients receive excessive treatment, and the indications of this destructive surgery should be more strictly controlled. Especially for the patients lacking evidence of genetic test such as pathogenic BRCA1/BRCA2 mutations, a more cautious attitude should be taken toward the implementation of contralateral prophylactic mastectomy just because of unilateral breast cancer or a diagnosis of atypical ductal and lobular hyperplasia and ductal carcinoma in situ. Wood pointed out that the canceration can be significantly reduced in most of the patients by using tamoxifen or aromatase inhibitors or in combination with chemotherapy, and the canceration of the contralateral breast can be significantly reduced or early detected through rigorous mammography and MRI monitoring, so that the contralateral breast can be retained in more patients.

In addition, the removal of normal tissues or organs because of imprecise morbidity or just because of the fear of cancer or in pursuit of physical beauty also must go through the justification of ethics and be approved by the ethics committee of experts of the hospital. Research shows that the vast majority of patients undergoing breast reconstruction after prophylactic mastectomy don't regret for their decisions, but the surgeons have an obligation to inform patients in detail about the pros and cons of this surgery, and other available conservative treatment options cannot take prophylactic mastectomy as the first choice and advise the patient to undergo it, and the patient must also receive rigorous counseling and guidance in aspects such as psychology, genetics, and pathology before surgery.

At present, the prophylactic mastectomy is still in the exploratory stage in China, and most domestic scholars have a conservative attitude toward the first-stage reconstruction after prophylactic mastectomy. There are extremely rare reports on bilateral prophylactic mastectomy. The first-stage reconstruction after contralateral prophylactic mastectomy has been carried out for younger patients with early breast cancers in some hospitals. China is the country with a lower incidence rate of breast cancer, but recent studies have shown that the incidence rate is rising. Compared with tens of thousands of cases of prophylactic mastectomy with breast reconstruction performed at abroad each year, the therapeutic mastectomy remains the main surgical method in our country, and the postoperative breast reconstruction has not been carried out widespread. Affected by social and cultural differences between east and west and the educational backgrounds, Chinese people have a low degree of recognition for such nontherapeutic prophylactic mastectomy; and due to limited medical conditions, the gene detection for high-risk groups is still at its preliminary stage, and it is not a routine detection item in various big hospitals, and the prophylactic mastectomy with breast reconstruction itself has some limitations, which were as follows:

Firstly, no matter what surgical method is adopted, it cannot remove all breast tissues, which is especially true for the surgical method with nipple-areola complex preserved to maintain the blood supply for nipples and areolas. Besides, it is difficult to clear the gland tissue out of the upper hole for those methods requiring the inframammary fold incision. Previous literatures have reported that the patients undergoing subcutaneous mastectomy still have breast cancers, but because the patients let their guard down, when the tumor is found, it is often at a late stage. Studies have shown that the presence of even trace amounts of breast tissue has the possibility of canceration.

Secondly, the prophylactic mastectomy will inevitably bring mental pressure to patients, as an important part of the female secondary sex characteristics. The breasts have a significant impact on women's physical appearance, although the breast reconstruction can alleviate this anxiety and feelings of inferiority to some extent; as a result, the psychological problems such as self-disidentification should also attract the attentions of the plastic surgeons and psychiatrists.

Moreover, the surgical risk, postoperative complications, breast shape distortion, as well as the nipple losing erectile function and the feeling of numbness and discomfort in anterior chest wall due to loss of innervation will also bring a heavy psychological burden to the patient.

There is no conflict between the breast-conserving surgery and the prophylactic mastectomy, and both have different applicable populations. The breast-conserving surgery reflects the requirement of the patient for preserving the breast at the affected side, and the prophylactic mastectomy is actually a preventive measure for the breast at the healthy side [10].

These abovementioned factors lead to that the prophylactic mastectomy with construction is not carried out widely in China; the research in this area is only at the preliminary exploration stage. At present, there is a lack of unified domestic standard and expert consensus on surgical indications. With the improvement of people's living standard and the wide development of health education, people have a further understanding of breast cancer and high-risk groups of breast cancer, and this surgery will certainly be understood and accepted by more and more patients; thus, it is necessary for the oncology plastic surgeons to more strictly grasp the applicable population of this surgery, fully weigh the pros and cons, and then put forward reasonable proposals to the patients, so that the patients can get the maximum benefit in the treatment process.

4 Nipple and Areola Reconstruction

Fazhi Qi

4.1 Overview

The nipple and areola reconstruction is a part of the breast reconstruction process and can play a finishing touch. The nipple and areola reconstruction can be applied to the damage and defect in the nipple and areola caused by trauma and infection.

The commonly used nipple reconstruction methods include two types of the reconstruction with skin or composite tissue transplantation and the reconstruction with local skin flap. The donor sites of skin and composite tissue which have been reported include the nipple and areola at the healthy side, labia minora, the upper medial thigh, earlobe, and the fifth toe, and the disadvantage is the destruction of normal tissue morphology in the donor site, especially in the areas of the nipple and labia minora at the healthy side. Sometimes it is difficult to be accepted by the patients. The nipple reconstruction with local skin flap is simple and practicable; the disadvantage is that the reconstructed nipple will become smaller or even disappear over time, and therefore, the nipple reconstruction with local skin flap requires a hypercorrection. At present, this method is the most commonly applied method. A method of free skin graft transplantation has been used for areola reconstruction in the past, and the site with a skin color similar to that of the areola is used as the donor site. Becker et al. used the method of skin tattooing for coloration and obtained a realistic effect [11].

The nipple and areola reconstruction is usually carried out at the third month after breast body reconstruction. When the appearance of the reconstructed breast is relatively stable, it is required that the reconstructed nipple and areola have the same size, symmetrical position, the same color, same bulging, and a certain feeling compared to the nipple and areola at the healthy side. At the third month after breast reconstruction, the local sensation has not been fully restored; thus, nipple reconstruction usually doesn't require anesthesia; if the anesthesia is required, 0.5% lidocaine can be used for local infiltration anesthesia [12].

4.2 Surgical Method

4.2.1 Preoperative Localization

The preoperative localizations of various nipple reconstruction methods are basically the same. It is required that the size and shape of the reconstructed nipple and areola are the same as those at the healthy side. The diameter is usually 35–45 mm, and the location is symmetrical. The patient takes a standing or sitting position, simultaneously bilateral upper limbs droop naturally, and the shoulders are at the same level. The chest midline and the connecting line between the middle point of the clavicle and the nipple midpoint at the healthy side are drawn at first. In the same horizontal line of the nipple at the healthy side, the chest midline is taken as the midpoint, and the central position of the nipple at the affected side is determined according to the principle of symmetry. After that, a transparent film is put on the nipple at the healthy side, then the sizes of the nipple and areola are drawn, and then the double circle model is cut off with the scissors according to the drawing line. The outer circle is the perimeter of the areola, and the inner circle is the size of the perimeter of the nipple. After the model is placed at the midpoint of the nipple at the affected side, the sizes of the reconstructed nipple and areola are drawn. At the moment, the connecting line between the middle point of the clavicle and the nipple midpoint at the affected side is drawn, which should be symmetrical to that at the healthy side.

4.2.2 Nipple and Areola Reconstruction with Trilobed Skin Flap

1. Skin flap design: Two concentric circles are drawn on the reconstruction area according to the sizes of the nipple and areola. The diameter of the intermediate small circle is equal to the size of the nipple, and the diameter of outer large circle is equal to the size of the areola. The diameter of nipple is taken as the width of a flap, and two small flaps are designed on its both sides (b and c flap).

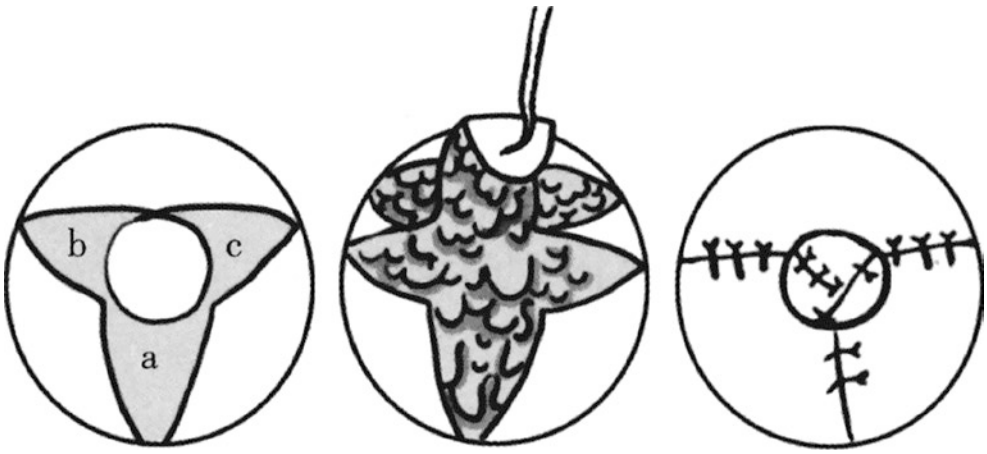

Fig. 15.20 Nipple and areola reconstruction with trilobed skin flap

2. Surgical operation: The skin is incised, a flap is raised at first, and the flap contains skin and subcutaneous adipose tissue; then two flaps on both sides are raised, and the flaps do not include the subcutaneous adipose tissue. The three flaps are sutured by means of cross-stitch (Fig. 15.20), and the subcutaneous tissue wound in the flap donor site is sutured, which facilitates the skin transplantation.
   The epidermis of the remaining skin in areola area is removed, then the split-thickness skin graft is harvested from the "orecchiette" at the side of TRAM flap donor site or the groin and is freely transplanted onto the areola area, and then the local pressure dressing is carried out. After the skin graft survives, the tattoo coloring is carried out, and the tattoo pigment fades over time. Thus some patients need another tattoo coloring.

4.2.3 Nipple Reconstruction with S-Shaped Flap

The nipple reconstruction with S-shaped flap is firstly proposed by Cronin in 1988. Different from the single-pedicled skate flap, the skin flap is supplied with blood by double pedicles, which increases the safety of surgery and reduces the probability of poor blood supply to the skin flap.

1. Skin flap design: A circle is drawn according to the size of the nipple and areola at the healthy side. An S-shaped flap is designed, and the height of skin flap at S-shaped side is equivalent to the height of the reconstructed nipple, while the width of the base of the skin flap is half of the circumference of the reconstructed nipple. The beginners tend to design the width of skin flap to be equal to the diameter of the nipple, leading to that the reconstructed nipple is too small.
2. Surgical operation: The skin including skin and subcutaneous adipose tissue is incised, and then two S-shaped skin flaps are raised; subsequently, the cross suture is performed (Fig. 15.21). The skin in the donor site of the skin flap is directly closed and sutured. The tattoo coloring is performed for the skin in areola area, and the tattoo coloring is performed again depending on the specific circumstances.

Fig. 15.21 The nipple reconstruction with S-shaped flap

4.2.4 Nipple and Areola Reconstruction with Free Transplantation of the Nipple and Areola at the Healthy Side

This method is suitable for the patients with larger nipple and areola at the healthy side, and the effect of killing two birds with one stone in nipple reconstruction at the affected side and the nipple reduction at the healthy side can be achieved.

1. Design: A horizontal line is drawn between 3:00 and 9:00 of the nipple at the healthy side, and a circular mark is made at the position of the nipple at the reconstruction side (Fig. 15.22a).
2. Surgical operation: After local anesthesia, the nipple at the healthy side is transversely incised according to the marker, and then its lower half nipple composite tissue is harvested from the basal surface and is wrapped with saline gauze for standby application; the upper half of nipple is overturned downward, and the wound is sutured. Then the epidermis in the circular mark at the affected side is removed, then the nipple composite tissue at the healthy side is freely transplanted, and then the suture and fixation are performed (Fig. 15.22b).

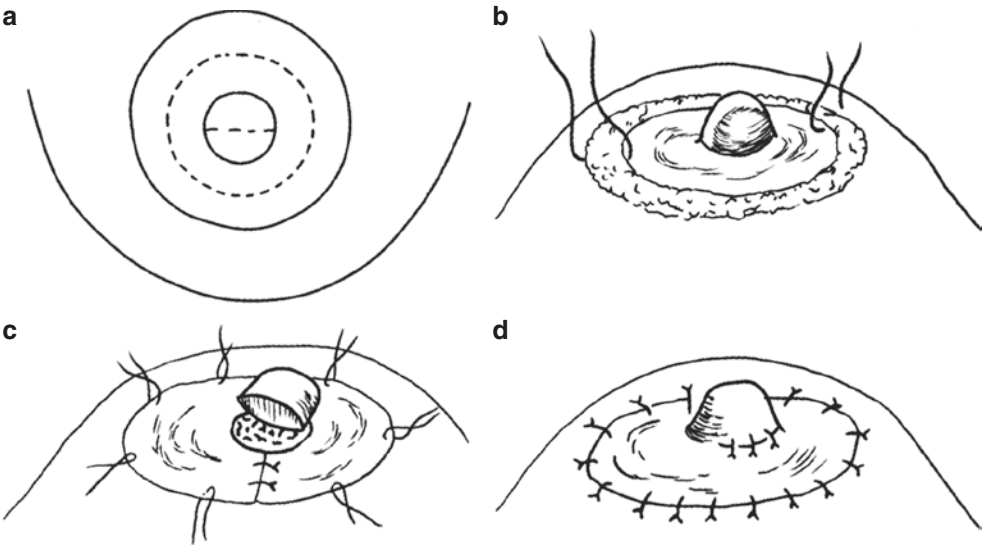

Fig. 15.22 Nipple and areola reconstruction with free transplantation of the nipple and areola at the healthy side

3. Suture and fixation: A part of peripheral areola at the healthy side is harvested and is freely transplanted onto the affected side, and the suture and fixation are performed (Fig. 15.22c, d). An opening is made in the dressing of reconstructed nipple during bandaging, and the pressure dressing is performed. The excessive compression of the nipple easily leads to applanation of the reconstructed nipple, which cannot bulge. The stitches are taken out about 10 days after surgery.

5 The Reshaping of the Contralateral Breast After Breast Cancer Treatment

William G. Austen Jr, Rong Tang, Tessler Oren, and Barbara L. Smith

5.1 Overview

The breast beauty is an important symbol of female beauty, and the symmetry of shape and position of the breasts is one of the most important criteria for the breast beauty. The surgical treatments of breast cancer, from breast-conserving surgery to a variety of breast reconstructions, all reflect the tireless efforts of people to reconstruct a beautiful breast at the affected side. Whether breast-conserving surgery or breast reconstruction, its roles in improving the appearance and improving the cosmetic results of the breast and quality of life in patients after surgery have been recognized [22]. However, the breasts are symmetrical organs, and the satisfactory plastic surgery of breast tumor should not only consider the aesthetic factor of the breast itself at the affected side in a way but also consider the symmetry with the contralateral breast. The asymmetry of bilateral breasts can affect the overall cosmetic effect, and it will also result in imbalance in the center of gravity of the human body in severe cases. Therefore, whether the symmetry of bilateral breasts can be achieved after breast cancer treatment is an important step to determine the surgical effect. Studies have shown that only when the breasts are further adjusted to be relatively symmetrical after breast reconstruction can the patient achieve a high degree of satisfaction. Therefore, after breast cancer treatment, the contralateral mammaplasty is performed, and the symmetry of bilateral breasts is restored from an aesthetic point of view. Such method is drawing more and more people's attention. It is reported that in Western countries, a substantial proportion (18–89%) of breast cancer patients require undergoing contralateral mammaplasty to achieve relatively symmetrical appearance [23–25].

There are main three methods for contralateral breast shaping in breast cancer patients: the breast reduction is performed in patients with too big contralateral breast, the breast augmentation is performed in patients with too small contralateral breast, while the mastopexy (suspension) is performed in patients with breast asymmetry caused by contralateral breast sagging. In order to achieve better symmetry, sometimes it is required to further combine with the shaping of the breast at the affected side. This section will introduce the contralateral breast treatment after breast cancer treatment from the aspects of the reason of asymmetry, treatment principles, surgical indications and contraindications, operation technique, and postoperative complications.

5.2 The Reasons for Bilateral Breast Asymmetry After Breast Cancer Treatment

Normally, the contralateral breast is a reference to breast shaping and reconstruction at the affected side in breast cancer patients, but the shape and position of the affected breast

after treatment depend on many factors, such as the preoperative breast shape at the affected side, the patient's wishes, surgical resection method, reconstruction method, and postoperative radiotherapy. All affect them. Therefore, even if the surgery takes the contralateral breast as a reference, the obvious bilateral asymmetry still often occurs after surgery. The bilateral asymmetry after breast-conserving surgery for breast cancer or breast reconstruction basically has following several kinds of situations:

1. When the breast-conserving surgery is carried out at the side of breast cancer, enough breast tissue must be removed to achieve oncological safety. While the breasts are too small in Asians, even partial resection of the breast can also cause significant change in breast appearance, combined with postoperative whole breast radiation therapy, so that the breast atrophies further aggravate bilateral asymmetry.
2. The atrophy of skin flap after autologous flap breast reconstruction.
3. The changes in position and morphology of the breast reconstructed with prosthesis make the reconstructed breast "younger," particularly significant in older women; or bilateral breasts are symmetrical in early period, but as time goes on, the contralateral normal breast gradually sags, and the reconstructed breast doesn't sag or sag insignificantly, which cause the asymmetry.
4. For others, for example, it is planned to carry out further surgery for the contralateral breast in the future when the tumor surgery is performed, and thus the contralateral breast is not taken as the reference; the complications of the oncoplastic surgery at the affected side such as capsular contracture can also cause bilateral asymmetry.

5.3 The Indications and Contraindications of the Contralateral Mammaplasty

As a supplementary surgery after the treatment of tumor, firstly, the contralateral mammaplasty should be subject to the principles of tumor treatment, and the surgeon should understand whether the tumor treatment for the affected breast has been completed and confirm no breast cancer recurrence and metastasis. The contralateral breast requires detailed preoperative physical examination and imageological examination; the patients with the presence of abnormalities require further oncology assessment. Only after the tumor treatment for the affected breast is completed, and the situations such as breast cancer recurrence, metastasis, and contralateral breast cancer are excluded, can the contralateral mammaplasty be considered.

As a plastic and aesthetic surgery, the patient's own wishes and requirements are particularly important. The surgeons should provide detailed information consultation to the patient, carry out in-depth communication with the patient, and understand the surgical purpose of the patient and the desired breast size and shape. The preoperative conversation should describe the surgical risks in detail, and the patients should be informed that it is still needed to follow the principles of tumor treatment after surgery and continue to carry out regular inspections on the breast after plastic surgery. The smoking patients should quit smoking at least for 2 weeks before surgery. The surgical contraindications include women at high risk of breast cancer and the contralateral breast with imaging abnormalities. The indications and contraindications summarized by Nahabedian et al. are shown in Table 15.2.

5.4 Selection of Surgical Timing

Various factors should be considered for the timing of the contralateral mammaplasty, including the patient's own wishes, tumor status at the affected side, changes in the affected side after postoperative radiotherapy, and the feasibility of plastic surgery at the same period.

If the patient is informed in advance that it can be predicted that the surgery at the affected side will result in obvious asymmetry of bilateral breasts, most patients would hope that the plastic surgery is performed at the same period, and thus the reoperation is avoided. If the surgery at the affected side may not result in obvious asymmetry of bilateral breasts, most patients will choose to make a decision after a period of observation after breast surgery at the affected side, and the benefits of doing so are that the waiting time is beneficial to make a detailed assessment of tumor status at the affected side and the patient has enough time to observe the degree of asymmetry of bilateral breasts and thus make a decision on whether the surgery will be performed.

Another important consideration is whether the tumor at the affected side can be completely removed. If the tumor is limited with negative margins, the contralateral mammaplasty can be performed at the first stage to correct asymmetry after tumor resection; and in the case of multiple and too big tumors, or uncertain margin status, both the breast reconstruction at the affected side and the contralateral mammaplasty should be postponed, and wait to be completed at the second stage.

The women with medium and severe hypertrophic and sagging breasts generally require breast reduction and/or mastopexy (suspension), but the selection of surgical timing is still controversial. The scholars who support performing contralateral mammaplasty at the same time of breast tumor surgery believe that the contralateral breast after plastic surgery can be used as a reference for the breast surgery on the tumor surgery side, which is conducive to bilateral symmetry.

Table 15.2 Indications and contraindications for contralateral mammaplasty

Indications	The patient has an intention to improve the symmetry with surgery
	The volumes of both breasts are obviously uneven
	The shapes and positions of both breasts are obviously asymmetric
	The clinical breast examination is normal
	The imaging examination shows no signs of breast cancer
Contraindications	There is no breast asymmetry
	Patients at high risk for breast cancer
	Mammography or MRI examination shows abnormal results

The pathological examination on the contralateral breast tissues can be carried out to eliminate hidden lesions at the same time. Studies have shown that among 77 specimens of contralateral breasts obtained in a group of patients undergoing contralateral breast plastic surgery after breast tumor treatment, it is found that the 12 (15.6%) specimens have breast atypical hyperplasia or lobular carcinoma in situ [26]. Therefore, the contralateral mammaplasty not only has a cosmetic effect but also can early detect the hidden lesions, and thus proper treatments can be carried out as soon as possible. The scholars in favor of the second-stage plastic surgery believe that the morphology of the breast after postoperative radiotherapy will have some changes, and enough time should be set aside, until after the morphological change of the breast caused by postoperative radiotherapy is completely stable, and the contralateral plastic surgery is performed.

In addition, the tumor surgery needs to be completed by the tumor surgeons, and the plastic surgery needs to be completed by plastic surgeons. If two groups of surgeons are needed to carry out the surgeries, the surgical timing may tend to select the second-stage reconstruction; if the surgeons simultaneously have licenses in oncology and plastic surgery, the breast tumor resection and breast reconstruction are preferably performed at the same period under feasible conditions.

5.5 Oncological Safety-Related Issues for the Contralateral Breast

The contralateral mammaplasty also needs to emphasize the oncological safety. According to studies, the history of breast cancer is the primary risk factor for contralateral breast cancer. If there is a previous history of breast cancer, the risk of developing breast cancer in the contralateral breast is two to five times as great as that in the normal population, and the annual risk rate of contralateral breast cancer is 0.5–1%.

After completion of cancer treatment, the patients need to continue to undergo breast examination and imageological examination to monitor the recurrence and metastasis of the breast cancer. The mammography should be carried out 6 months after contralateral breast surgery to establish a new baseline of observation. Because of their history of tumor and high risk of onset, the patients undergoing contralateral mammaplasty should lay more emphasis on the monitoring of tumor than the general population, and the surgeons should be more cautious about the suspicious lesions detected by the physical or radiological examination in these patients. The breast reduction surgery may change the structure of the breast and form new calcifications, but generally these calcifications have a significant difference from the tumor calcifications; therefore, the breast reduction surgery generally does not affect breast cancer surveillance [27].

For the patients who need to undergo contralateral breast reduction, the plastic surgery will help improve the oncological safety. As mentioned earlier, in the contralateral mammaplasty, if the breast specimen can be obtained, the pathological examination can be performed to early detect the hidden lesions. In addition, since a part of the breast tissue is removed, the incidence rate of contralateral breast cancer will be reduced correspondingly, and studies have shown that the risk of breast cancer is reduced by 28% in patients undergoing breast reduction.

However, although the prosthesis itself does not increase breast cancer risk in patients who need to undergo contralateral breast augmentation, especially in patients undergoing prosthetic breast augmentation, but due to the presence of the prosthesis, the physical examination and mammography of the breast are affected, which may cover up the early lesions and bring difficulty to early detection and early diagnosis of contralateral breast cancer. The patients should be told about this risk before surgery, and the patients are advised to use more effective methods for monitoring the breast after breast augmentation, for example, MRI or mammography which aims at the improved position of the breast with prosthesis is used to continuously monitor the breast.

5.6 Surgical Methods

The selection of surgical method is determined according to the size and morphology of the breast, original position of the nipple, and the designed position of the nipple, and the most commonly used techniques include breast reduction, mastopexy, and breast augmentation. The patients after breast cancer treatment are often required to undergo appropriate plastic surgery of the breast at the affected side simultaneously, including: the fat is transplanted to achieve a mellow and full breast, the envelope of the prosthesis is incised and sutured again to adjust the position of the

prosthesis, the prosthesis is replaced to change the size of the breast, and the mastopexy is performed to elevate the position of the nipple. Finally the desired cosmetic effect can be achieved.

5.6.1 Breast Reduction Surgery

The breast reduction surgery is applicable to patients with hypertrophic and significant sagging contralateral breasts, and this surgery can reshape the appearance of the breast and replace the position of the nipple and areola to achieve bilateral symmetry.

The most important thing for preoperative design is to determine the new position of the nipple. The new position of the nipple depends on many factors. Firstly, it is necessary to examine whether the nipple-areola complex (NAC) is preserved in the breast tumor surgery. If the whole NAC is preserved at the affected side, it is required to assess whether the position of the nipple needs modification. If the position of the nipple at the affected side is ideal, the breast reduction surgery at the healthy side which is symmetrical to the position of the new nipple at the affected side is designed. However, if the position of the nipple at the affected side is not ideal and needs further modification, when the position of the nipple of the breast at the healthy side is designed, it is required to consider the position of the nipple of the breast at the affected side after modification. If the NAC at the affected side has not been preserved, and the NAC at the affected side can be reconstructed in the best nipple position, the position of the new nipple at the healthy side should also be designed in the best nipple position. In a few cases, the nipple at the affected side cannot be reconstructed in the best nipple position. At the moment, the design of the position of the new nipple at the healthy side should strike a balance between the best nipple position and the position which can be reached by the reconstructed NAC of the breast at the affected side.

There are two commonly used methods for determining the best nipple position: Lejour designed that the inframammary fold and the connection line between the clavicle midpoint and the nipple are marked in patients in a standing position. The site at 2 cm under the upper arm midpoint is taken as the upper margin of the new areola, and the position of the new nipple is shifted down again by 2 cm. At present, it is more common to find and take the Pitanguy point as the new nipple position, which is the point of intersection of the projection line of the inframammary fold line on breast surface and the midclavicular line (Fig. 15.23).

After the new nipple position is determined, the breast reduction surgery is designed continuously. There are a lot of surgical methods for breast reduction. The pedicle nipple and areola transplantation are generally used, and the design methods are roughly divided into the inverted T-shaped breast reduction (Wise-pattern method), vertical incision breast reduction, and periareolar breast reduction. According to the different positions of the dermo-glandular pedicle, the design methods are also divided into horizontal double pedicles, vertical double pedicles, superior pedicle, inferior pedicle, lateral pedicle, medial pedicle, and central pedicle. Of which, the inferior pedicle, superior pedicle, and horizontal double pedicles are more commonly used methods. In addition, the double ring methods are more commonly used in at home.

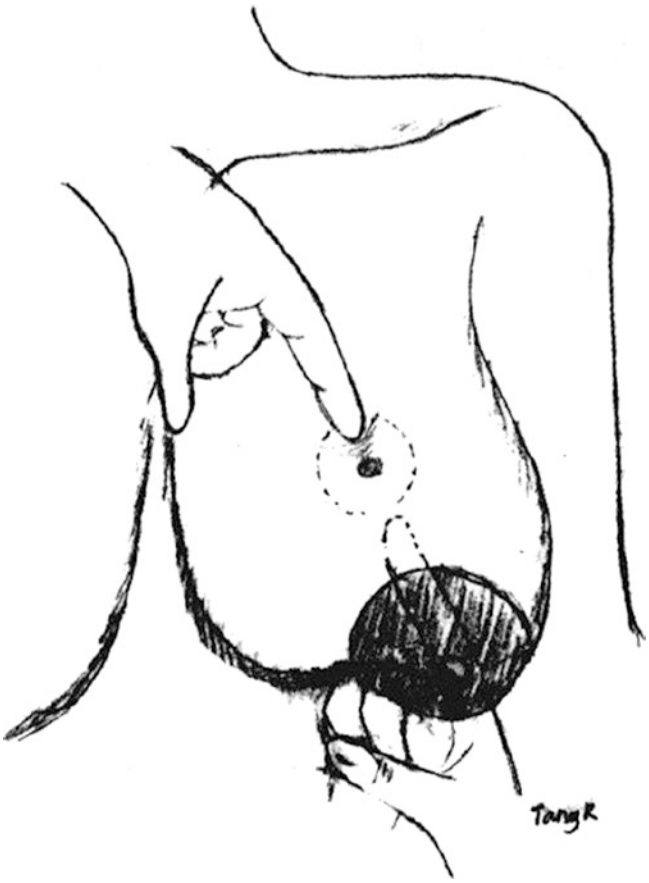

Fig. 15.23 Pitanguy point (the point of intersection of the projection line of the inframammary fold line on breast surface and the connecting line from the clavicle midpoint to the nipple)

1. Wise-pattern inferior pedicle: The Wise-pattern inferior pedicle is one of the most commonly used methods for contralateral breast reduction. This method can not only remove a lot of breast tissue but also better retain the NAC blood supply and can flexibly adjust the nipple position, and the disadvantage is that the inverted T-shaped scar will be left. The Wise-pattern inferior pedicle is taken as an example in the following article to explain the surgical methods.
   (1) Surgical design: The patient takes a standing position, the new nipple position is determined as point a at first, then the point a is taken as the center, and 3.5–4.5 cm is taken as the diameter to draw a circle as the position and size of the new areola. Two about

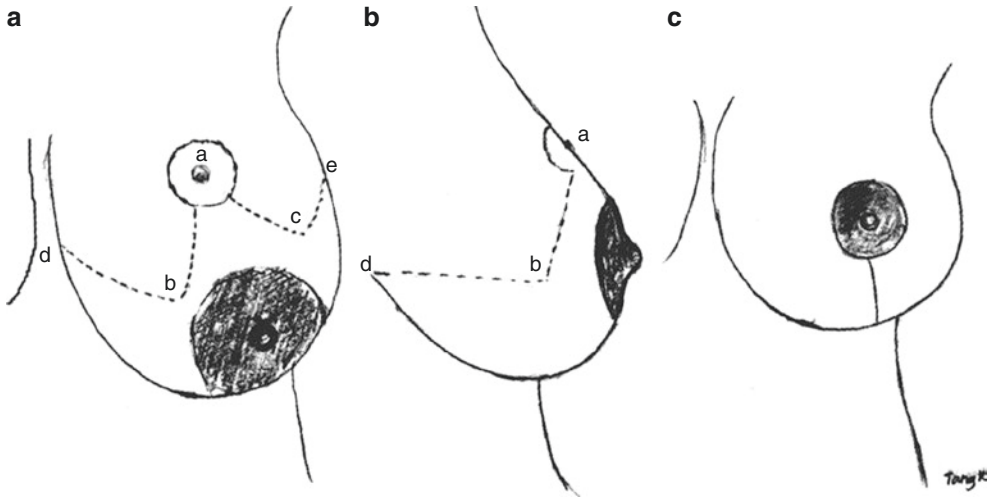

Fig. 15.24 Design of Wise-pattern breast reduction surgery. (**a**) Frontal view of preoperative design (point a is the new nipple position), while the areola is reduced. (**b**) Lateral view of preoperative design. (**c**) Frontal view and scar after surgery

6.5 cm long incision lines with an inclined angle of about 90° are designed respectively at both sides of point a, and their end points are the point b and e; furthermore, the lengths of ab and ac and the inclined angle can be adjusted according to the degree of breast protrusion and removal volume of the breast. Then the points d and e at the breast margin are reversely folded and marked upward respectively by 90–100° from points b and e (Fig. 15.24). The inframammary fold (IMF) is marked on the breast, starting from the anterior axillary line to the parasternal line. It should be designed as far as possible that the length of bd + ce is equivalent to the length of the marked inframammary fold as far as possible, in order to reduce the "orecchiette" deformity. Then 8–10 cm-wide corium and glandular tissue flap is designed from the original nipple to the inframammary fold to be taken as the skin pedicle of NAC.

(2) Surgical operation: The patient takes a supine position, and the hip is placed in the location corresponding to the rotation axis of the operating table. During surgery, the patient can be replaced into a sitting position to observe the bilateral symmetry. The upper limbs of the patient are fixed in 90° abduction position, and attentions are paid to avoid uneven local compression on upper limb during fixation. The intermittent pneumatic compression devices can be used on double lower limbs to prevent postoperative venous thrombosis. The general anesthesia is performed, and after endotracheal intubation, the disinfection and draping are carried out.

If it is necessary to carry out breast plastic surgery at the affected side, the breast plastic surgery at the affected side is firstly carried out until the shape and size of the breast and position of the nipple are satisfactory, and then the contralateral breast reduction surgery is carried out (Fig. 15.25). According to preoperative design, the new margins of NAC are marked out with a scalpel, and then an 8–10 cm-wide pedicle is designed in the inferior area which is the continuation of NAC. Subsequently the skin on the inferior pedicle is stripped off with the scalpel (the original NAC skin is retained). Along the remaining preoperative marker lines, the skin is incised to subcutaneous tissues with a scalpel, and then the deep surface fat and glandular tissue are incised to the fascia tissue of the pectoralis major muscle with an electric knife. The separation is made at the superficial surface of the pectoralis major fascia, and the corium and glandular tissue flap in the inferior pedicle are fully dissociated from the skin and breast tissues at both sides, then a part of breast and fat tissues at the deep surface of the pedicle are appropriately removed, and then the bilateral skin flap is pulled toward the medial inferior side. The surface of corium and glandular tissue flap in the pedicle is covered, and the size and shape of the breast is observed. A part of skin and glandular tissue under the breast are removed, and the removal of gland includes the nipple and part of breast tissue at the bottom of the areola. When removing the glandular tissue at lower end of the breast, it is required to strip off the skin from the gland, and the resection range of glandular tissue slightly exceeds the resection range of skin, observe at the same time of removal until it is satisfactory. The bilateral skin flap is pulled toward the medial inferior side and is fixed with the midpoint of the inframammary fold, and then the areola incision is fixed; after the skin margins are closed with skin staples, the patient is replaced into a sitting position, and the sizes, shapes, and nipple positions of bilateral breasts are compared. If they are not satisfactory, they can be repaired and trimmed appropriately after the skin staples are removed. After they are adjusted to be satisfactory, the skin and subcutaneous tissues on the areola area are sutured using 3-0

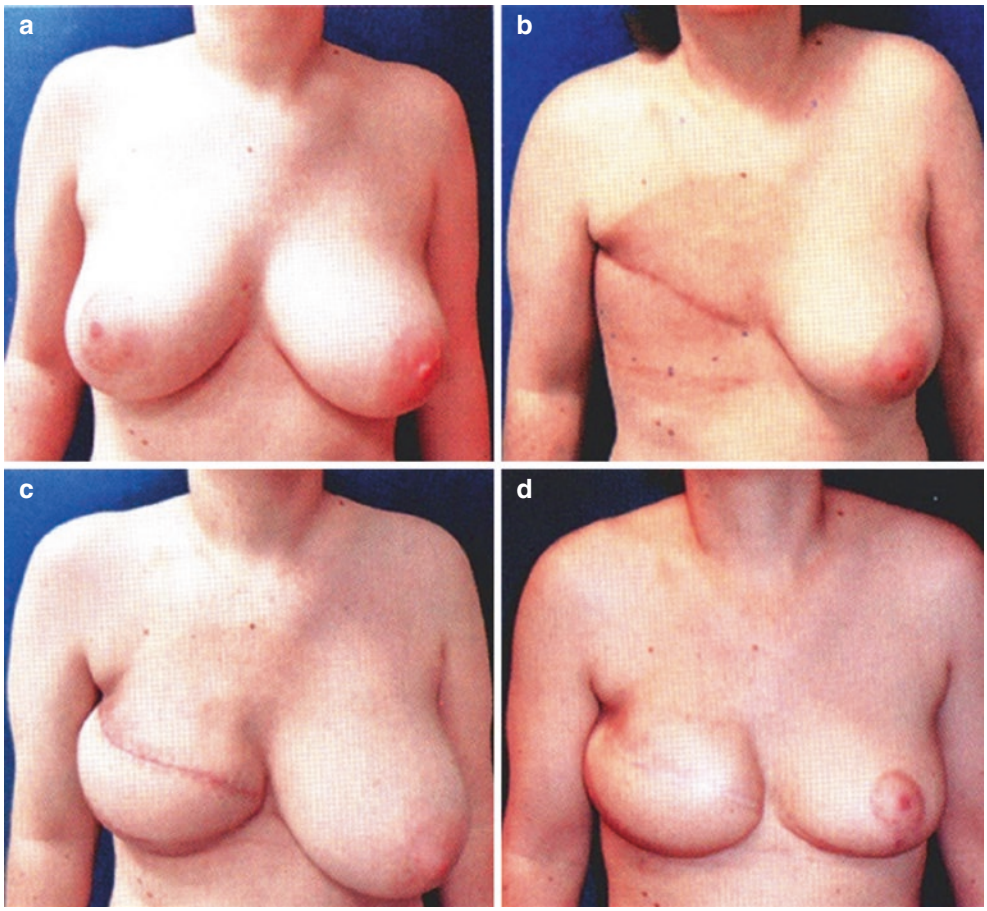

Fig. 15.25 Before and after Wise-pattern inferior pedicle breast reduction surgery. (**a**) Before right breast cancer surgery. (**b**) After right modified radical mastectomy and chest wall radiotherapy. (**c**) The second-stage right breast reconstruction with latissimus dorsi myocutaneous flap plus 350 ml round breast prosthesis. (**d**) Four months after left Wise-pattern inferior pedicle breast reduction surgery, bilateral breasts were symmetrical, and the preparation was made to carry out nipple reconstruction

Monocryl lines, and the subcutaneous and intradermal tissues in the rest of the incision are sutured by layers. When the suture is performed, the skin is allocated appropriately to prevent the formation of "orecchiette" around the areola, the skin can be interruptedly sutured additionally with 5-0 lines or closed with skin glue, and the incision is tightly closed.

Generally, it is not necessary to place a drainage tube after surgery, and a negative pressure drainage tube can also be placed for 2–3 days. The bandages or the surgical bras instead of bandage are used to help support and protect the breasts. Attention is paid to observing the blood supply of the nipple and areola after surgery, and usually the stitches are taken out 10 days after surgery. The patients are informed to avoid strenuous physical activity within a month and visit the department of plastic surgery for follow-up respectively in 1 month, 3 months, and 6 months after surgery.

2. Vertical incision superior pedicle: Lejour method is the most representative method, and they carry out the superior pedicle breast reduction surgery to avoid the transverse scar traveling along the inframammary fold in inverted T-shaped scars in former classic surgical method.
   (1) Surgical design: The new nipple position is determined in the patient in a standing position. The new nipple is taken as the center, and a circular arc with a length of about 14 cm is made to mark the size of the new areola, whose shape looks like a mosque dome. The length of the circular arc is equivalent to the circumference of the new areola; the opening of the circular arc is the width of the dermal-gland pedicle of the nipple and areola, and the size of the opening is determined according to the degree of hyperplasia and sagging of the breast. The more serious the degree of hyperplasia and sagging of the breast is, the larger the width of the pedicle, namely, the opening of the circular arc is. Two fingers are placed on both sides of the lower portion of the breast and are clenched toward the opposite directions to estimate the volume of the gland to be removed. The transposition of the nipple and areola uses the superior dermal-gland pedicle. A U-shaped curve is drawn bypass the area at 0.5 cm below the areola downward from the both ends of the opening of the design line of the new areola, and this area and the dermal-gland flap within the circular arc above the nipple and areola are the range of removing epidermis.
   (2) Surgical operation: The patient position and auxiliary preparation and anesthesia of the surgery are the

same as previously described. The epidermis in area of the pedicle of the skin flap with the nipple and areola is removed (the skin in the original NAC is retained), and the superior dermal-gland pedicle is formed. 1–3 cm-thick glandular tissue is retained in the area of the pedicle. A part of skin and glandular tissue under the breast is removed, and the removal of gland includes the nipple and part of breast tissue at the bottom of the areola. When removing the glandular tissue at lower end of the breast, it is required to strip off the skin from the gland, and the resection range of glandular tissue slightly exceeds the resection range of skin, which facilitates the shaping of the gland into a cone shape (Fig. 15.26). The underside of the breast tissue flap with the nipple and areola is separated. The bottom of glandular tissue is sutured throughout at the site equivalent to the upper margin of the areola and is fixed to the pectoralis major fascia above the new areola. The aim of the suture is not only to fix the gland but also conducive to the shaping of the gland. The lower bilateral glands are sutured, the breast morphology is reconstructed, and if there is residual glandular tissue in the lower end of the incision, it is removed. At the same time, too thick subcutaneous tissues are trimmed to facilitate the retraction of the skin. The patient is replaced into the sitting position as before, and the sizes of bilateral breasts are compared. If necessary, they are adjusted to be satisfactory. The subcutaneous tissues and skin are sutured from both ends of the up and down, and the drainage tube may be placed depending on the situation. At the moment after surgery, the upper breast shows excessive fullness, and the lower end of the sutured incision may have "orecchiette" deformity and is not sufficiently flat, which will gradually improve over time, and the morphology tends to be natural [28].

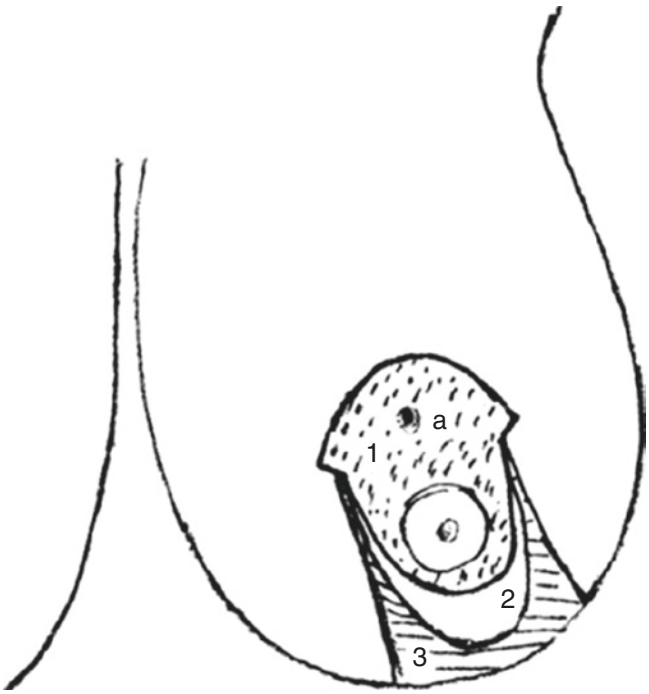

Fig. 15.26 Design of vertical incision inferior pedicle breast reduction surgery a is the position of new nipple; *1* is the area where the epidermis is removed; *2* is the incision; *3* is the site where the gland is removed

5.6.2 Mastopexy

The mastopexy is also known as breast lift fixation or breast suspension. In the contralateral mammaplasty in breast cancer patients, it is commonly used in patients in whom the contralateral breast tissue is adequate but obviously sagging and can be symmetrical to the affected breast (it is generally the reconstructed breast) only after the nipple position is replaced. This surgery can simultaneously replace the nipple position and remove excessive loose skin and achieve an effect that bilateral breasts are more symmetrical.

The method for determining the new position of the contralateral nipple is same as that for the breast reduction. The method for breast fixation is determined according to the distance needed for the nipple to be lifted and the skin volume to be removed. If the size of the breast and the skin volume are approximately equivalent to those at the contralateral side, it is only needed to lift the nipple upward by 1–2 cm, and the satisfactory symmetrical effect can be achieved through performing the periareolar mastopexy. However, if the contralateral breast is obviously sagging or the skin is obviously loose and redundant, it is required to carry out Wise-pattern mastopexy. In addition, there are still mastopexy with crescent-shaped incision on the upper margin of the areola and mastopexy with vertical incision. The preoperative preparation is similar with that of breast reduction, and similarly, if the affected breast needs to be repaired and trimmed, that is also required to be completed prior to the contralateral breast surgery.

1. Periareolar mastopexy: It can lift up and reduce the NAC within a certain range. Firstly, mark out an ideal circular areola area on the original areola. Find the best nipple position, mark the new nipple position and areola range, and then design an oval incision ring around the areola; the upper pole of the ring is the upper margin of the new areola. The surgical preparation is the same as before, the skin between two marker rings is removed with a scalpel, the skin is incised in the periphery of the outer ring, and then the subcutaneous tissues are appropriately separated until the NAC has enough mobility; subsequently, NAC is moved to the designed new position. After complete hemostasis, firstly, 2.0 absorbable suture lines are used to

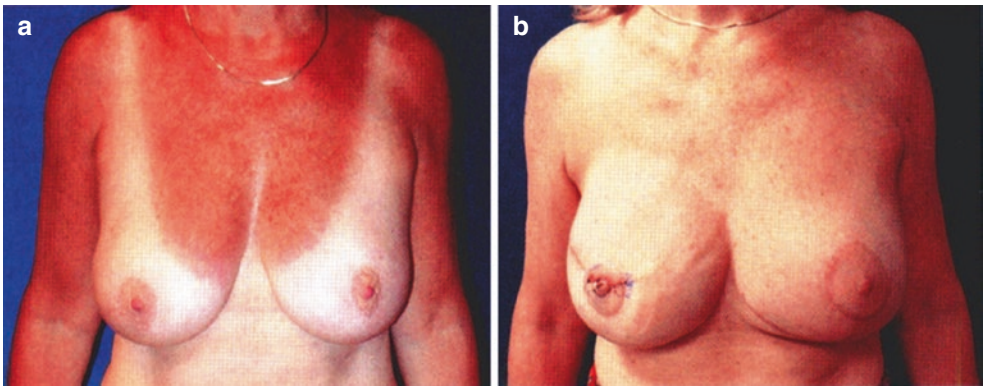

Fig. 15.27 Before and after Wise-pattern mastopexy. (**a**) Before right breast cancer surgery, bilateral breasts were sagging. (**b**) At 12 months after right skin-sparing mastectomy combined with one-stage reconstruction through implantation of 650 ml prosthesis, 5 months after left Wise-pattern mastopexy + one-stage prosthesis implantation, 2 months after right nipple reconstruction and 2 weeks after the nipple and areola were embroidered, bilateral breasts were symmetrical, and the sagging of the breasts were significantly improved

carry out the purse string suture for the skin around the areola, which promotes wound healing and prevents postoperative areola distortion; then the silk threads are used to carry out the layered suture for intradermal and subcutaneous tissues, and the wound adhesive can be used to close the incision tightly.

2. Wise-pattern mastopexy: If Wise-pattern mastopexy is used, the preoperative design and surgical methods are similar to those of the breast reduction, but it is not needed to remove a lot of breast skin and gland. This method can easily and accurately adjust the tissue volume of the breast, can significantly lift up the nipple position, and is the best surgical approach for patients with severe breast ptosis (Fig. 15.27).

5.6.3 Breast Augmentation

1. Breast augmentation with prosthesis: The breast augmentation of the contralateral breast can be performed individually or simultaneously with the mastopexy. Generally the breast at the affected side is reconstructed, and the tissue volume in the contralateral breast is relatively insufficient. The selection of method for mastopexy is the same as previously mentioned, but it should be noted that, if it is necessary to perform mastopexy and breast augmentation at the same period, the breast augmentation should be completed at first, and then the mastopexy is performed after the breast volumes are substantially symmetrical, which is due to the fact that the change in the breast volume, especially the prosthesis implantation, will change the position of the nipple and then change the design of the mastopexy.
   (1) Surgical design: For the breast augmentation which increases the symmetry with the affected side, its selection of surgical incision is different from that of the general cosmetic breast augmentation. For the patients who undergo breast reconstruction at the affected side, it is often needed to adjust the position of the contralateral nipple to achieve the basic symmetry, namely, it is mostly required to perform mastopexy simultaneously; therefore, in patients with mild breast ptosis, the periareolar incision is used for breast augmentation, and the periareolar mastopexy can be performed in the same period; while in patients with moderate to severe breast ptosis, Wise-pattern breast lateral margin incision can be used for breast augmentation, Wise-pattern mastopexy can be performed in the same period. Only the patients who do not require mastopexy will use the inframammary fold or periareolar incision which is commonly used for ordinary cosmetic breast augmentation. In addition to the incision, the dissection scope should be designed before surgery.
   (2) Surgical methods: The surgical preparation is the same as the former. The prosthesis can be implanted into the subglandular plane, the plane under the pectoralis major muscle, the dual plane, and the clearance behind the pectoral fascia, of which the operation at the subglandular plane is convenient and easy, and the patient has less pain and recovers quickly, but the prosthesis margin shows a high probability of visibility, and the rate of capsular contracture is higher; furthermore, the imageological examination of the breast is interfered. While the prosthesis is implanted into the plane under the pectoralis major muscle, which can reduce the rate of capsular contracture and avoid the interference of the prosthesis on the imageological examination, the coverage of the muscle onto the upper part of the prosthesis reduces the probability of visibility of the prosthesis margin and wrinkles and reduces the appearance of ladder on the upper part of the breast, but there are also disadvantages such as upper shift of the prosthesis and

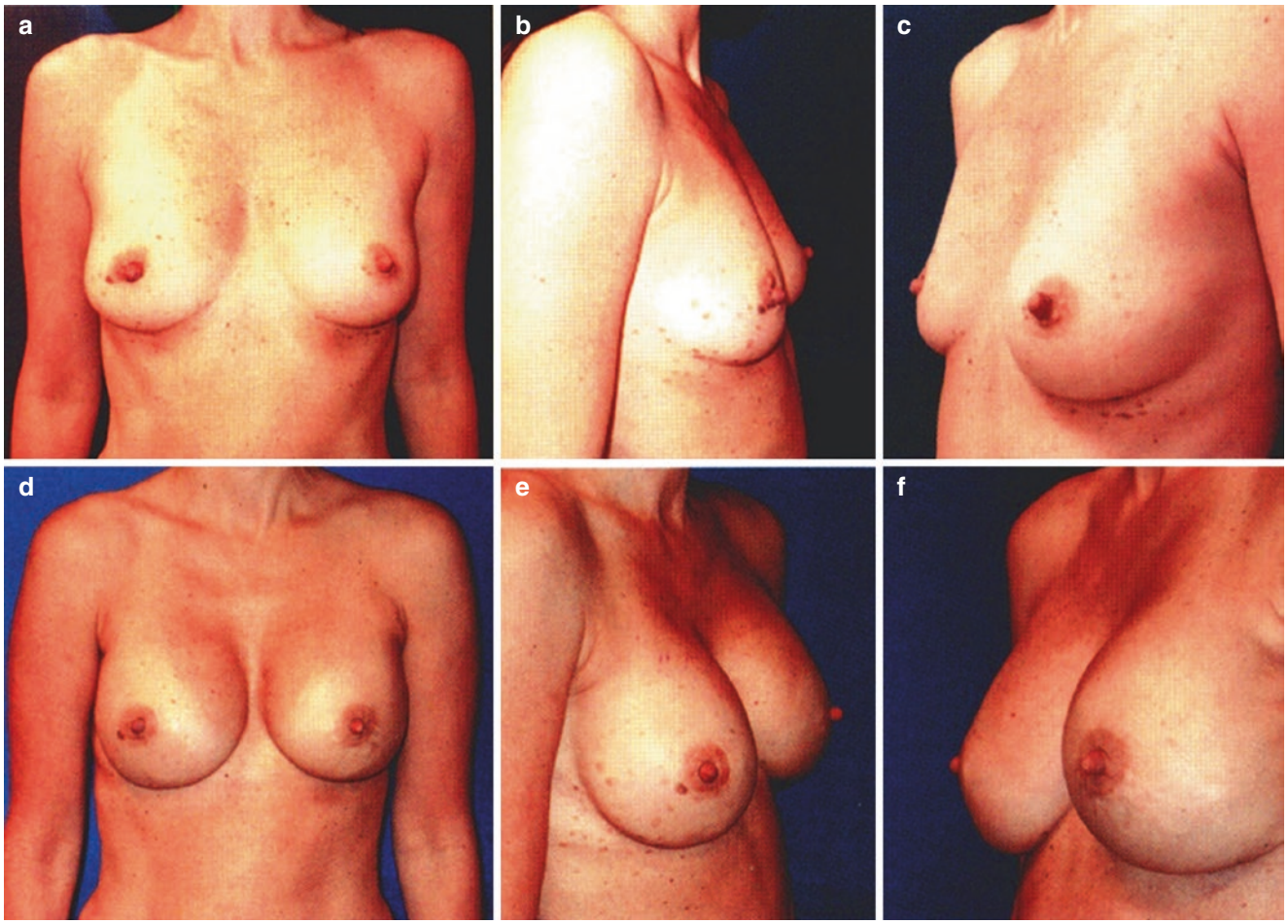

Fig. 15.28 Before and after contralateral prosthetic breast augmentation. (**a**–**c**) Before left breast cancer surgery, the breast was flat. (**d**–**f**) At 9 months after the first-stage reconstruction with prosthesis implantation after left mastectomy with preservation of nipple-areolar complex plus right breast augmentation with prosthesis implantation at the same period, bilateral breasts were symmetrical, and the breasts are obviously more well rounded

occurrence of changes in position or morphology of the prosthesis when pectoralis major muscles contract. At present, the commonly used method is the dual plane breast augmentation, namely, the prosthesis is simultaneously located at two planes (a part of prosthesis is located under the breast, and another part of prosthesis is located under the pectoralis major muscle). This method is to completely dissociate the starting point of the pectoral muscle at inframammary fold under the pectoralis major muscle and retain the starting point of the pectoral muscle beside the sternum, the advantages of both implantation methods in the subglandular plane and the plane under the pectoralis major muscle are combined, considering the relative relationship between the position of the prosthesis and soft tissue coverage, the satisfaction rate on breast shape after surgery is high, and the capsular contracture is rare (Fig. 15.28). After the surgical plane is determined, stripping, hemostasis, and rinsing the stripping cavity were carried out according to the preoperative design range. The prosthesis is placed in antibiotic solution after being taken out from the package. After the cavity is stripped, the prosthesis is implanted and then is washed with antibiotic solution again. The wound is sutured by layers with nylon monofilament line, and the bandage or surgical bra is used to support and protect the wound.

2. Breast augmentation with autologous tissue: This method is not commonly used in the surgery of improving the bilateral symmetry through contralateral augmentation after breast cancer surgery; it is used only for patients in whom the breast at the affected is reconstructed with autologous skin flap, and the reconstructed breast has a large volume, and using the prosthesis at the contralateral side or using only the prosthesis is not easy to achieve basic symmetry with the affected side. In such patients, it is often needed to thinly trim the skin flap for the breast reconstruction at the affected side. Among the autologous

tissue flaps, the latissimus dorsi myocutaneous flap is most commonly used in the contralateral breast augmentation; specific surgical steps and the advantages of various flaps can be seen in related contents of the second section of this chapter.

5.6.4 Other Methods

The fat transplantation is used to repair and trim the small asymmetry and contour defects. The fat often comes from the abdomen fat suction in the patient, it is simple and easy to get, the supplying volume is large, generally the morphology or function of the donor site will not be affected, and the abdomen fat suction can be repeated.

5.7 Common Complications and Prevention

The complications of contralateral mammaplasty in breast cancer patients are the same as those of the same kind of plastic surgery.

5.7.1 Common Complications

Common complications include hematoma, seroma, delayed wound healing, wound dehiscence, infection, incision scar, fat liquefaction, asymmetry of bilateral breasts, etc.

1. Incision dehiscence: The severe macromastia may cause incision dehiscence due to the fact that too much skin is removed during surgery; thus, the suture tension is too large; and if the prosthesis used in breast augmentation is too large while the breast flap is not dilated, the incision dehiscence may occur. The incision dehiscence may lead to situations such as secondary infection, delayed healing, and aggravated scars. Therefore, when the surgical operations are performed, too large suture tension should be prevented, and attentions are paid to the stratified suture.
2. Hematoma: The hematoma is rarely formed. Usually it forms within 24 h after surgery. The treatment method is to take out the stitches and remove the hematoma and suture the incision again after careful hemostasis, while the hemostatic drugs are given by intravenous drip. Accurate and meticulous intraoperative hemostasis is the main preventive measure. When necessary, a drainage tube can be placed at the bottom of the incision, and the chest compression bandage is performed after surgery; both can be very effective in preventing hematoma formation.
3. Fat liquefaction: The fat liquefaction occurs relatively late, it is generally found that the breast is harder or there is partial breast induration when the stitches are taken out, and the wound healing is poor. It occurs mainly in patients with obesity or severe hyperplasia, more hyperplastic tissues are removed during surgery, the damage to the blood supply of the breasts is larger, or it is caused by improper use of the electric knife during surgery. The treatment method is to carry out adequate drainage and timely dressing to make the wound heal as soon as possible. If the fat liquefaction is observed, it is required to carry out early treatment to avoid abnormal changes in morphology of the breast.
4. Asymmetry of bilateral breasts: The preoperative design is very important; the new position of the nipple and areola, the range of the skin needing to be removed, and various marker points and lines of the breast contour must be taken into full account at first; and then the positioning is performed. Before the skin is removed during surgery, the designed new skin margin should be drawn closely, and the appearance of the breast and the incision tension are confirmed again; the adjustment is carried out if necessary, in order to avoid excessive resection of the skin. If failing to fully estimate the tension and postoperative shape and position, the phenomenon of asymmetry of bilateral breasts will occur; this can be repaired and trimmed with reoperation.

5.7.2 Complications of Breast Reduction

In addition to the abovementioned common complications, the complications which may occur after breast reduction include the following several kinds [29]:

1. Skin necrosis: During breast reduction, if the subcutaneous stealth separation is too extensive or the separated layer is inaccurate, this can cause skin necrosis, and the consequence is more serious. Mastering the correct anatomical layer during surgery is the key to prevent skin necrosis. A larger area of skin necrosis requires repair with local skin flap or treatment with skin graft transplantation.
2. Sensory deprivation in the nipple and areola: At present, there are still no certain technologies for fully retaining the sensation of the nipple and areola after surgery. However, studies have shown that the use of surgical methods such as breast central pedicle and inferior pedicle can retain more sensation of the nipple and areola.
3. Nipple-areola necrosis, although it is less common, but the consequence is serious. In order to avoid this complication, the operators should be very familiar with the blood supply of the nipple and areola. The blood supply of the breast is extremely rich; the nipple-areola subdermal vascular network is extremely important to the blood supply of the nipple; if the epidermis is removed unevenly in depth during surgery, the incision is too deep and the surrounding skins are extensively stripped; and all can undermine the release of subdermal vascular network and cause the nipple-areola necrosis.

4. The sebaceous cyst in incision: It is mainly caused by incomplete removal of the epidermis of the dermal pedicle; increasing the thickness of the epidermis to be removed during surgery can reduce the postoperative incidence rate of sebaceous cyst in incision and will not affect the blood supply of the nipple and areola.

5.7.3 Complications of Breast Augmentation

1. Fibrous capsular contracture of the prosthesis: The fibrous capsular contracture after prosthesis breast augmentation is related to many factors such as infections, individual factor, surgical operation, prosthesis leakage and rupture, prosthesis type, implanted layer, and hematoma. The operations must be gentle during surgery, and generally the dissection range should be slightly larger than the prosthetic chassis. The hematoma can cause and aggravate the capsular contracture; therefore, the adrenaline saline is locally injected into the surgical area before surgery, the complete hemostasis is carried out intraoperatively, and the effective postoperative suction drainage is very important. If the fibrous capsular contracture of the prosthesis occurs, removing the fibrous capsule and releasing the fibrous capsule can be performed, and the capsule can also be incised and released under endoscopy.
2. Prosthesis exposure: When the surgical dissection is performed, the pectoralis major muscle is ruptured, or the dissected cavity is smaller, so that the prosthesis is folded into an angle, and the capsular contracture is formed after surgery. The prosthesis continues to stimulate the weak area of the breast tissue, and if not timely treated, it may lead to prosthesis exposure. If the weak area is smaller after surgery, the local continuous compression bandaging can be carried out to make the prosthesis flat and prevent the herniation of the prosthesis. If the weak area is larger, or the prosthesis exposure is about to occur, it must be repaired surgically.
3. Breast prosthesis displacement: If it is caused by capsular contracture, after the capsule is removed, the cavity is dissected and expanded, so that bilateral breasts are symmetrical; if it is caused by the shift of the prosthesis, the opposite directional pressurization should be carried out at early stage. If there is still breast prosthesis displacement at 3 months after surgery, the upward displacement of prosthesis requires performing surgery to dissect downward to make the prosthesis move downward; the downward displacement of prosthesis requires performing surgery to remove the capsule at the site of downward displacement and suture the capsule at the side of the chest wall with the capsule at the side of breast, so that two layers of capsules can heal together.
4. Effect on the diagnosis of breast cancer: The prostheses can affect the physical examination and mammography of the breast and bring difficulty for early detection and early diagnosis of breast cancer; please refer to the oncological safety-related issues for the contralateral breast in the above article.
5. Complications of autologous tissue transplantation: The complications after autologous tissue transplantation are seen in related contents of the first section of this chapter.

5.7.4 Complications of the Mastopexy

In addition to the abovementioned common complications, the mastopexy has complications similar to those of the breast reduction, but its complications are relatively rare.

Conclusions

The plastic surgery for the breast at the affected side can reduce the deformity of the breast at the affected side in breast cancer patients, but bilateral asymmetry may still be left, and thus the overall appearance will be affected. The plastic surgery for the breast at the healthy side can be implemented to recover bilateral symmetry in breast cancer patients, so as to maximize the aesthetic effect, which is very helpful in improving patient satisfaction and is a direction of the development of breast oncoplastic surgery.

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Repair and Reconstruction of Defects After Resection of Chest Wall and Abdominal Tumors

16

Fazhi Qi, Gaoming Xiao, Yuejun Chen, Yunliang Qian, Yixin Zhang, Jun Yang, and Danru Wang

1 Repair of Chest Wall Defect

Fazhi Qi

The chest is located between the head and neck and the abdomen and is a concentrated area of important organs such as respiratory and circulatory organs. The chest wall is divided into three layers of skin, support structure (consists of bones, cartilage, and ligaments), and pleural membrane, which commonly constitute the thoracic cage and protect vital organs such as the heart, lung, and trachea; meanwhile the activities of the thoracic cage also provide the ideal conditions for the body's circulatory and respiratory movements.

The chest wall tumors include primary tumors in chest wall soft tissue and bone, metastatic chest wall tumors, and the chest wall tumors due to the fact that the intrathoracic tumors directly invade the chest wall. Currently, after tumor surgery, radiation injury, surgery, infection, and trauma are the common causes of chest wall defect, of which the ulcer after tumor surgery and the radiation-induced ulceration are most commonly seen in clinics. The resection range of benign tumor of the chest wall is smaller, and its postoperative defect resection has less effect on chest wall integrity and breathing exercises; generally, the defect is retained without the need for repair; for larger chest wall benign tumors, whether the repair and reconstruction of chest wall defect are performed is determined according to the defect size and position. The defects after resection of malignant tumors of the chest wall refer to the chest wall defects resulted after the extended tumor resection is carried out due to primary and metastatic malignant chest wall tumors and the fact that the malignant tumors in organs adjacent to chest wall (such as lung cancer, mediastinal malignant tumor, malignant pleural mesothelioma, breast cancer, and upper abdominal malignant tumors) invade the chest wall, including the defect in covering soft tissue of the chest wall and the defect in the bony structure of the chest wall [1–5] (Fig. 16.1). The chest wall defect not only affects the appearance but also is accompanied by varying degrees of thoracic visceral damages, and the larger chest wall defect often causes paradoxical breathing, interferes with normal respiratory and circulatory function, and even leads to death. Before any repair surgery is performed, it is necessary to determine the respiratory and circulatory functions and the general condition of the patient; when necessary, the repair is carried out after the cardiopulmonary function is improved appropriately.

Therefore, the chest wall defect repair should aim to restore the continuity of the chest wall structure to protect the thoracic organs, maintain normal respiratory and circulatory functions, and obtain a good shape at the same time.

1.1 Resection of a Chest Wall Tumor

Before deciding to carry out the chest wall mass resection, it is required to confirm the diagnosis to exclude chest wall tuberculosis, multiple myeloma, and lymphoma. As long as the general conditions in the patients are good, and there is no distant metastasis, all benign and malignant chest wall tumors should be surgically removed. The metastatic chest wall tumors, including the direct chest wall invasion of malignant tumors of intrathoracic internal organs, as long as the primary focus has no recurrence, or has been removed completely, the surgeon should strive to resect the metastatic chest wall tumor, to achieve the purpose of curing or prolonging the life and reducing the pain. For radiosensitive malignant tumors such as lym-

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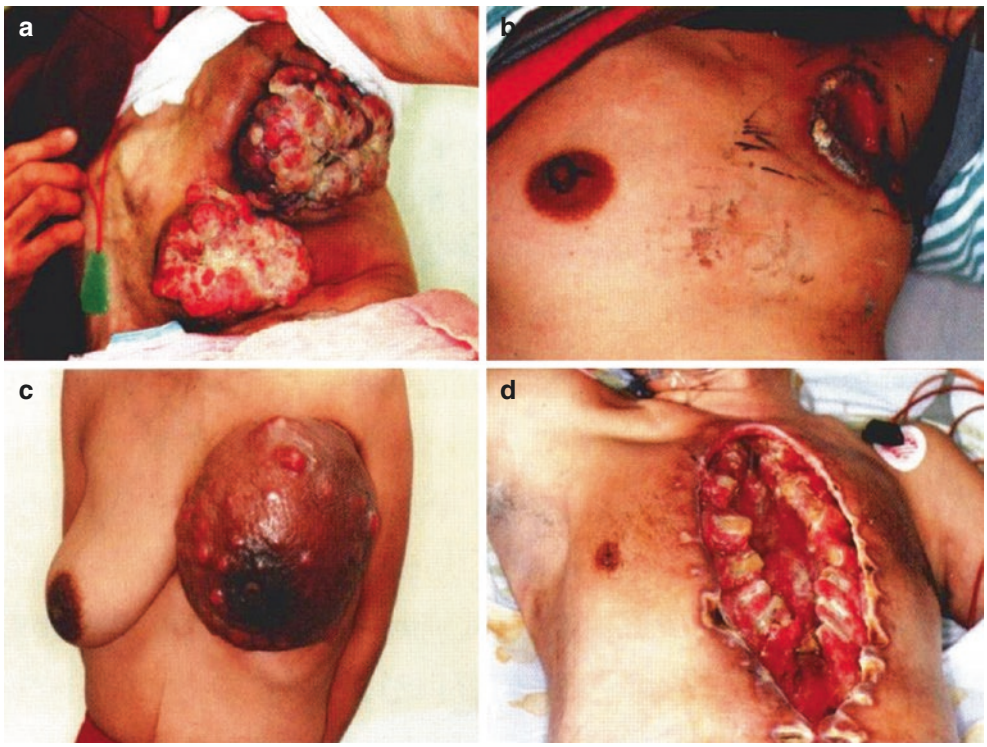


Fig. 16.1 Different types of chest wall tumors may cause complex chest wall defects. (**a**) Cauliflower-like tumor. (**b**) Ulcerative type tumor. (**c**) Expansive type tumor. (**d**) Sternal defect tumor

phoma and Ewing's sarcoma, most scholars believe that the use of radiotherapy + surgery has a more satisfactory curative effect. The patients with multiple myeloma should be treated mainly with chemotherapy and supplemented by radiotherapy, and the patients with solitary single myeloma without systemic symptoms may undergo resection and receive postoperative radiotherapy and chemotherapy. The patients with breast cancer and chest wall invasion of lung cancer should receive postoperative chemotherapy and radiotherapy according to the principles of treatments of breast cancer and lung cancer. The osteosarcoma patients should receive postoperative chemotherapy. For various rare malignant bone tumors in ribs and sternum including single well-circumscribed tumor, such as malignant osteoblastoma, malignant eosinophilic granuloma, and malignant giant cell tumor, the patients should be treated by surgery as far as possible. Some tumors should receive radiotherapy after chemotherapy at first, and then they can be resected when the tumor bodies are reduced.

The surgical method should be selected according to the growing location, size, and pathological type of the chest wall tumor. The patients with smaller benign chest wall tumors just need to undergo local tumor resection, and without the need for the repair with artificial materials; but the patients with large area chest wall defect after tumor resection need to undergo chest wall reconstruction with artificial materials. For chest wall tumors which are primary or metastatic malignant or have malignant biological behaviors, if involving the ribs, the tumor including a normal rib respectively above and below the lesion, and all ribs, muscles, and soft tissue attached by the tumor, parietal pleura, and regional lymph nodes should be removed, its front and rear surgical margins should also be kept a distance of 3–5 cm away from the tumor margins, and the samples are taken from the margins (top, bottom, left, and right) and sent for rapid pathological frozen section examination. If the tumor has invaded the lungs, partial lung resection or pulmonary lobectomy should be carried out simultaneously. For malignant tumors which directly invade the chest wall (such as breast cancer and lung cancer), en bloc resection of the chest wall including the primary focuses should be performed.

Sometimes, the chest wall cancer patients have undergone surgical treatments for many times when they visit the hospital, with repeated recurrence, the tumor body is huge, or the ulcer ruptures repeatedly, accompanied by the stench or distant metastases; it is required to confirm the nature of the treatment before surgery, whether it is radical treatment or palliative treatment.

If the tumor has a biological characteristic that is prone to local recurrence, but is not prone to distant metastasis or has no distant metastasis, it is needed to emphasize the thoroughness of tumor resection and provide opportunity of radical cure to the patient. If the patient has a distant metastasis at the same time, the treatment is mainly aimed at treating the burst bleeding and stench of the ulcer, removing the local disease and improving quality of life, or creating the conditions for postoperative chemotherapy and radiotherapy (only suitable for chemotherapy-sensitive tumors). It belongs to the palliative treatment. It is noteworthy that even the pallia-

tive treatment should also emphasize the thoroughness of local resection or the incision that is located within the tumor body; it is difficult to heal completely.

It is required to confirm the nature of the local ulcer in patients receiving radiotherapy; whether it is radiation-induced ulceration or tumor recurrence, it requires biopsy or intraoperative frozen section examination. If it is radiation-induced ulceration, some patients may retain the support structure such as ribs, and the remaining radioactive damage can be biologically removed by the covering tissues with good blood supply; if it is tumor recurrence, it is required to carry out complete resection. For some patients with breast cancers which are mainly presented as ulcers, the neoadjuvant chemotherapy can be carried out to reduce the range of the tumor body, and then the surgical treatment is performed.

1.2 Classification of Chest Wall Defects

1.2.1 Classification According to the Extents of the Defects

The chest wall defects can be divided into the simple skin and soft tissue defects, the defects in chest wall support structure such as ribs and sternum, and the full-thickness chest wall defect according to the extents of the defects. The classification according to the extents of the defects may provide guidance for the repair of the chest wall layer by layer.

1.2.2 Classification According to the Positions of the Defects

The chest wall defects can be divided into sternal defect, anterior chest wall defect, lateral chest wall defect, and posterior chest wall defect according to the positions of the defects. The classification according to the positions of the defects can offer help in selection of skin flaps for repair. It is noteworthy that the transverse rectus abdominis myocutaneous (TRAM) flap often can't reach the upper end of the chest wall, and the forced application will result in distal flap necrosis.

1.2.3 Partition of Chest Wall Defect

The partition of chest wall defect generally refers to the partition of anterior chest wall. For selection of therapeutic regimen, the anterior chest wall can be divided into eight regions. The upper boundary of the anterior chest wall is the clavicle, the lower boundary is the margin of the hypochondrium, the lateral sides are bilateral axillary lines, and the anterior chest wall is divided into three parts such as left, middle, and right parts through the midclavicular lines; then through the horizontal line at the lower boundary of the third rib and the xiphoid process level, the chest wall is divided into three parts, such as upper, middle, and lower parts, so that the chest wall is divided into eight regions (Fig. 16.2).

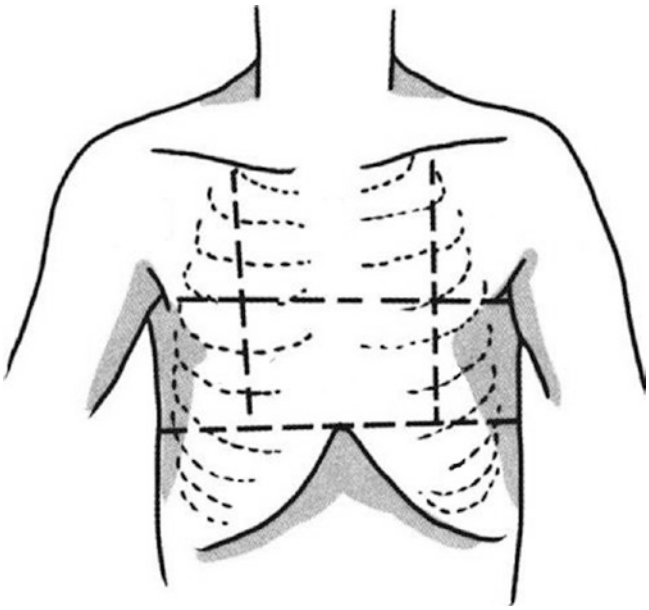


Fig. 16.2 Partition of anterior chest wall *1*, *4*, and *7* are the right region; *3*, *6*, and *8* are the left region; and *2* and *5* are the central region

1.3 The Principles for Repair of Chest Wall Defect

In principle, the appropriate method should be selected for chest wall repair and reconstruction according to the range (size), position, and degree of the chest wall defect caused by surgery [6–9].

1.3.1 Objectives of Chest Wall Reconstruction

1. To completely close the thoracic cavity, maintain the integrity of the thoracic cavity and maintain negative intrathoracic pressure.
2. To protect vital organs such as the heart, lungs, and mediastinum, try to maintain the original shape and beauty of the thorax.

1.3.2 Key Points of the Chest Wall Reconstruction

1. Various materials are used to reconstruct the rigid chest wall, in order to restore the ruggedness and stability of the chest wall.
2. The soft tissue and skin are used to cover the rigid chest wall to keep the tightness of the chest wall.

1.3.3 The Surgical Plan Is Determined According to Defected Tissue in the Chest Wall

1. The pleural defects mostly do not require repair, the pleural defect is repaired through the crawling growth of the pleura after repair of chest wall, or the pseudomembrane

is formed to close the pleural cavity. The pleural cavity can be closed through fascia transplantation under very rare circumstances.

2. The chest support structure can be repaired through cross-transplantation of ribs, or selectively using titanium, titanium mesh, Medpor bracket, Terylene membrane and bone cement, etc., so as to maintain the stability of the chest wall to prevent paradoxical breathing. Usually it does not require repair when less than three ribs are removed, and it is required to repair the support structures when more than four ribs or sternum are removed. Currently, the titanium mesh and Terylene membranes are most commonly used for repair of the support tissue of the chest wall, of which the titanium mesh not only has a certain support strength, but also has a certain activity, and is used widely in recent years. When used, the titanium mesh is bent into the thoracic curvature and is fixed onto the ribs and sternum with 3–5 mm titanium screws.
3. The repair of soft tissue such as the skin should take into account the etiologic factors of the chest wall defect; the invasive tumors often cause deep and widespread defects; the blood supply of the area surrounding the radiation damage is often poor, which often results in poor wound healing. According to the size of the defect, the local or ortho-position skin flap can be selectively used for repair. The commonly used flaps include the pectoralis major myocutaneous flap, latissimus dorsi myocutaneous flap, transverse rectus abdominis myocutaneous flap, and omental flap. It is worth noting that, although the microsurgical technology has matured, there are more available tissue flaps in the thoracoabdominal wall, the technical requirements for microscopic free skin flap transplantation with vascular anastomosis are high, and the clinical application is less. In addition, since the presence of involuntary movements such as breathing in the chest, and compared to other sites, the skin flap has a certain shearing force, it is easy to form effusion, the drainage tube should be placed for a long time and should not be taken out in a hurry even in the case of small drainage volume, and it should be placed for 3–5 days.

1.3.4 The Surgical Plan Is Determined According to the Partition of Chest Wall Defect

1. Repair of chest wall soft tissue defects: Due to different ranges of chest wall soft tissue defects, their repair methods are different. The repair methods of region 1, 4, and 7 are the same as that of region 3, 6, and 8, the local rotation flap is used for repair, the skin flap donor site is repaired with skin transplantation, or the vascularized latissimus dorsi myocutaneous flap transplantation is used for repair. For the chest wall soft tissue defect in single region such as region 4 or 6, when the defect range does not reach the midline area of the bone, the chest rotation skin flap is often selectively used for repair, and the skin flap donor site is repaired with skin transplantation. The soft tissue defect in region 2 or 5 is repaired with unilateral pectoralis major myocutaneous flap transplantation, and the donor site is repaired with free skin transplantation. Region 1 and 3 defects combined with region 2 and 5 defects are repaired with chest rotation flaps at the healthy side and the affected side, and the donor sites are repaired with skin transplantation. In the bone defect in the central region of the chest wall (region 2 and 5), or when there are lateral region defects (region 1, 4, 7, 3, 6, and 8) combined with partial bone defect in region 2 and 5, their repair methods can adopt the sandwich-type chest wall prosthesis made by double layer polyester mesh plus bone cement or the titanium mesh and the pectoralis major myocutaneous flap transplantation, or the pectoralis major myocutaneous flap plus latissimus dorsi myocutaneous flap transplantation, or two local rotation flaps are used for repair; the female patients can also use the breast transfer for repair (relatively simple), or the transverse rectus abdominis myocutaneous flap (TRAM flap) and inferior epigastric artery perforator flap are used for repair.
2. Repair of chest wall bone defect: For the chest wall bone defects in different sites, the emphasis points of the chest wall reconstruction are also different.
   (1) The defects in sternal region, namely, region 2 and 5: After the occurrence of the sternum and bilateral rib cartilage defects, the thoracic integrity and stability are damaged to a greater extent, then the heart and great vessels behind it are also vulnerable to external force influence, and therefore it is required to carry out chest wall reconstruction and focus on the reconstruction of its bony framework. The authors believe that the titanium mesh or the sandwich-type chest wall prosthesis consisting of Prolene mesh + bone cement + Prolene mesh is used to repair the bony framework, and then the pectoralis major muscle flap or latissimus dorsi muscle flap is used for coverage. These ruggedness, stability and shaping, and clipping of this method are satisfactory. But attentions must be paid to avoid the exothermic effect of the bone cement in the process of shaping damages to the adjacent tissues or organs.
   (2) The defects in the upper chest wall, namely, region 1 and 3: Because the upper chest wall, namely, region 1 and 3, is covered by thicker tissues such as the scapula, latissimus dorsi muscle, and pectoralis major and minor muscles, if the defect is smaller, it can be

directly sutured or covered by local muscle flap. Especially for the chest wall defect locating in the scapula area, the defect can be retained without chest wall reconstruction. But for the patients with defect area larger than 6 × 6 cm, continuous removal of more than three ribs and intercostal tissues, the chest wall reconstruction should be carried out; it is recommended that Prolene mesh is used to repair the defect.

(3) The defects in the middle and lower chest wall, namely, region 4, 6, 7, and 8: Because the middle and lower chest wall is not covered by thicker tissues, if it cannot be directly sutured to carry out the chest wall reconstruction, the diaphragm or Prolene mesh can be selectively used for reconstruction; if the diaphragm cannot be used for reconstruction, the Prolene mesh is used to repair the chest wall defect, and its surface is covered with latissimus dorsi muscle flap or TRAM flap.

3. Repair of full-thickness chest wall defects: If the defects in the skin, muscles, and bones of the chest wall are greater, they often need to be repaired by combined use of artificial materials and autologous tissue materials, the artificial materials are used to repair the bony structure of the chest wall, and the autologous tissue materials are used to repair the local skin and muscle defects. The authors advocate that it is better to use the artificial materials such as Prolene mesh or titanium mesh or sandwich method of Prolene mesh and bone cement to repair the chest wall defects, the skin flap and artificial materials should be separated with the muscle flap or greater omentum, which can improve the surgical successful rate. The adjacent myocutaneous flap or latissimus dorsi myocutaneous flap or TRAM flap is used as the myocutaneous flap.

During chest wall reconstruction, attention must be paid to placing drainage tubes between layers of materials to timely drain the exudate and eliminate the dead space, so that various layers of tissues can timely cling close and heal early. If there is fluid retention, the secondary infection will easily occur, resulting in failure.

1.4 The Commonly Used Repair Method

1.4.1 Local Skin Flap

The wounds after resection of tumor in the resection can be repaired with local skin flap; the design of the skin flap is to contain blood vessels as far as possible, such as lateral chest wall flap and intercostal flap; and when the random pattern skin flap is used, attention should be paid to the length-to-width ratio of the skin flap.

1. Case I After chest wall tumor resection, if the support structures of the chest wall are intact, the random pattern skin flap is used for repair (Fig. 16.3).
2. Case II Giant chest wall tumor. The patient underwent multiple surgeries in other hospitals and had tumor recurrence involving the sternum, and the abdominal skin flap is used for defect repair after extensive resection (Fig. 16.4).

1.4.2 Latissimus Dorsi Myocutaneous Flap

The latissimus dorsi muscle is a flat and triangular muscle with its flat and wide aponeurosis starting from the lower six thoracic vertebras, all lumbar vertebras, sacral vertebras, supraspinous ligament, and posterior iliac crest. The muscle fibers are divided into two parts, such as the upper horizontal part and the inferior oblique part, and aggregate toward the upper outer side and end at the spine of the lesser tubercle of the humerus. The latissimus dorsi myocutaneous flap has a blood supply from multiple sources, including the thoracodorsal artery, intercostal artery, and lumbar artery as well as their accompanying veins, of which the thoracodorsal vessels are the main nutrient vessels. The thoracodorsal artery is the terminal branch of the subscapular artery. The subscapular artery is given off from the third section of the axillary artery and passes through the armpit to run downward, subsequently gives off the circumflex scapular artery, and, finally, becomes the thoracodorsal artery. The thoracodorsal artery and vein run under the myolemma at the inner surface of the latissimus dorsi muscle; after entering into the muscle,

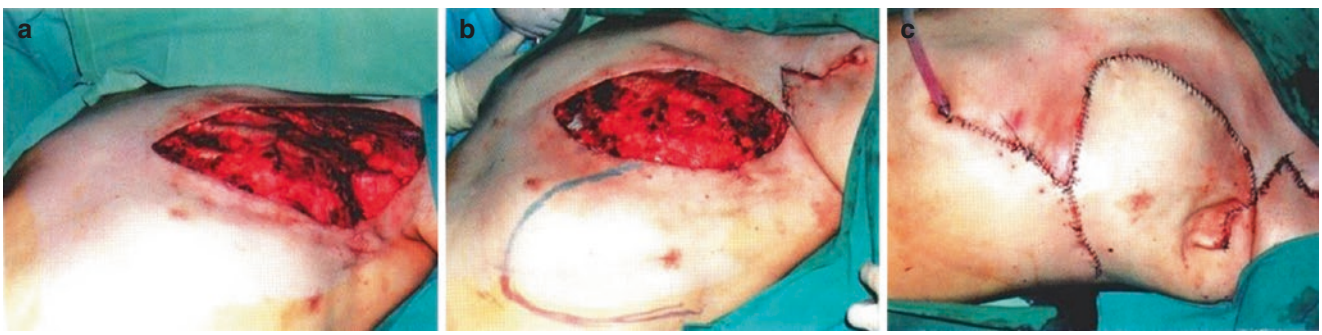


Fig. 16.3 Case I. (**a**) The wound after chest wall tumor resection. (**b**) Skin flap design. (**c**) After repairing and suturing the wound with rotation of random pattern skin flap

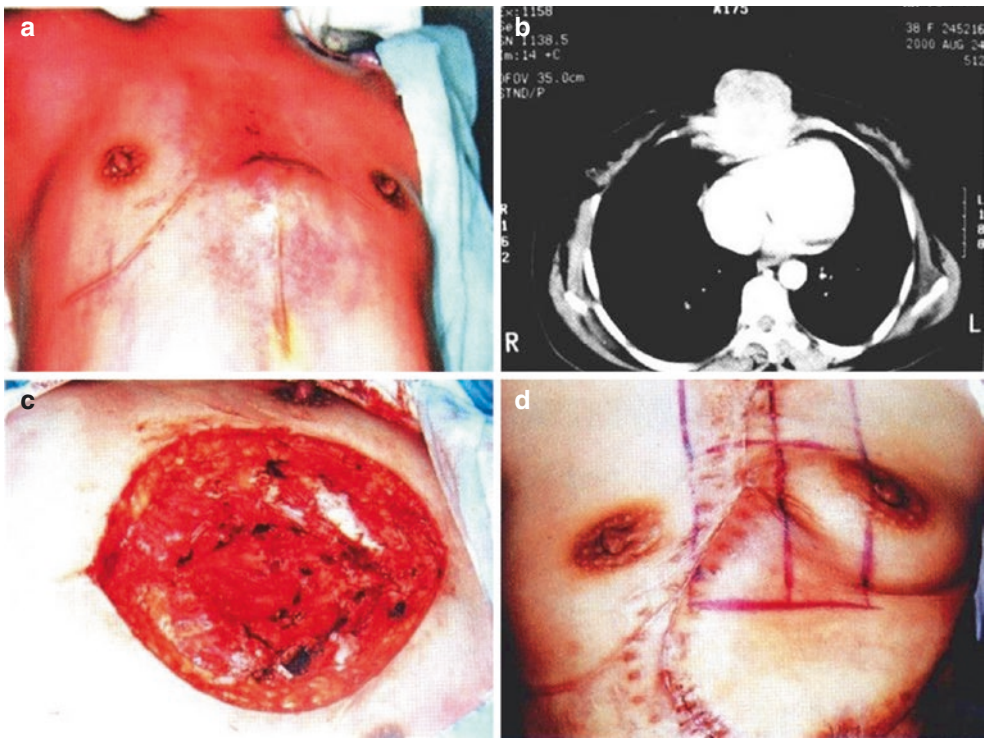


Fig. 16.4 Case II. (**a**) Giant chest wall tumor before surgery. (**b**) Preoperative chest CT showed that the tumor involved the sternum. (**c**) The wound after extensive resection of the tumor. (**d**) After repair of the wound with rotation of abdominal skin flap

they are divided into the lateral branch and the medial branch; the lateral branch runs downward at 2–3 cm behind the anterior margin of the muscle bell, and the medial branch is parallel to upper margin of the muscle and run inward. The motor nerve of the latissimus dorsi muscle is the thoracodorsal nerve, which accompanies with the blood vessels to enter into the muscle.

The latissimus dorsi myocutaneous flap pedicled with the thoracodorsal artery, and its rotational arc can reach up to the head and neck, shoulder, upper limb, and ipsilateral chest. It has a wide range of clinical applications, is one of skin flaps with most extensive range and most versatile functions in the body which are available for free transplantation or pedicled transplantation, and is commonly used for repair of a large area of skin and tissue defects and the defects which are associated with muscle defects and require carrying out functional reconstruction and the breast reconstruction.

An oblique line which is parallel to the anterior margin of the latissimus dorsi muscle is drawn at 2 cm behind the anterior margin of the latissimus dorsi muscle, and it is the body surface projection of the thoracodorsal vessels. The myocutaneous flap is designed along the body surface projection line. The transplanting method and harvesting range for latissimus dorsi myocutaneous flap are determined according to the wound status in the donor site. The more commonly used design methods include the latissimus dorsi myocutaneous flap which takes the skin on the waist and back as the main donor site and the transverse latissimus dorsi myocutaneous flap which takes the upper half back of the transverse skin as the main donor site. When the surgery is performed, the patient takes the lateral position or hemilateral position, the skin tissue is incised for the armpit along the anterior margin of the latissimus dorsi muscle, the anterior margin of the latissimus dorsi muscle is exposed, the clearance behind the muscle is bluntly dissected, and the thoracodorsal artery, vein, and nerve can be exposed. The blunt dissection is continuously performed toward the distal end, the travel path of the neurovascular bundle in muscle is determined, the end point of the muscle is cut off, the desired width and length are harvested, and the latissimus dorsi myocutaneous flap is formed to repair the wound. The donor site is directly sutured or treated with skin transplantation.

1. Case III The patient, female, 56 years old, had left chest wall radiation-induced ulceration caused by the radiotherapy after bilateral breast cancer surgery, and the ribs were exposed; after the diseased tissues were removed, the titanium mesh was used to repair the ribs, and the latissimus dorsi myocutaneous flap was used to repair the soft tissue defect (Fig. 16.5).
2. Case IV The patient, female, 42 years old, had left chest wall radiation-induced ulceration caused by the radiotherapy after left breast cancer surgery, and the ribs were exposed and necrotized; after resection of diseased tissue, the titanium mesh was used to repair the ribs, and the latissimus dorsi myocutaneous flap was used to repair the soft tissue repair defect (Fig. 16.6).

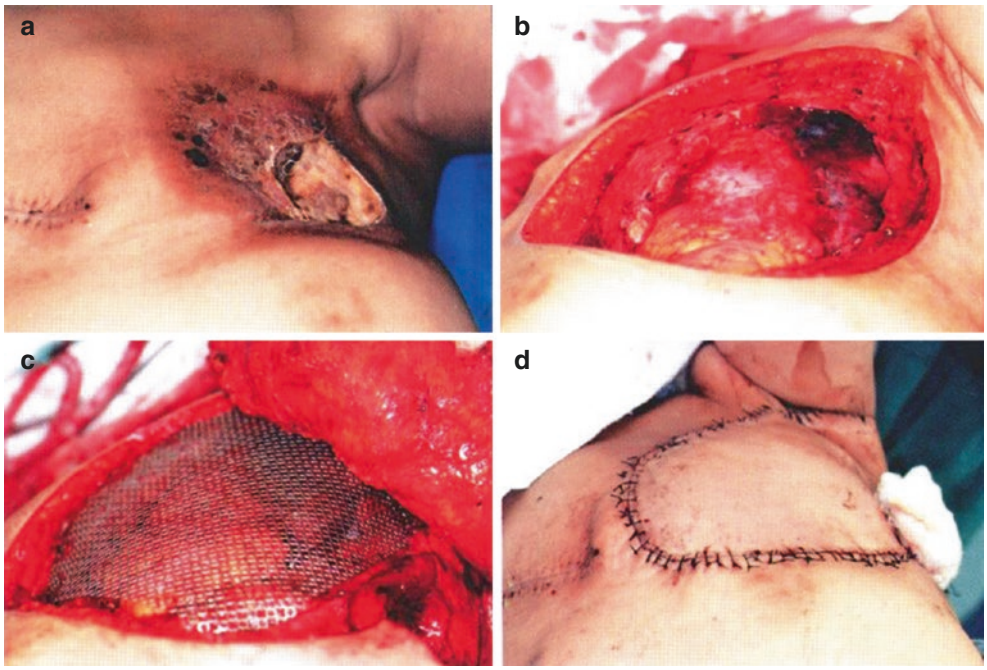


Fig. 16.5 Case III. (**a**) Left chest wall radiation-induced ulceration caused by the radiotherapy after bilateral breast cancer surgery, and the ribs were exposed. (**b**) The wound after resection of diseased tissue. (**c**) The titanium mesh was used to repair the ribs. (**d**) After repair of soft tissue repair defects with latissimus dorsi myocutaneous flap

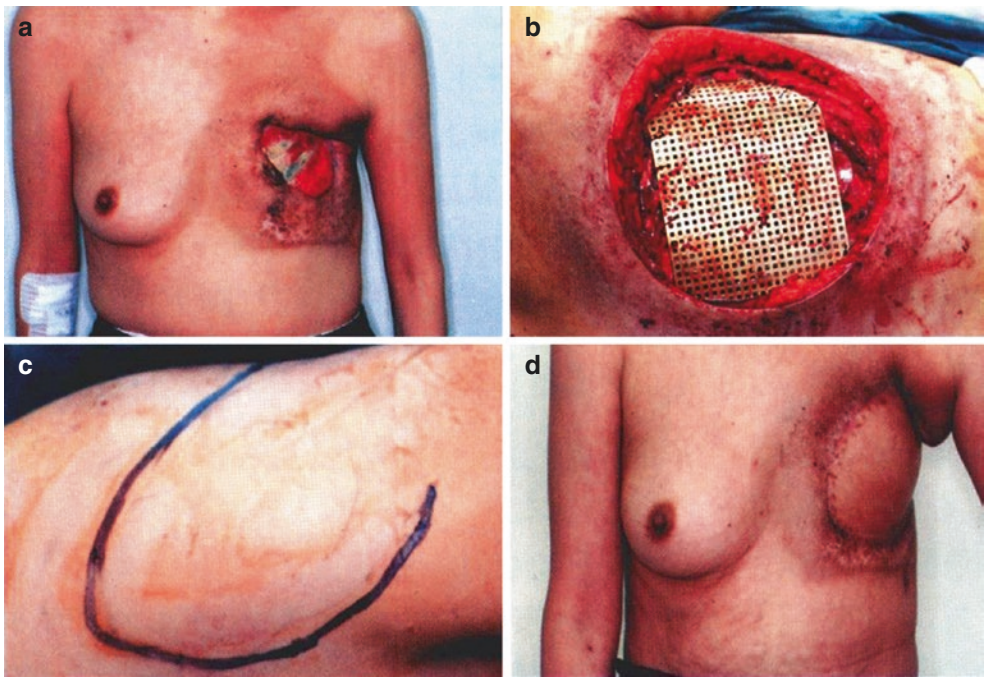


Fig. 16.6 Case IV. (**a**) The radiation-induced ulceration caused by the radiotherapy after left breast cancer surgery, and the ribs were exposed and necrotized. (**b**) After resection of diseased tissue, the titanium mesh was used to repair the ribs. (**c**) Design of the latissimus dorsi myocutaneous flap. (**d**) The latissimus dorsi myocutaneous flap were used to repair the soft tissue repair defects

1.4.3 Rectus Abdominis Myocutaneous Flap

According to the need of the repair, the rectus abdominis myocutaneous flap can be designed as longitudinal rectus abdominis myocutaneous flap and transverse rectus abdominis myocutaneous flap. For repair of the chest wall defects, the longitudinal rectus abdominis myocutaneous flap is more commonly used, and it is required to confirm that the internal thoracic vessels are not damaged before surgery; otherwise it is needed to selectively use other skin flaps for repair. The lower abdominal TRAM flap is mostly used for breast reconstruction.

The rectus abdominis muscle is located on both sides of the abdominal midline and is separated by the abdominal white line. It starts from the pubic symphysis and pubic bone, travels upward, and ends at the front of the sternum xiphoid periosteum and the fifth to seventh costal cartilages. The whole length of rectus abdominis muscle is divided into several muscle bellies by three to four transverse tendinous intersections; the tendinous intersections are closely integrated with the anterior sheath of the rectus abdominis muscle. The blood supply of the rectus abdominis myocutaneous

flap is mainly from the superior and inferior epigastric arteries; the superior epigastric artery is a direct continuation of the internal thoracic artery, and it passes through the sternocostal triangle downward to reach the rectus abdominis muscle, penetrates into the muscle from behind the rectus abdominis muscle, and is anastomosed with the branch of the inferior epigastric artery near the navel; the inferior epigastric artery is given off from the medial wall of the external iliac artery below the inguinal ligament, at the junction of the inner two fifth and the outer three fifth of the inguinal ligament, and it runs obliquely toward the upper inner side behind the transversalis fascia, after crossing the lateral margin of the rectus abdominis muscle; it goes up to enter into the rectus abdominis muscle from behind the muscle and forms into the terminal branch near the area beside the navel. In the process of running within the muscle, both the superior and inferior epigastric arteries give off myocutaneous perforators to feed the skin tissue on the surface and are anastomosed respectively with the branches of lateral perforators of the posterior intercostal arteries, the anterior cutaneous branches of lumbar arteries, superficial epigastric artery, and superficial iliac circumflex artery. The rectus abdominis muscle is subject to control of the lower six pairs of intercostal nerves.

When the longitudinal rectus abdominis myocutaneous flap is designed, the myocutaneous flap ranges up to the xiphoid process and down to the site above the pubic symphysis. The medial side is the abdominal midline, and the lateral side can exceed the lateral margin of rectus abdominis muscle. The skin tissue, fascia, and the anterior layer of anterior sheath of the rectus abdominis muscle are incised layer by layer. When the superior epigastric artery is taken as the pedicle, the rectus abdominis muscle is transversely cut off at the distal end of the myocutaneous flap, and the inferior epigastric artery and vein are ligated and severed; the dissection is performed at the deep surface of the rectus abdominis muscle to the pedicle of the xiphoid myocutaneous flap, and the pedicle of skin should have enough length to facilitate rotation. The navel is retained in situ. The incised anterior sheath of the rectus abdominis muscle is sutured, and the abdominal donor site is closed and sutured (Fig. 16.7). If the required tissue volume is large, the TRAM flap in the lower abdomen can be used.

1. Case V The patient, female, 48 years old, had right advanced breast cancer, with locally recurrent ulceration and bleeding, accompanied by the stench. After the removal of the tumor from the rib surface, the defect was repaired with the contralateral longitudinal transverse rectus abdominis myocutaneous flap, and the postoperative chemotherapy was carried out, which significantly improved the quality of life of the patient (Fig. 16.8).
2. Case VI The patient, female, had left chest wall tumor. There was left chest wall defect after the removal of the chest wall tumor; through skin flap design, the transverse rectus abdominis myocutaneous flap was used to repair the chest wall defect, and then the wound was sutured (Fig. 16.9).

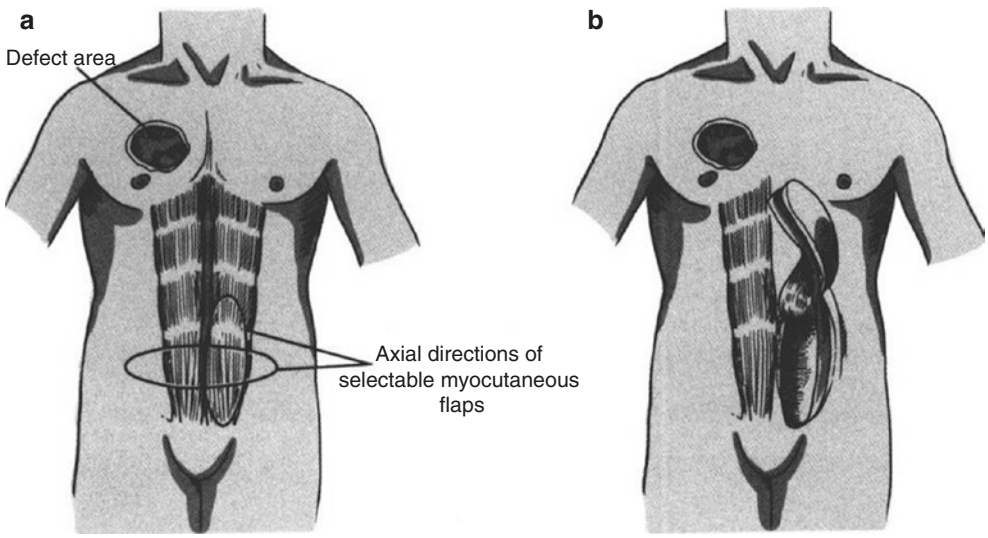


Fig. 16.7 Schematic diagram of repair of the chest wall defect with longitudinal transverse rectus abdominis myocutaneous flap. (**a**) The myocutaneous flap ranges up to the xiphoid process and down to the site above the pubic symphysis. The medial side is the abdominal midline, and the lateral side can exceed the lateral margin of rectus abdominis muscle. (**b**) When the superior epigastric artery is taken as the pedicle, the rectus abdominis muscle is transversely cut off at distal end of the myocutaneous flap, the dissection is performed at the deep surface of the rectus abdominis muscle to the pedicle of the xiphoid myocutaneous flap, the pedicle of skin should be easy to rotate, and the navel is retained in situ

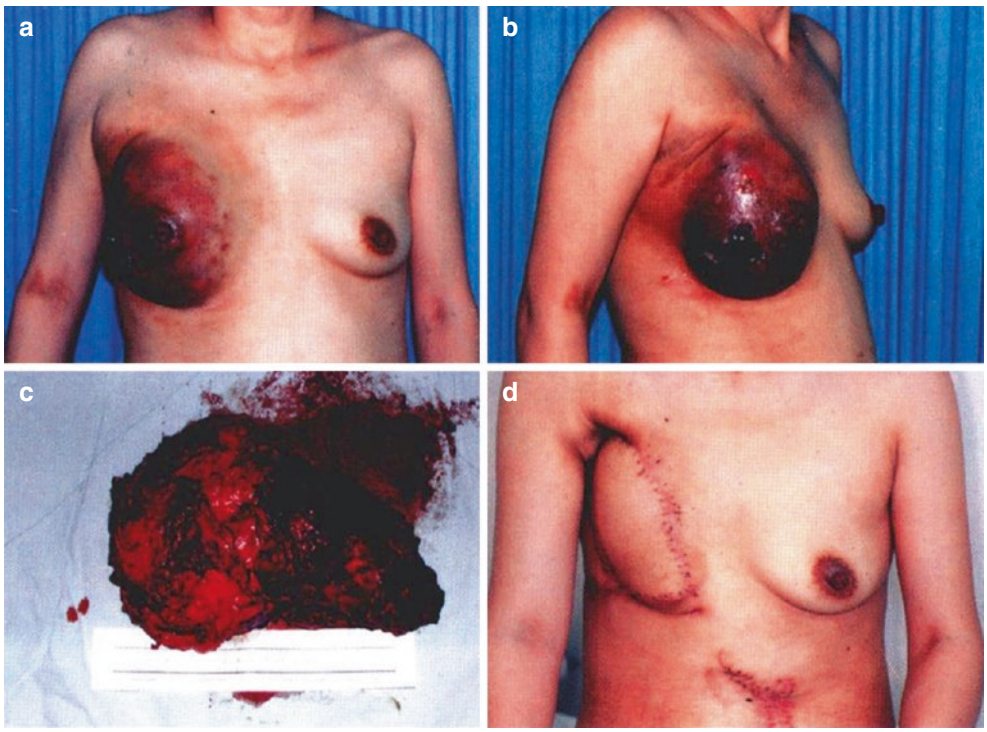


Fig. 16.8 Case V. (**a**, **b**) Before resection of right advanced breast cancer, there was local ulceration and bleeding. (**c**) The resected tumor tissue. (**d**) After repair with the contralateral longitudinal transverse rectus abdominis myocutaneous flap

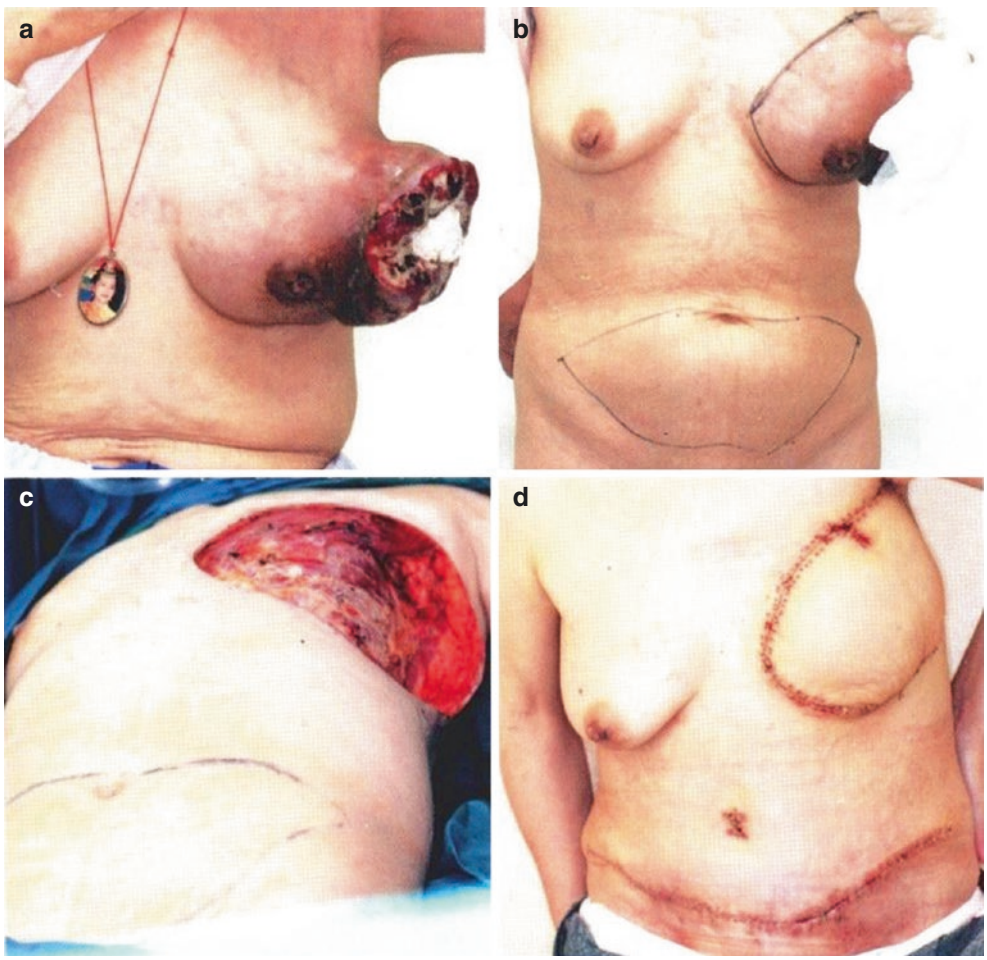


Fig. 16.9 Case VI. (**a**) Before left chest wall tumor surgery. (**b**) Skin flap design. (**c**) The chest wall defect after resection of the chest wall tumor. (**d**) The defect after resection of the chest wall tumor was repaired with TRAM flap in the lower abdomen

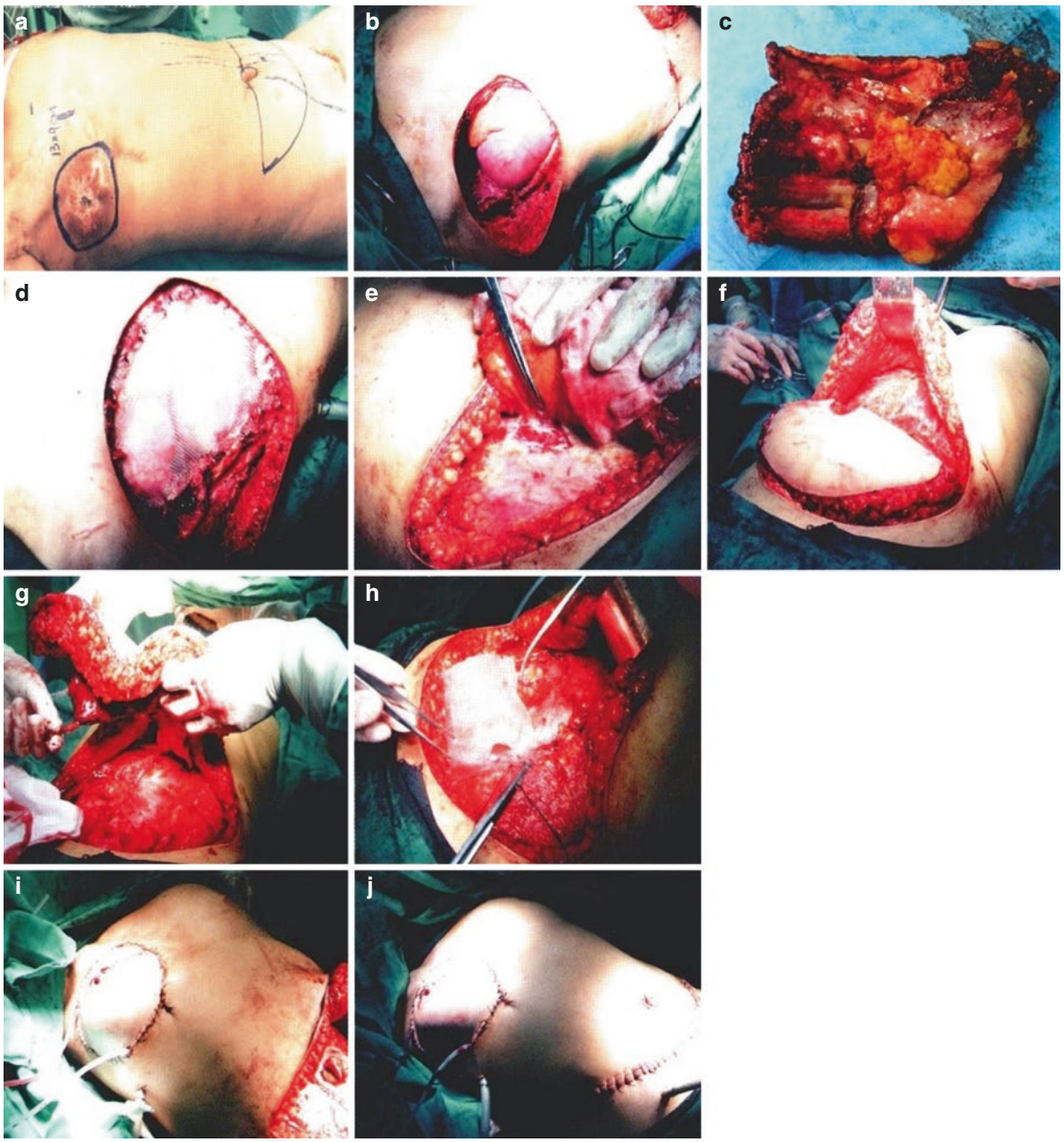


Fig. 16.10 Case VII. (**a**) Recurrence after resection of right breast cancer, the performance of local ulceration after radiotherapy and chemotherapy. (**b**) The chest defect wound after tumor resection. (**c**) The resected tumor tissue included five ribs and cartilages. (**d**) Prolene mesh was used to repair the chest wall defect. (**e**) The TRAM flap was dissected. (**f**) The dissection of TRAM flap was completed. (**g**) The TRAM flap with preservation of unilateral inferior epigastric artery and vein. (**h**) Prolene mesh was used to repair and reinforce the abdominal wall in the skin flap donor site. (**i**) TRAM flap transplantation and the vascular anastomosis were performed, and the chest wall defect was repaired. (**j**) The appearance after surgery

3. Case VII The patient, female, had right breast cancer recurrence after mastectomy, with local ulcers after radiotherapy and chemotherapy. The chest wall defect was repaired after tumor resection with the combined use of Prolene mesh and TRAM flap, and the abdominal donor site was repaired and reinforced with Prolene mesh (Fig. 16.10).

1.4.4 Pectoralis Major Myocutaneous Flap

The pectoralis major is fan shaped with a large range, and the starting point is divided into three parts such as clavicular part, sternocostal part, and abdominal rib part. The clavicular part starts from the medial half of the clavicle, and the muscle fibers travel obliquely toward the lower outer side; the sternocostal part starts from the front of upper six costal car-

tilages on the lateral side of the sternum, and in general, the muscle fibers travel parallelly and outwardly; the abdominal rib part starts from the anterior sheath of rectus abdominis muscle and the distal ends of fifth to seventh ribs, and the muscle fibers travel obliquely toward the upper outer side. Three parts of muscle fibers aggregate outwardly to form a flattened tendon to the end of the crest of the greater tubercle of the humerus. The blood supply of the pectoralis major muscle comes from multisource; there are three main sources: the thoracoacromial artery, the pectoral branch of the axillary artery, and the perforating branches of the internal thoracic artery. The pectoralis major muscle is mainly controlled by the lateral pectoral nerve and the medial pectoral nerve.

There are mainly two methods of chest defects repairment with pectoralis major muscle: The first method is to take the perforating branch of the internal thoracic artery as the pedicle to form the myocutaneous flap, and then the myocutaneous flap is turned over reversely to repair the wound. The second method is to take the thoracoacromial artery as the pedicle to form the myocutaneous flap to repair the wound.

The marking method for the body surface projection of thoracoacromial artery approach is shown in Fig. 16.11, ab is the connecting line between the shoulder peak to the xiphoid process, the point o is the point of intersection between the line cd made from the clavicle midpoint and the connecting line ab, both lines are vertical, and the cob line is the body surface travel path of thoracoacromial artery.

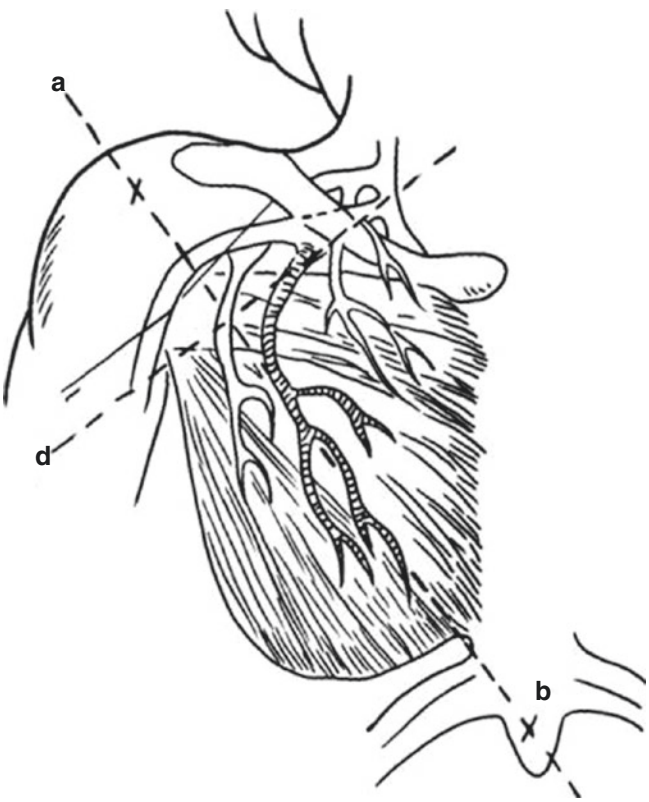


Fig. 16.11 Design of pectoralis major myocutaneous flap (the *cob line* of the body surface travel path of thoracoacromial artery)

The myocutaneous flap is designed along the body surface line according to the need of repairing the defects, the range of the design reaches upward to the level of armpit crimple and downward to the level of the xiphoid process, the inner boundary reaches the sternal margin, and the outer boundary reaches the anterior axillary line. When the surgery is performed, the pedicle skin is incised firstly, and then the skin and the full-thickness pectoralis major muscle are incised along the outer margin of the skin flap, and the myocutaneous flap is separated at the deep surface of fascia propria. After the pectoralis major muscle is lifted up, the blunt dissection is performed at the deep surface of the pectoralis major muscle to the pedicle, and after the neurovascular bundle locating at the deep surface of pectoralis major muscle is found, the skin at the medial margin of the skin flap is incised along the design line and the full-thickness pectoralis major muscle; the pectoralis major myocutaneous flap is formed and transferred to repair the wound.

1. Case VII The patient, male, 57 years old, had a sternal tumor. The sternal tumor was extensively resected, and after the chest wall defect was repaired with the titanium mesh, the pectoralis major myocutaneous flap is transferred to repair the wound (Fig. 16.12).
2. Case IX The patient, male, 49 years old, had a sternal tumor. After extensive resection of tumor tissue (including four pairs of costal cartilage and part of the sternum), the sandwich-type chest wall prosthesis made of double layer polyester mesh plus bone cement and the pectoralis major myocutaneous flap are transferred for repair and reconstruction, and the skin flap donor site was repaired with skin transplantation (Fig. 16.13).

1.4.5 Breast Tissue Flap

The blood supply of the breast tissue is rich and mainly comes from the branches of the peripheral arteries, and its arterial sources mainly include the intercostal perforators of internal thoracic artery, lateral thoracic artery, intercostal arteries, and the chest wall branch of the thoracoacromial artery. The arterial system of the breast consists of its medial, lateral, and deep arterial branches, and these arterial branches are anastomosed with each other to form two groups of superficial and deep vascular networks, respectively, at the gland surface of the breast and within the gland. The ends of arterial blood vessels in superficial group eventually aggregate toward the nipple and areola to form annular vascular network, and the blood vessels within the gland travel to the nipple along the thoracic diaphragm of the breast.

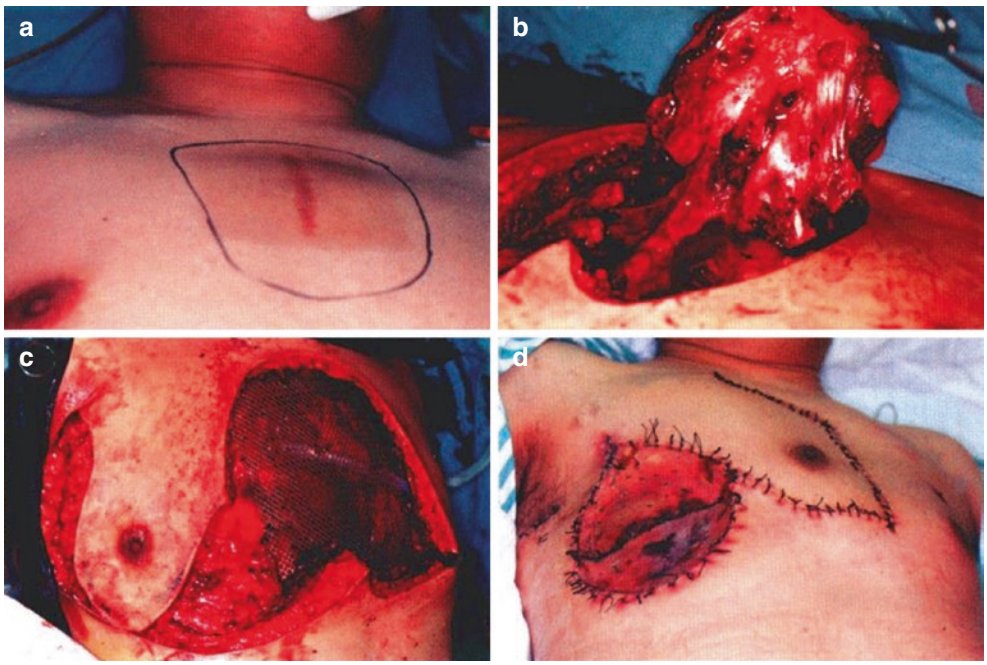


Fig. 16.12 Case VII. (**a**) Before surgery, the pectoralis major myocutaneous flap was designed. (**b**) The sternal tumor tissue was extensively resected. (**c**) The titanium mesh was used to repair the chest wall defect. (**d**) The pectoralis major myocutaneous flap was transferred to repair the wound, and the skin flap donor site was repaired with skin transplantation

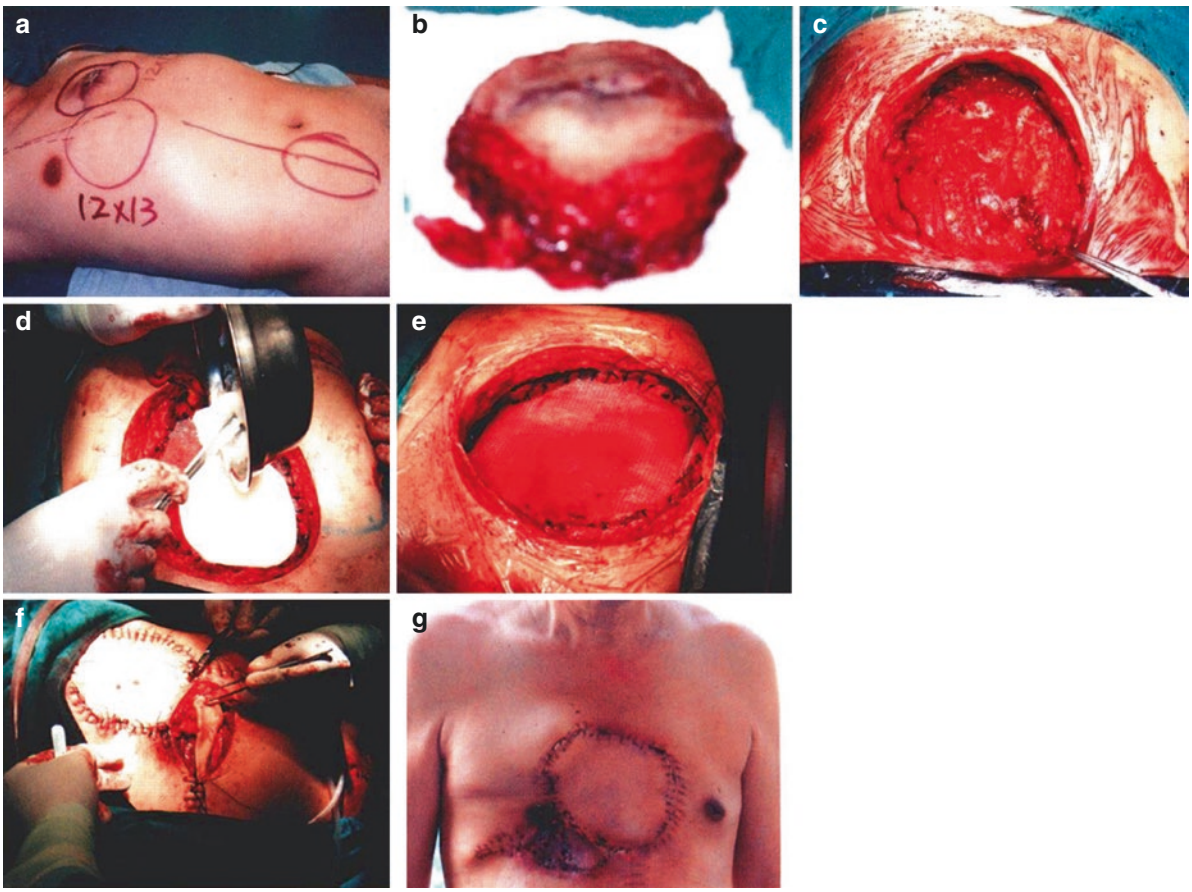


Fig. 16.13 Case VII. (**a**) The lesion resection range and the range of pectoralis major myocutaneous flap to be transferred which were designed before surgery. (**b**) The chest wall tumor, four pairs of costal cartilages and a part of sternum were resected. (**c**) The wound after resection of the chest wall tumor. (**d**) The Prolene mesh was sutured at first, and the bone cement was used for shaping. (**e**) The Prolene mesh was sutured again at the surface of the bone cement. (**f**) After transfer of island pectoralis major myocutaneous flap for repair, the wound was treated with skin transplantation. (**g**) The wound at the 12th day after surgery

Because the breast has a good blood supply, which has certain glandular tissues, it can fill the dead space at the same time of covering the wound. The breast tissue flap has a milder trauma and is especially suitable for older patients with poorer general conditions; for young women, it is required to avoid damaging the breast at the healthy side, and other skin flaps are selectively used. The breast tissue flap can be separated with the pectoralis major muscle flap, can be turned into two layers of the tissue flaps to be transferred, respectively, and can also be combined with pectoralis major muscle to form a tissue flap to be transferred, thus increasing the thickness of the tissue. The transfer methods for the breast tissue flap are flexible and diverse, and they can be superior pedicle, inferior pedicle and medial pedicle, or lateral pedicle. The superior pedicle is more commonly used in repair of the chest wall defect, and the pedicle should include well-known blood vessels during surgery to ensure the blood supply of the tissue flap.

1. Case X The patient, female, 48 years old, had recurrence after right breast cancer surgery, involving the sternum and ribs. After extensive resection of the breast tumor, the defect was repaired with the titanium mesh and contralateral breast tissue flap (Fig. 16.14).
2. Case XI The patient, female, had a sternal tumor, with multiple recurrences after surgery. After radical resection of the tumor, the breast tissue flap was used to repair wound, and the postoperative adjuvant radiotherapy was carried out (Fig. 16.15).

1.4.6 Greater Omentum Flap

1. Indications and contraindications: For a large area of chest defect or exposed deep tissue, when it cannot be repaired with general flap and myocutaneous flap, the omental pedicle graft can be used, and then the free skin transplantation is performed on the greater omentum. Clinical practice found that when the greater omentum is used to repair the body surface defect, if the upper surface of the greater omentum is not immediately covered with skin grafts, there will be a process of granulation tissue formation, and the greater omentum will be hardened; if the skin implantation is performed immediately, the softness of the greater omentum can be maintained. But in patients with histories of abdominal surgery and abdominal infection, there may be omental adhesion or fibrosis, which shall be considered as surgical contraindications. When the greater omentum is transferred, it is required to carry out a laparotomy. The trauma is greater, and the intestinal adhesion, intestinal twist, and death caused by peritonitis have been reported. The indications should be strictly controlled.

   The greater omentum has two arterial arches such as upper and lower arterial arches; the left and right gastroepiploic arteries form the upper arterial arch of the greater omentum, and the left and right gastroepiploic arteries run downward to the free margin of the greater omentum to form the lower arterial arch of the greater omentum.

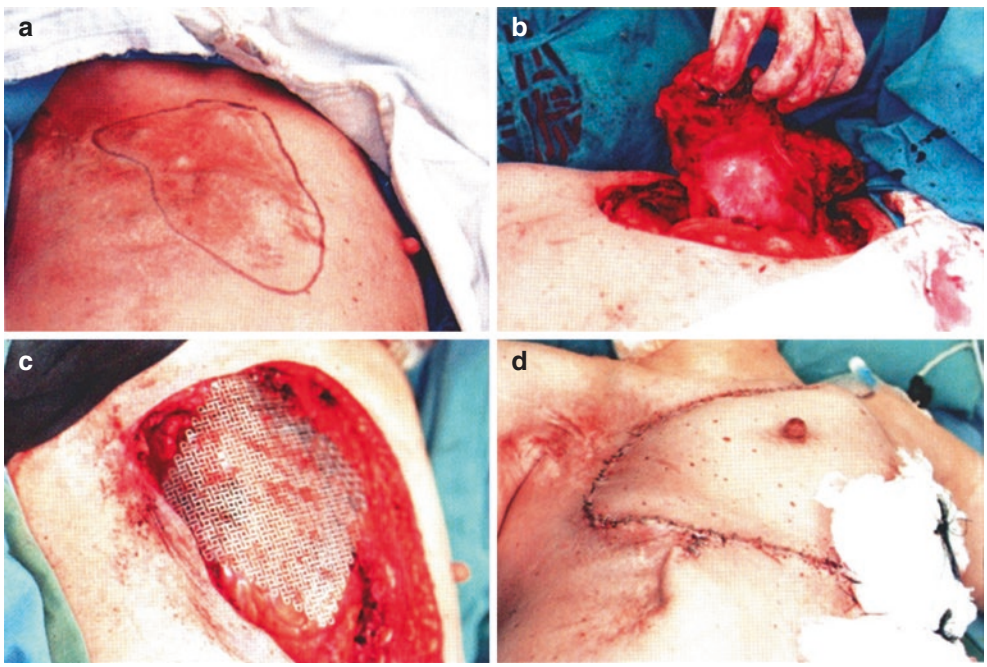


Fig. 16.14 Case X. (**a**) The resection range of the tumor was marked before surgery. (**b**) The tumor tissue was removed. (**c**) The titanium mesh was used to fix and repair the chest wall. (**d**) The contralateral breast tissue flap was used to repair the chest wall

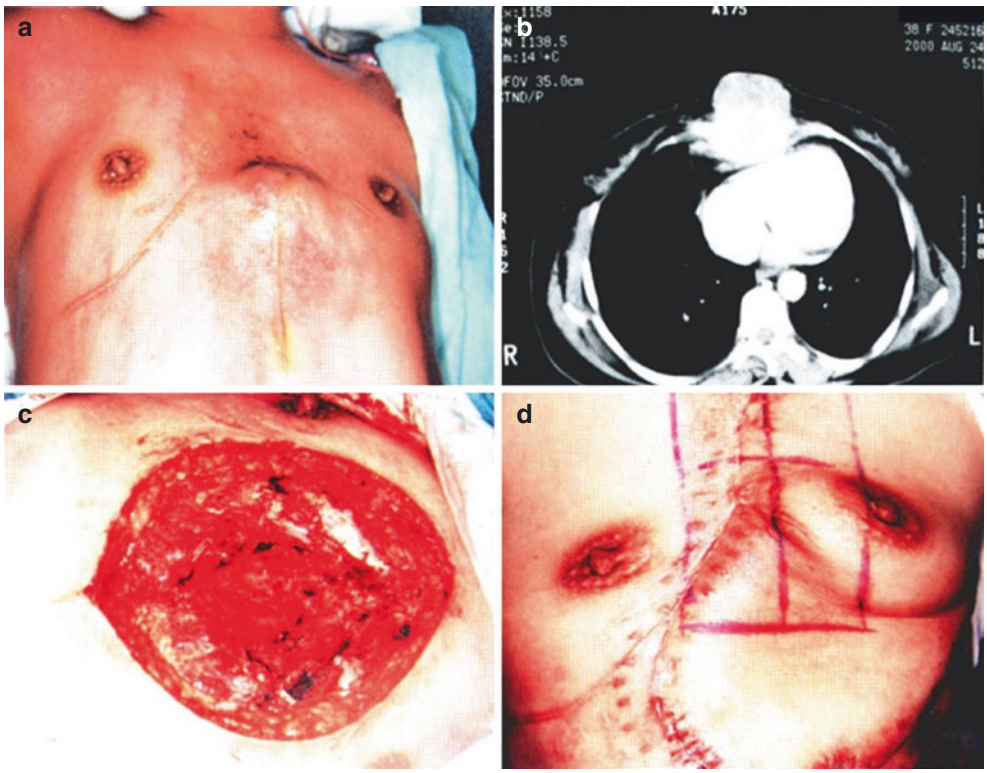


Fig. 16.15 Case XI. (**a**) The sternal tumor before surgery. (**b**) Preoperative chest CT. (**c**) The wound after radical resection of the tumor. (**d**) The wound was repaired with breast tissue flap

The upper abdominal median or paramedian incision is made. After the abdominal cavity is opened, the stomach and greater omentum are taken out of the abdominal cavity and are flattened, and the left gastroepiploic artery or right gastroepiploic artery is selected as the pedicle (Fig. 16.16). According to the repair status in the donor site, the greater omentum is repaired and trimmed reasonably, and the bleeding point should be carefully ligated to prevent hematoma formation within the greater omentum. When being transferred to the receptor site, the subcutaneous tunnel should be wide and large, and it should be avoided to make the greater omentum flap pass through a long distance within the abdominal cavity, in order to prevent the occurrence of the internal hernia and intestinal adhesion. After being transferred to the receptor site, the periphery sides are fixed with several stitches, the greater omentum is flattened, and the skin is transplanted onto the greater omentum. The bandaging pressure should not be too large after surgery.

2. Case XII The patient, female, 68 years old, had axillary scar contracture and radiation-induced ulceration after breast cancer surgery, accompanied with exposed and necrotic ribs; after the ulcer was debrided, it is repaired with the latissimus dorsi myocutaneous flap and the greater omentum flap (Fig. 16.17).

1.4.7 The Inferior Epigastric Vessel Perforator Flap

1. Indications: The inferior epigastric vessel perforator flap is the inferior epigastric vessel perforator flap without rectus abdominis muscle, and is the hypogastric skin flap which takes the inferior epigastric vessels as the vascular pedicle, and takes its major vascular branches around the navel as the nourishing blood vessels. The shape and design of the skin flap is the same as those of the TRAM flap. The inferior epigastric vessels are found out behind rectus abdominis muscle, the rectus abdominis muscle is separated along its running direction, and the inferior epigastric vessels are traced until they penetrate out of anterior sheath of rectus abdominis muscle. To protect the feeding perforator vessels, a little muscle tissue is retained around the blood vessels. After the skin flap is formed, the inferior epigastric vessels are anastomosed with the blood vessels in the chest receptor site under a microscope. The advantages of this skin flap are that it can maximally retain the morphology and function of the rectus abdominis muscle to reduce the damage degree of the abdominal wall to the lowest level and have the effect of body shaping and beautification in female patients and the patients with loose abdominal walls. In addi-

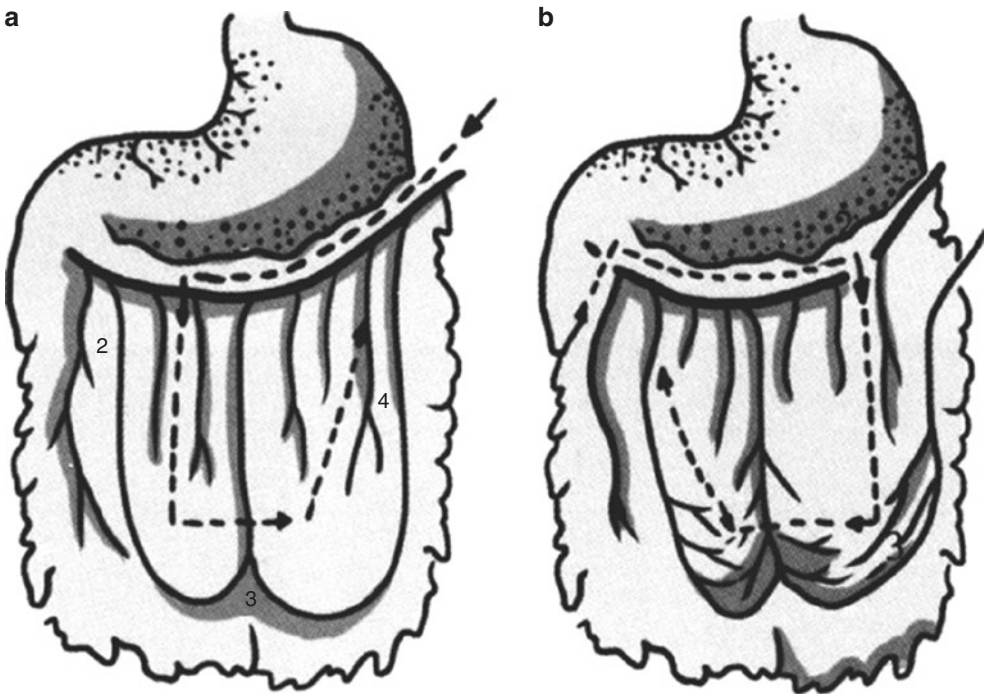


Fig. 16.16 Preparation of greater omentum flap. (**a**) The right gastroepiploic artery is selected as the pedicle. (**b**) The left gastroepiploic artery is selected as the pedicle

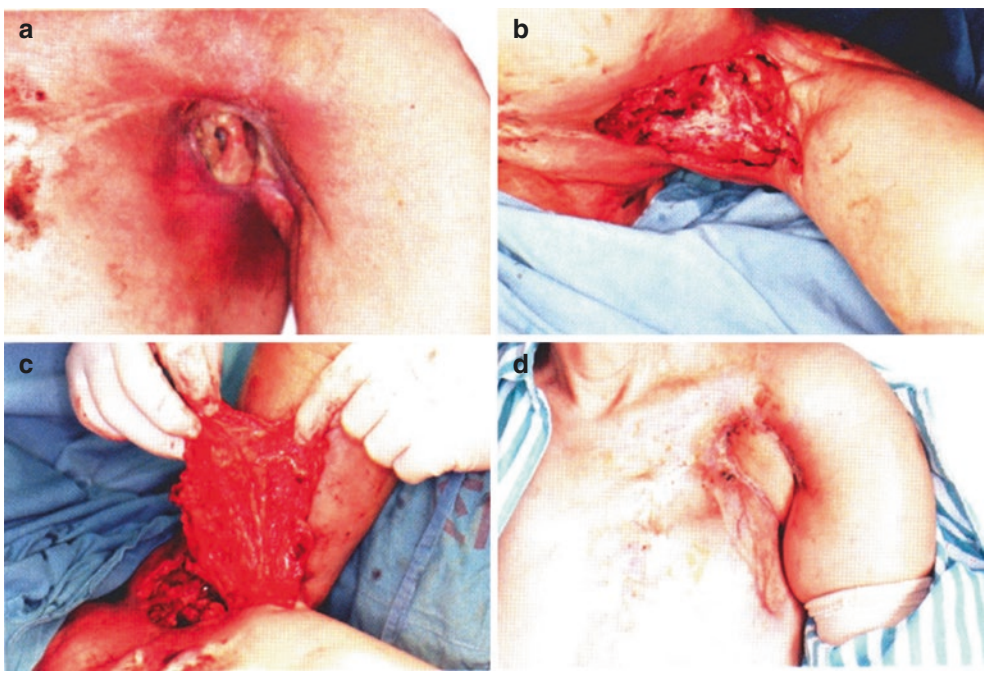


Fig. 16.17 Case XII. (**a**) The axillary scar contracture and radiation-induced ulceration after breast cancer surgery. (**b**) The wound after the ulcer was debrided. (**c**) The transferred greater omentum flap. (**d**) After repair with the latissimus dorsi myocutaneous flap and the omental flap with latissimus dorsi muscle flap and greater omentum flap

tion, due to vascular anastomosis, the position of receptor site is not restricted. The disadvantages are that surgical technique is relatively demanding, the operation time is prolonged, and it is easy to damage the perforator vessel during separation of the blood vessels, especially when the complete rectus abdominis muscle is not carried, and the probability of skin flap failure is increased.

2. Case XIII The patient, female, had immediate breast repair and reconstruction after modified radical mastectomy with the inferior epigastric vessel perforator flap (Fig. 16.18).

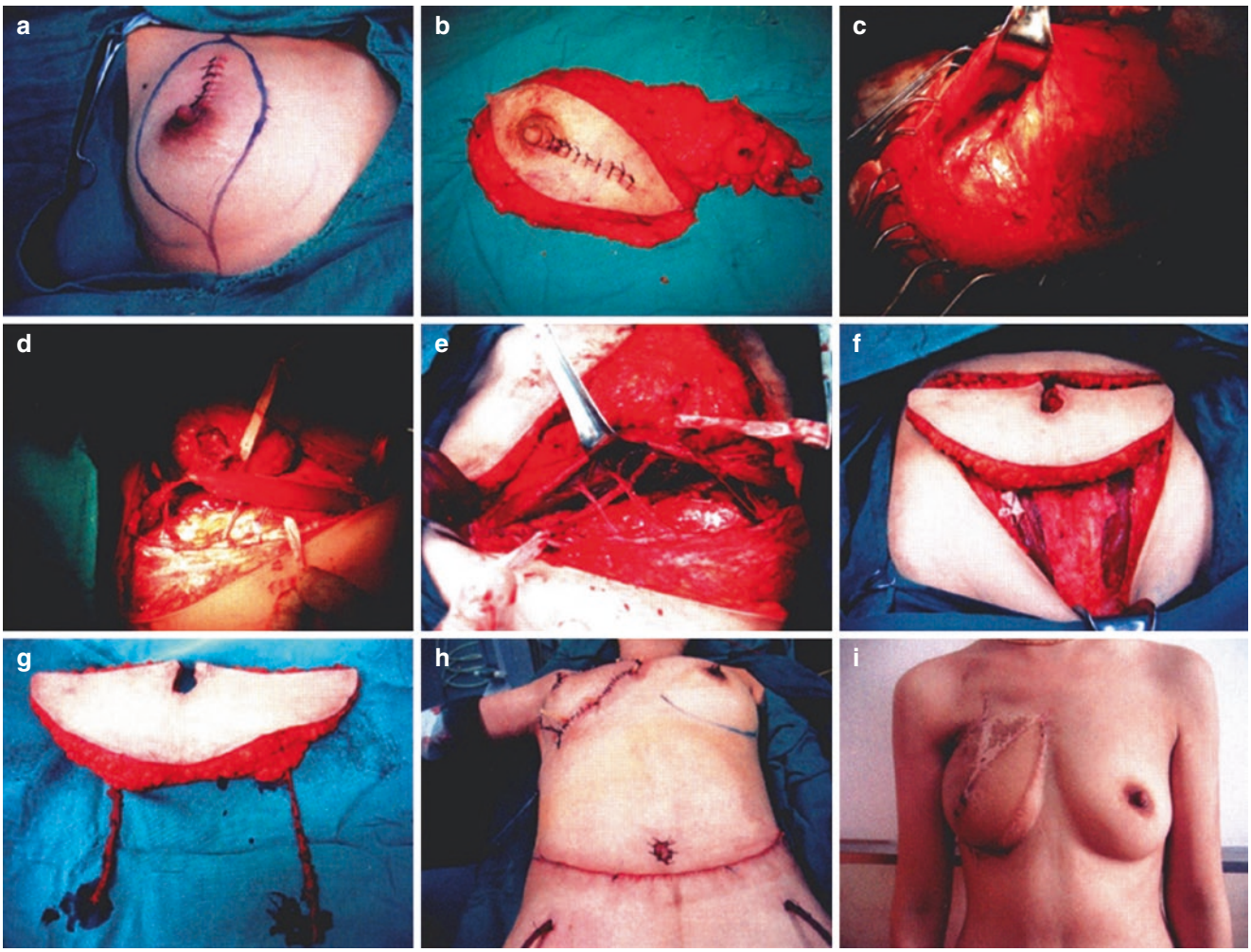


Fig. 16.18 Case XIII. (**a**) The resection range of the breast tumor. (**b**) The breast and axillary lymphatic tissues which were resected en bloc. (**c**) The chest wound after modified radical mastectomy. (**d**) The perforating branches of the inferior epigastric artery and vein at the rectus abdominis muscle were dissected. (**e**) The inferior epigastric artery and vein and the motor nerves were dissected. (**f**) The dissection of the inferior epigastric vessel perforator flap was completed. (**g**) The dissociated inferior epigastric vessel perforator flap. (**h**) Breast reconstruction with inferior epigastric vessel perforator flap. (**i**) Two months after postoperative radiotherapy

2 Repair of the Intrathoracic Defects

Fazhi Qi

The anastomotic fistula after resection of intrathoracic malignant tumors such as esophagus cancer often leads to intrathoracic infection, resulting in pulmonary empyema, which can be ruptured to form a chronic sinus; the diseases such as the stump fistula after lung surgery and the bronchopleural fistula can also lead to intrathoracic infection, delayed healing of the sinus tract, and malnutrition in patients (Fig. 16.19), and even can threaten the lives of the patients.

2.1 The Conventional Treatment of Esophageal Anastomotic Fistula and Intrathoracic Fistula

After the esophageal anastomotic fistula occurs, the opening of the fistula is examined under a gastroscope at first, the foreign bodies such as anastomotic nails are taken out as far as possible, the stent is placed to block the opening of the fistula, the gastric tube is inserted, the diet channel is diverted, and the primary disease is actively treated.

The patients with intrathoracic acute infections, especially the patients with pulmonary empyema, often have poor general conditions, accompanied by fever and leukocy-

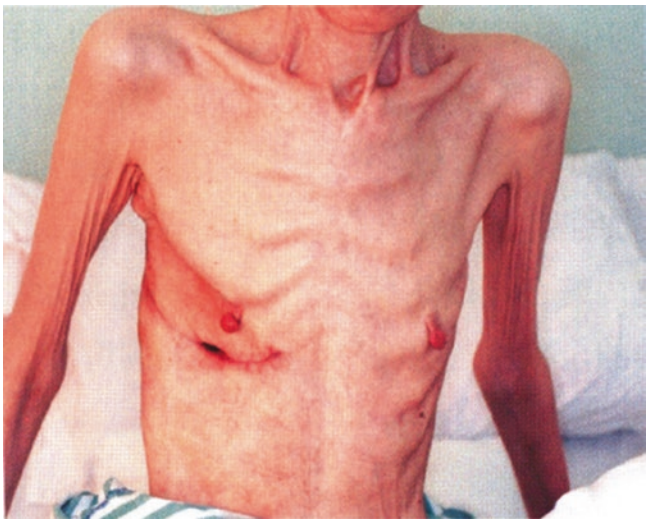


Fig. 16.19 The esophageal anastomotic fistula after surgery caused the sinus tract of the intrathoracic abscess, and the patient mostly had severe malnutrition

tosis. The first step of the treatment is to release the pus, wash the wound with plenty of normal saline, scrape the pus moss with reservation, prevent damage to vital organs, perform open drainage, carry out wound dressing and control the infection, and also carry out continuous lavage with antibiotics saline. After 1–2 weeks, when the intrathoracic granulation tissue is fresh, the white blood cell count decreases to normal and the fever subsides, and the muscle flap is transferred into the thoracic cavity to close the thoracic cavity.

The bronchopleural fistula is more common in lung cancer patients who undergo partial hepatectomy with adjuvant radiotherapy, the contamination of thoracic cavity after rupture of bronchial stump leads to the secondary infection, and thus the pulmonary empyema or chronic sinus tract is formed. For patients with the pulmonary empyema, the open drainage should be carried out, and the acute infection should be controlled. The treatment requires debridement at first, the chest expander is placed through intercostal incision, and once the thoracic cavity is entered to release the pus, gently scrape the pus moss and prevent damage to vital organs; while the thoracic cavity is washed with hydrogen dioxide solution or a lot of normal saline, the opening of the bronchopleural fistula is found out, the surrounding necrotic tissue is removed, and the opening of the fistula is closed; the opening of the fistula can be blocked with tissue flap or artificial dermis and collagen plugs. Then the healthy muscle flap is transferred into the thoracic cavity to cover the surface of the closed fistula opening.

Similarly, the stump fistula after partial lung resection also needs to be found, and the stump fistula is closed and is then covered with the muscle flap to strengthen the closure of the fistula opening. The commonly used muscle flap for closure of the fistula opening is the serratus anterior muscle flap.

After the internal fistula opening of the esophageal anastomotic fistula is found, the fistula opening is gently scraped to form a fresh wound. The muscle tissue flap is transferred and deepithelialized to clog the fistula opening and is fixed with several stitches using absorbable suture line if necessary, and the foreign bodies such as thread residues should be minimized. The myolemma or other fascial tissues are good materials to close the internal fistula opening, which facilitate the mucosa around the fistula opening to climb into the opening, and compared to fat or muscle tissue, it is difficult to form the protruded granulation tissue, which hinders the mucosal growth or the formation of pseudomembrane.

After the fistula opening is covered by the muscle flap, the method for closing the dead space is selected according to the size of the lacuna in the chest.

2.2 Treatment of Special Circumstances

The pulmonary empyema lasting for a long time can compress the lung tissue and form a huge dead space; when the tissue volume of a simple muscle flap tissue is not enough, and cannot completely fill the dead space, the following methods can be selected:

1. Two or more muscle tissue flaps are combinedly used for reconstruction, such as the rectus abdominis muscle flap and latissimus dorsi muscle flap, and the muscle flaps are used to completely fill the dead space.
2. The muscle tissue flap combined with cavernostomy is used, two to three ribs above and below the lesion are removed, and after the dead space is reduced, the intrathoracic filling of the muscle tissue flap is performed. The dead space caused by the pulmonary empyema is often located in the lower chest; the muscle tissue flaps commonly used for intrathoracic filling include the latissimus dorsi muscular flap, reverse latissimus dorsi muscle flap, rectus abdominis muscle flap, and greater psoas muscle flap.
3. After the muscle tissue flap is used to block the fistula opening with the Clagett method, the skin incision is sutured and two stitches are left. After the chest cavity is fully filled with antibiotic saline, the suture line of the skin is knotted to close the incision. While the intrathoracic normal saline is absorbed, the granulation tissue grows and closes the dead space.

The application of Clagett method has a history of nearly 50 years, the success rate of one operation is 75–80%, and the operation is repeated if necessary. The method is that after the intrathoracic fistula is repaired and strengthened with muscle flap, the dissection above and under the skin incision is performed to easily suture the incision without tension, and the dermis and skin are sutured from both front and rear ends. Two layers of the skin are sutured, and the intradermal suture can achieve the purpose of watertightness. Several stitches of the dermis at the middle of the incision are left and are not knotted temporarily, all intrathoracic air is discharged out, the chest cavity is fully filled with antibiotic saline, the intradermal suture line is knotted, and then the skin is sutured.

2.3 Typical Case

1. Case XIV The patient, male, 52 years old, had esophagogastrostomy fistula with thoracic dorsal huge fistula, and the local muscle flap was used for reconstruction (Fig. 16.20).
2. Case XV The patient, female, 57 years old, had esophageal fistula and the sinus tract of the intrathoracic abscess after esophagus cancer surgery. After two ribs such as the upper and lower ribs were removed to carry out the partial thoracoplasty, the latissimus dorsi myocutaneous flap was deepithelialized to fill the intrathoracic dead space (Fig. 16.21).

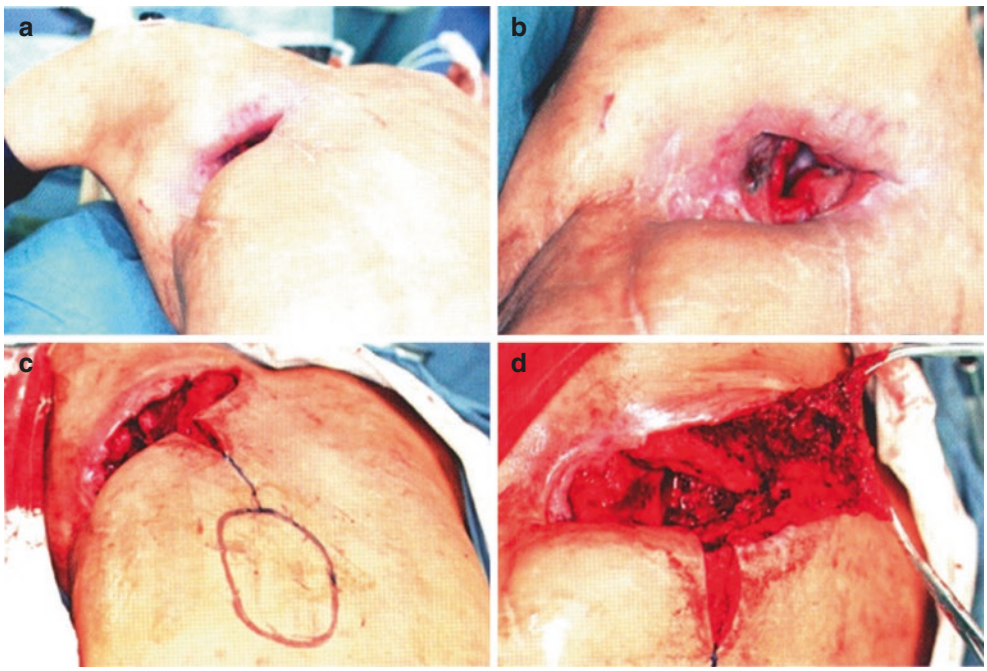


Fig. 16.20 Case XIV. (**a**) The esophagogastrostomy fistula with thoracic dorsal huge fistula. (**b**) Gastroesophageal anastomotic fistula. (**c**) The local muscle flap was designed. (**d**) The local muscle flap was transferred for filling repair

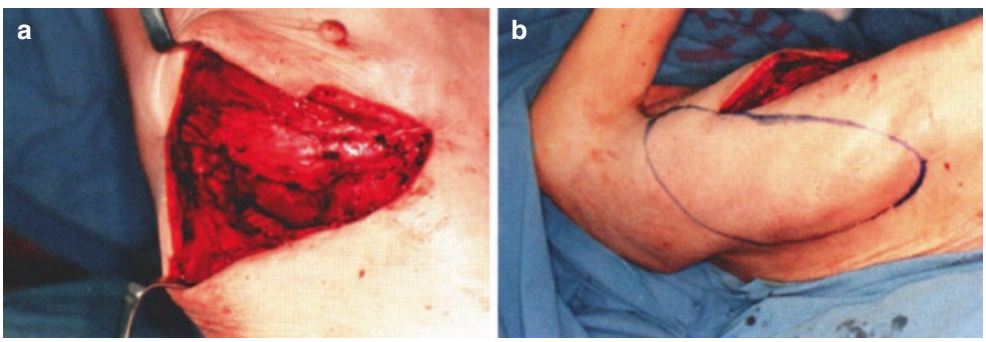


Fig. 16.21 Case XV. (**a**) The esophageal fistula after esophagus cancer surgery and the sinus tract of the intrathoracic abscess. (**b**) It was designed that two ribs such as the upper and lower ribs were removed to carry out the partial thoracoplasty, in combination with the fact that the latissimus dorsi myocutaneous flap was deepithelialized to fill the intrathoracic dead space

3 Repair and Reconstruction of Combined Thoracic and Abdominal Wall Defect

Fazhi Qi, Gaoming Xiao, and Yuejun Chen

3.1 Overview

The joint thoracoabdominal wall defects occur mainly due to the tumors in the region 7 and 8 of the chest wall or the chest wall invasion of upper abdominal wall tumor, the tumors in this place easily involve the diaphragm and abdominal wall, and the tumor resection not only causes the partial chest wall defect but can also cause partial defect in abdominal wall and diaphragm. Therefore, when such repair and reconstruction are performed, we often use the Prolene mesh to close the thoracic cavity and make the thoracic cavity in costophrenic sinus abdominal cavity intraperitoneal chemotherapy (but not exceed diaphragmatic dome), so as to prevent paradoxical breathing, and then Prolene mesh was used to close the abdominal cavity. In most cases, the muscles in this place (serratus anterior muscle, internal oblique muscle, and external oblique muscle) have been resected, and it is needed to use the autologous tissues such as latissimus dorsi muscular flap or greater omentum to cover between the skin and the artificial material to prevent the foreign body exposure after skin flap necrosis.

3.2 Typical Case

1. Case XVI The patient, male, 45 years old, had right chest hypochondrium costochondrosarcoma, and five ribs and part of the diaphragm and abdominal wall were resected. The joint right thoracoabdominal wall defects were repaired with Prolene mesh + latissimus dorsi muscular flap and had good recovery (Fig. 16.22).
2. Case XVII The patient, male, 32 years old, had a huge fibrosarcoma in the left chest and upper abdominal wall with pleural effusion, the tumor had invaded the ribs and compressed the kidney and spleen, the tumor and a part of the thoracoabdominal wall and diaphragm were removed, and the defects were repaired with Prolene mesh (Fig. 16.23).

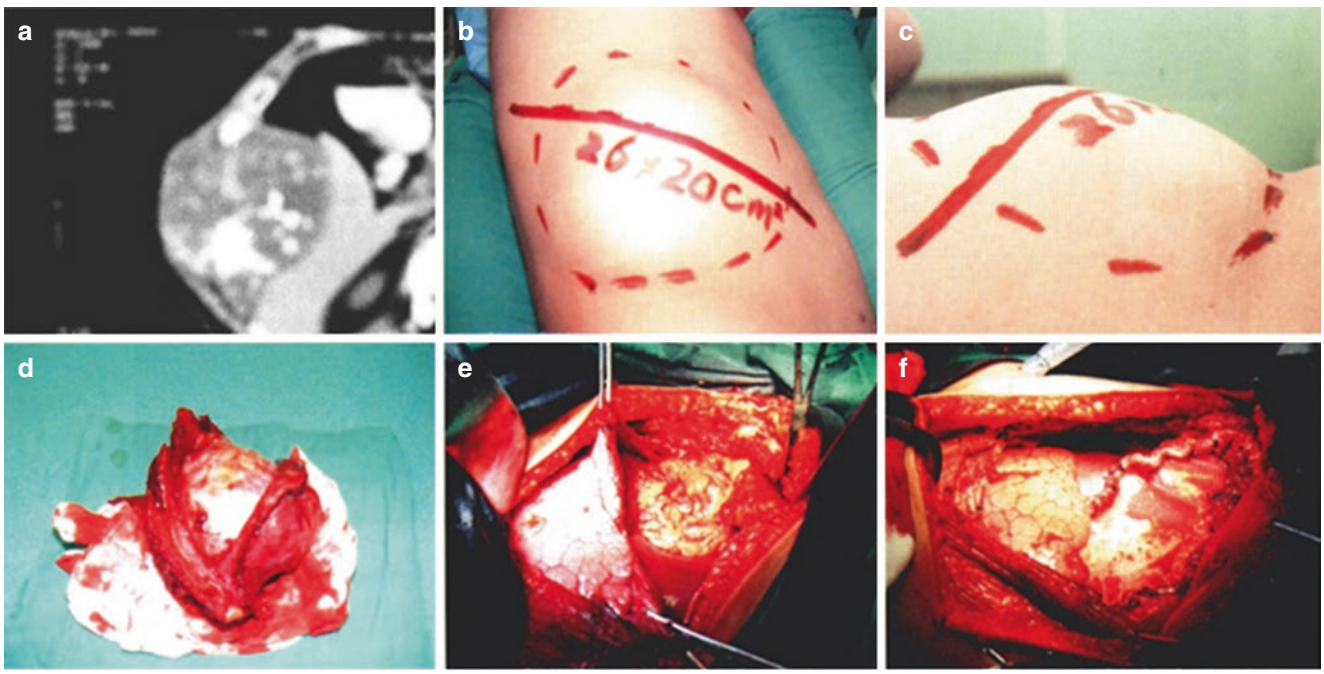
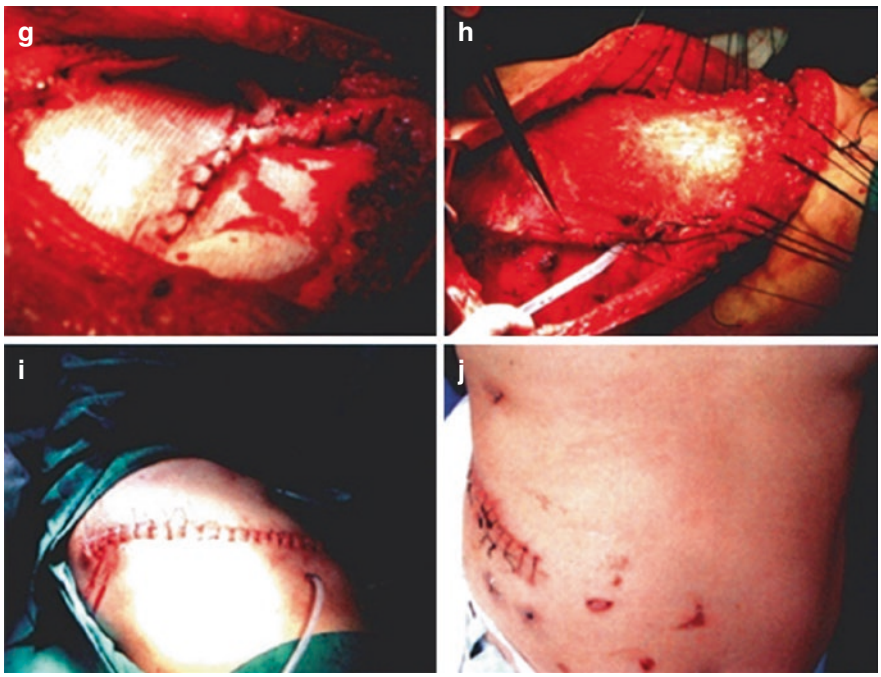


Fig. 16.22 Case XVI. (**a**) The preoperative chest CT indicated that the chest wall tumor compressed the liver. (**b**, **c**) The chest wall mass was marked. (**d**) The resected mass included five ribs, a part of the diaphragm, and the abdominal wall. (**e**) The defect after chest wall tumor resection. (**f**) Prolene mesh was used to repair the abdominal wall and diaphragm. (**g**) Prolene mesh was used to repair the chest wall defect. (**h**) The latissimus dorsi muscular flap was used to cover the artificial materials. (**i**) The chest appearance after surgery. (**j**) The appearance of the abdominal wall on the 10th day after surgery

Fig. 16.22 (continued)



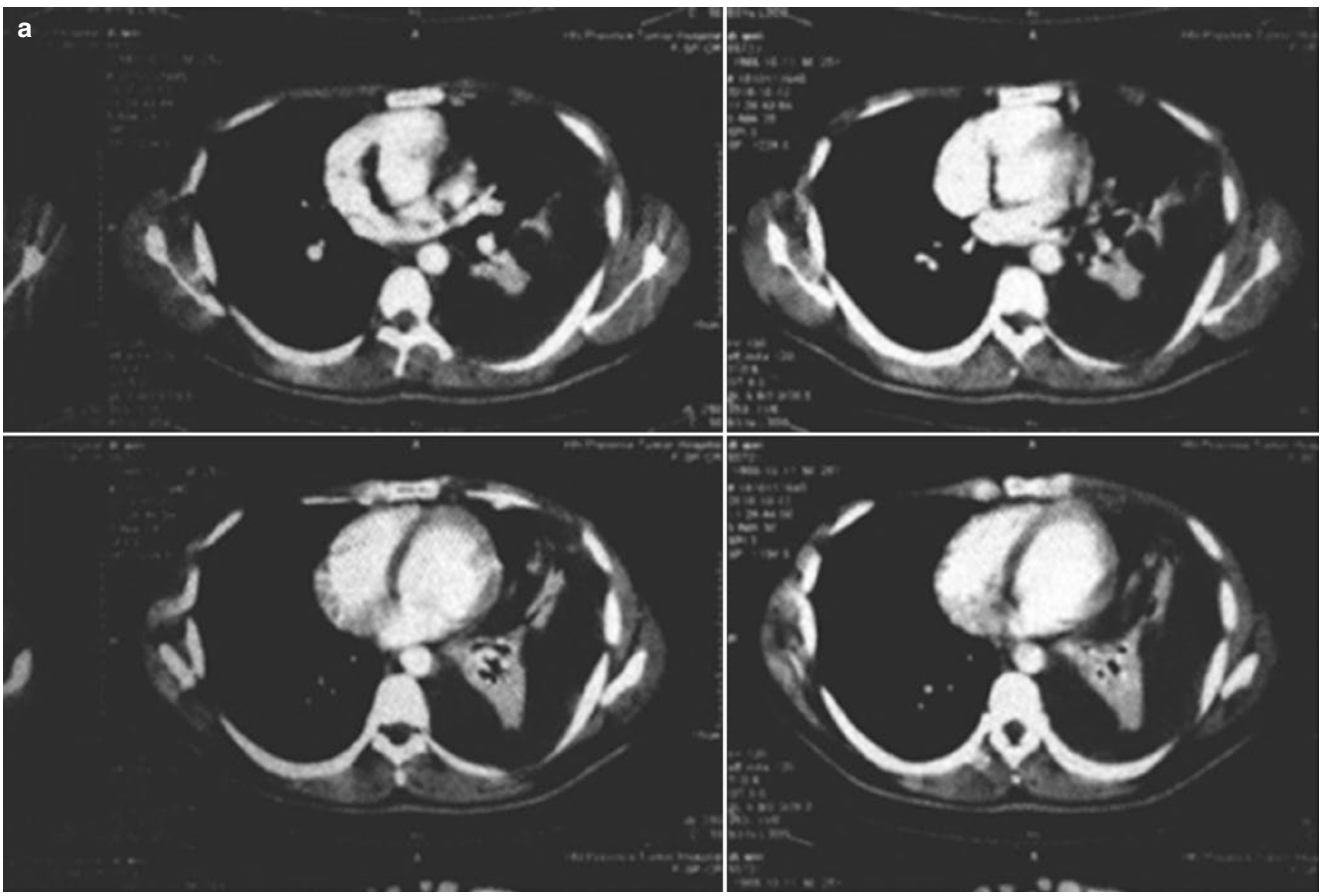


Fig. 16.23 Case XVII. (**a**) Chest CT image. (**b**, **c**) Abdominal CT image. (**d**) Sagittal abdominal CT image. (**e**) The body surface projection of the palpated mass. (**f**) The mass was dissociated during surgery. (**g**)The tumor and a part of the thoracoabdominal wall and diaphragm were removed. (**h**, **i**) The resected mass included five ribs, a part of the diaphragm, and abdominal wall. (**j**, **k**) Partial defect in thoracoabdominal wall and diaphragm. (**l**) The greater omentum was dissociated. (**m**) The thoracic cavity was closed with Prolene mesh. (**n**) The Prolene mesh was covered with the greater omentum. (**o**) The Prolene mesh was used to close abdominal cavity. (**p**) The Prolene mesh was covered with another greater omentum. (**q**) Postoperative appearance

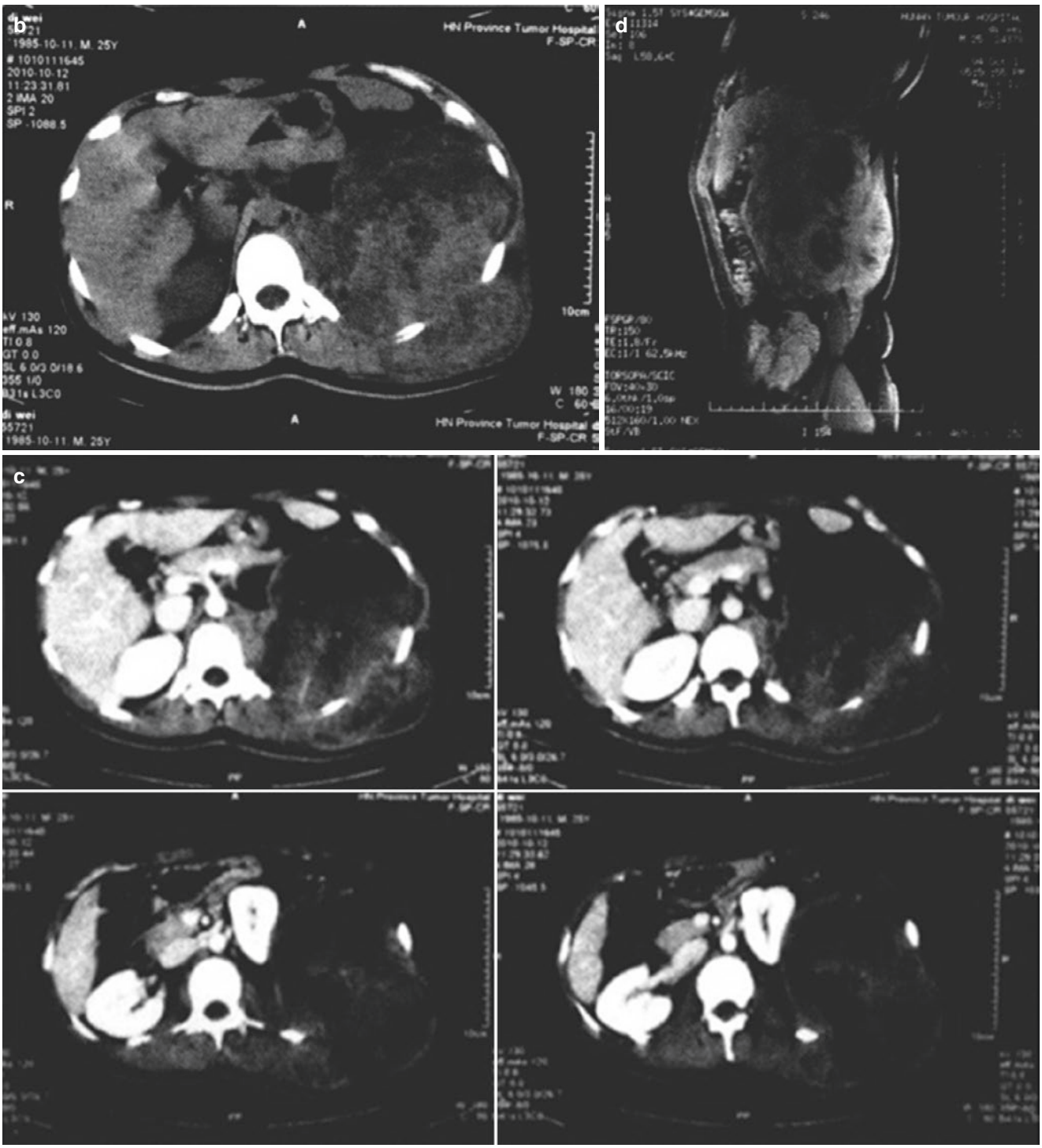


Fig. 16.23 (continued)

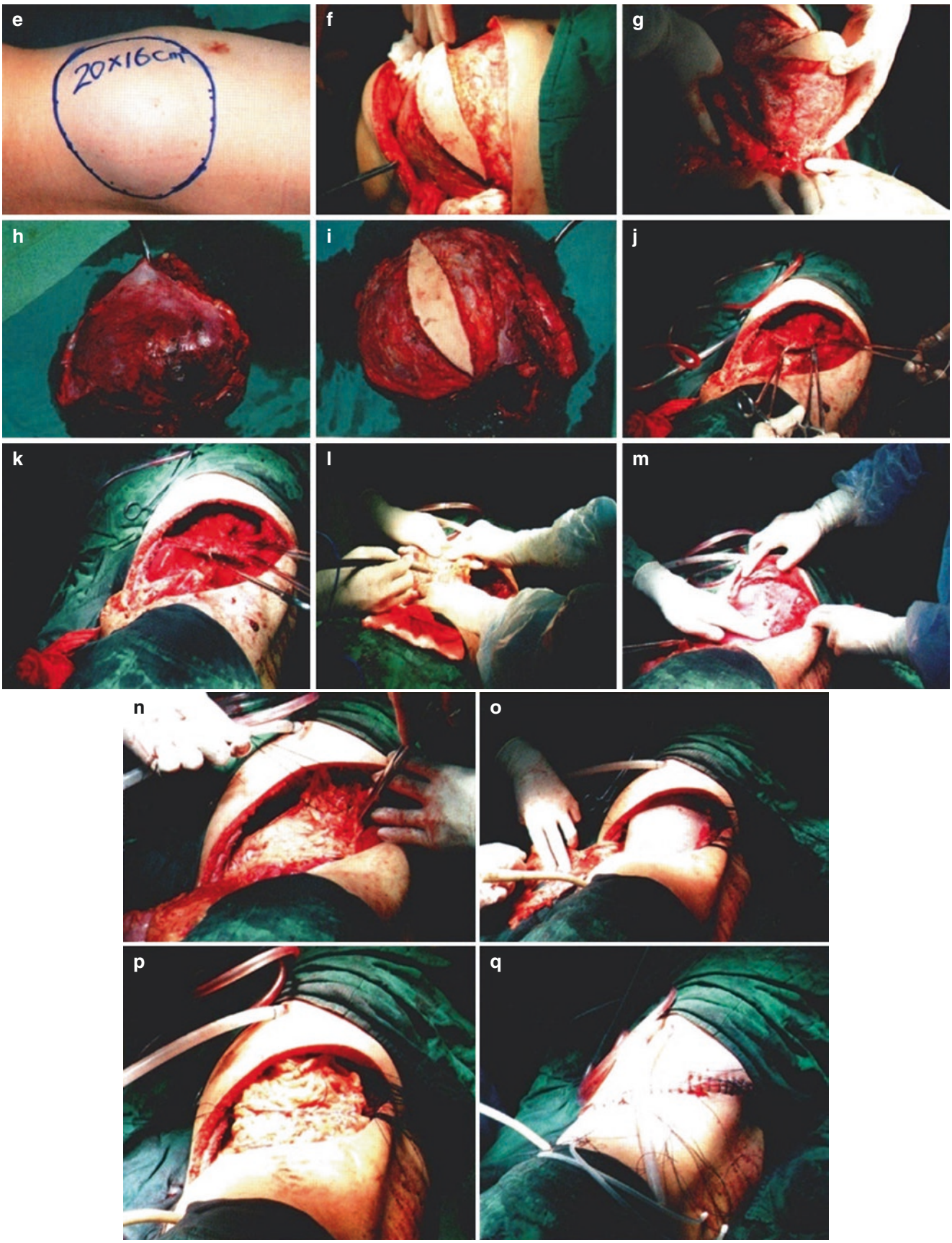


Fig. 16.23 (continued)

4 Repair of Composite Tissue Defects in the Abdominal Wall

Yunliang Qian, Yixin Zhang, Jun Yang, and Danru Wang

4.1 Overview

The abdominal wall consists of the skin, subcutaneous tissue, fascia, muscles, and aponeurosis, and it is the protective layer of the largest cavity – abdominal cavity. The anatomical integrity of the abdominal wall tissue can not only support and enhance the physiological functions of abdominal visceral organs (such as defecation, urination, and breathing) while also playing an important role in human body movement functions (such as maintaining body posture, walking, bending down, and other activities). When various reasons such as trauma, infection, and surgery cause the defects in the abdominal wall tissue, the abovementioned various functional activities will be damaged. The abdominal wall defects can be divided into three types according to their tissue components [1–3]:

1. Pure skin and subcutaneous tissue defects: For this type of defects, if the defect area is small, it can be directly closed and sutured by layers; if the defect area is large, it can be repaired by means of local skin flap transposition or skin flap transplantation.
2. Muscle and aponeurosis tissue defects with intact skin and subcutaneous tissue: The incision hernia is a typical example of this type of defects. This type of defects needs to be repaired with transplantation of autologous fascia or biological patch.
3. Full-thickness abdominal skin, subcutaneous tissue, muscle and aponeurosis defects, and exposure of abdominal cavity: This is clinically the most serious defect in the abdominal wall and is called as composite abdominal wall defect. The gunshot wound and the extensive resection of abdominal malignant tumor are the main causes of this defect. The treatment of such defect often requires the cooperation between surgeons in general surgery and plastic surgery. The ultimate goal of the plastic surgeon treating the composite abdominal wall defect is to recover and reconstruct the structural continuity and functional integrity of musculo-aponeurotic system in the abdominal wall, and the skin defect wound is repaired stably and permanently.

This section will focus on the repair of the composite soft tissue defect after extensive resection of abdominal wall tumor.

4.2 The Surgical Anatomy of the Abdominal Wall

4.2.1 Morphology and Structure of the Abdominal Wall

The upper boundary of the abdominal wall is the xiphoid process of sternum and the costal arch; the lower boundary is the iliac crest, the inguinal ligament, and the pubic symphysis; and the shape of hexagonal diamond is formed. The appearance of the abdominal wall may vary depending on the size, age, gender, the development of muscle, and the volume of fat. On the abdominal wall surface of the normal human body, the bone landmarks such as the xiphoid process, rib arch, and iliac crest can be palpated. The navel is located at the medioventral line which is equivalent to the position between the second and third lumbar vertebras or the horizontal position of the anterior superior iliac spine. When the abdominal muscles contract, it is possible to observe the bulge of the rectus abdominis muscles and the tendinous intersection. The outer margin of the rectus abdominis muscle is the semilunar line, which is jointly formed by the external oblique muscle, internal oblique muscle, and the aponeurosis of transverse abdominal muscle. Above the semilunar line, the external oblique muscle and the aponeurosis of internal oblique muscle form the anterior sheath of the rectus abdominis muscle, and the internal oblique muscle and the aponeurosis of the transverse abdominal muscle form the posterior sheath of the rectus abdominis muscle; under the semilunar line, the abovementioned three muscle aponeuroses commonly form the anterior sheath of the rectus abdominis muscle.

4.2.2 Anatomy of the Abdominal Wall Soft Tissue

The abdominal wall soft tissue consists of the skin, subcutaneous tissue, muscle, aponeurosis, and peritoneum and is divided into six layers of skin, superficial fascia, muscle aponeurosis layer, the transverse fascia, extraperitoneal fat, and parietal peritoneum.

1. Skin: The abdominal wall skin is thinner with greater flexibility and is loosely attached to the subcutaneous tissue, but it is densely adhered to the abdominal white line of the subcutaneous tissue at the medioventral line and the navel ring. The mobility of the abdominal wall skin is large, and therefore, it can adapt to the increased intra-abdominal pressure and is presented as overexpansion. Therefore, when there is a large defect in the abdominal skin, it can also be closed and sutured directly.
2. Superficial fascia: There are two layers. The superficial layer, namely, the Camper fascia, is the fat layer, and the thickness varies with the size of individual body. The deep

layer is also called the fascia layer (Scarpa fascia), is a layer of elastic fibrous tissue, and is attached to the abdominal white line in the midline, and bilateral sides travel downward to cross the inguinal ligament and end at the fascia lata.

3. Musculoaponeurotic muscle layer: Five pairs of muscles are divided into two groups, namely, bilateral flat muscles and the central vertical muscle. The flat muscles include external oblique muscle, internal oblique muscle, and transverse abdominal muscle. The external oblique muscle starts from the muscle fibers of the lower eight ribs obliquely from the external upper side to the internal lower side, internal oblique, and transverse abdominal muscles, some attach to the iliac crest, and most are transmigrated into aponeuroses. The internal oblique muscle starts from the iliac crest and the outer two thirds of the inguinal ligament, the upper muscle fibers attach to the lower three ribs, the remaining muscle fibers are transmigrated into the flattened tendon, and the muscle fibers travel obliquely from the external lower side to the internal upper side. The transverse abdominal muscle starts from the lower six costal cartilages, the deep lobe of the lumbodorsal fascia, iliac crest, and the outer half or outer one third of the inguinal ligament, and the muscle fibers travel horizontally into flattened tendon. Three layers of muscle are arranged crossly, and they jointly participate in the anterior and posterior sheaths of the rectus abdominis muscle at the lateral margin of the rectus abdominis muscle. This anatomical relationship between the muscles and tendons can effectively enhance the muscle strength of the abdominal wall.

The rectus abdominis muscles are perpendicular to both sides of the abdominal midline, and it starts from the pubic bone and ends at the fifth to seventh ribs and xiphoid process. The medial margin of the muscle is the abdominal white line, and the lateral margin of the muscle is the semilunar line. The posterior sheath terminates at the middle point between the navel and the pubic symphysis to form an arcuate free margin – the semicircular line. The anterior sheath above the semicircular line consists of the anterior layers of aponeuroses of the external oblique muscle and the internal oblique muscle, and the posterior sheath consists of the posterior layer of the internal oblique muscle and the aponeurosis of the transverse abdominal muscle. The aponeuroses of three flattened muscles under the semicircular line form the anterior sheath, and the posterior sheath consists of the thickened transverse fascia. The pyramidalis muscle starts from the pubic symphysis and attaches to the abdominal white line and the medial margin of the rectus abdominis muscle.

4. Transverse fascia: The transverse fascia is a layer of transverse fiber membrane lining between the deep surface of transverse abdominal muscle and the abdominal cavity. The transverse fascia in upper abdomen is weaker, and it becomes denser when getting close to the inguinal ligament and the lateral margin of the rectus abdominis muscle. The fascia is connected upward to the diaphragm muscle of the diaphragmatic fascia, backward to iliolumbar fascia, and downward to the inner margin of the iliac crest and the outer half of the inguinal ligament.
5. Extraperitoneal fat: The extraperitoneal fat is the fat tissue which is filled in the space between the transverse fascia and the abdominal wall layer and is connected with the loose tissue in the retroperitoneal space.
6. Parietal peritoneum: The parietal peritoneum is the innermost layer of the abdominal wall, and it directly contacts with the intra-abdominal organs.

4.2.3 The Blood Supply and Nerves of the Abdominal Wall

1. Blood supply: The epigastric artery is divided into the deep and superficial arterial systems; the superficial arterial system is located between two layers of superficial and deep fascias, mainly including the superficial epigastric artery and the superficial iliac circumflex artery; the former travels toward the navel and the latter travels toward the iliac crest; the deep arteries are located in the rectus abdominis muscle and its posterior sheath; they mainly come from the superior and inferior epigastric arteries and the deep circumflex iliac artery; the superior epigastric artery originates from the internal mammary artery. The superior and inferior epigastric arteries are anastomosed with each other in the posterior sheath of the rectus abdominis muscle. In addition, the abdominal wall also receives its blood supply from the lower six intercostal arteries and four lumbar arteries; these branch vessels are mainly located between the internal oblique muscle and transverse abdominal muscle and widely anastomosed within the abdominal wall form a rich vascular network.
2. Nerve: The innervation of the abdominal wall mainly comes from the intercostal and subcostal nerves, the iliohypogastric nerve, and the ilioinguinal nerve between the 12th thoracic vertebrae to the 4th lumbar vertebrae. The anterior branches of the intercostal nerves run between the internal oblique nerve and the transverse abdominal muscle, pass through the posterior sheath and run between the muscle and the posterior sheath, pass through the anterior sheath again, and terminate in the skin. The lateral branches of the intercostal nerves are distributed in the flat muscles and skin in the lateral side of the abdominal wall. The iliohypogastric and ilioinguinal nerves originate from brachial plexus and are located between the transverse abdominal muscle and the internal oblique muscle, and its terminal branches control the cutaneous sensation on the pubic bone, the root of penis, and the perineum.

4.3 The Repairing Principles and Methods Restoration for Complex Abdominal Wall Defects

4.3.1 Preoperative Evaluation

1. General condition: The history collection, physical examination, and laboratory examination are performed before surgery to comprehensively understand the general health condition of the patient, including previous medical history and surgical history which are related to the existing disease. The diagnosis of the disease is determined, and the laboratory examinations for vital organs such as the heart, lung, liver, and kidney are carried out to exclude and treat any abnormalities and diseases that may affect the surgical outcome. Any issues that might affect and reduce the endurance of the patient to operation and increase the surgical risk must be treated and corrected before surgery.
2. The condition of the diseased region: The defect type, scope, and area in surgical treated area or the abovementioned defects which may be caused by extensive resection of disease tissues should be determined. The health conditions and the anatomical and structural relationships of the tissues and organs surrounding the defect are understood, and the imageological examination is performed when necessary. Whether there is any surgical incision scar or skin ulceration in the diseased region and the adjacent soft tissues is examined, the surrounding soft tissue inflammation and the wound contamination or infection must be controlled before surgery. The cytological examination and drug sensitive test are carried out when necessary.
3. Appropriate tissue provision: When the surgical method for repair of defects with autologous tissue transplantation is determined, selecting the appropriate tissue provision is a critical step to ensure successful operation and exact postoperative effect, generally the donor site with ample tissue provision and thick and solid texture is selected, and the simple and convenient tissue dissociation and dissection and little effects on the postoperative activity function of the donor site are the principles for the first choice of preoperative donor site.
4. Understanding the patch: If it is expected that the patch or biological patch is selectively used for repair of abdominal wall aponeurosis defect, the surgeons must understand the biological characteristics of various patches and the advantages and disadvantages of the clinical applications and the patient's ability to accept the prices of the patches.
5. Surgeon's technological level: The surgeon's technical capability and clinical experience are important factors for the success of surgery. The selection of any surgical method, the reaction which may occur during surgery, the treatment of various complications that may occur after surgery, and the remedial measures for surgical failure are also one of the important contents of the preoperative assessment.

4.3.2 The Advantages and Disadvantages of Various Patch Materials

When the defect area in the abdominal wall aponeurosis tissue system is larger and the autologous tissue transplantation is insufficient to repair the defect, we need to selectively use the allograft patch. Clinically, there are a variety of patch types available for selection, and the commonly used patch types include synthetic patch and biological patch [10–15]. The synthetic patch can be divided into mesh and non-mesh patches, as well as absorbable and nonabsorbable patches. Each patch material has different clinical indication and advantages and disadvantages. It is reported that the non-mesh patch can reduce bacterial penetration and reduce the scar conglutination between the peripheral tissues or internal organs and the patch. The mesh patch allows the growth of tissue fibers into the patch and can enhance the spreading intensity of the patch, but at the same time, it can increase the scar conglutination with the surrounding tissue and is easy to hide the bacteria and cause the wound contamination or infection. The absorbable patches are only used for temporarily covering the wound in clinic, and it cannot permanently repair the aponeurosis defect.

At the present, the commonly used patch materials in clinic include polypropylene and expanded polytetrafluoroethylene (ePTFE), and these patches are not absorbable and can be permanently implanted in the body. Its clinical application has advantages such as easily obtaining material, simple operation and effectively increasing the degree of resistance of the abdominal wall to the tension, and less incidence of hernia. But the disadvantages are that the anti-infection ability is low and the adhesion and friction among surrounding adjacent tissues and organs can cause intestinal ulceration, erosion, and perforation which lead to the defect of the abdominal wall with intestinal fistula (Figs. 16.24 and 16.25) and the rejection or the seroma formation; when there is abdominal activity, there is a foreign body sensation. Therefore, they must be used in cleaning wounds and avoid direct contact with intra-abdominal tissues and organs, while the healthy and thick autologous soft tissue with an area greater than that of the patch material is used to cover the patch and repair the skin wound to reduce and avoid the generation of the abovementioned disadvantages. Considering from the aspects of improving the material properties and reducing complications, currently, a lot of new composite materials have already been used in clinical practice. The new composite material can be made with absorbable and nonabsorbable materials, such as Composix and Sepramesh.

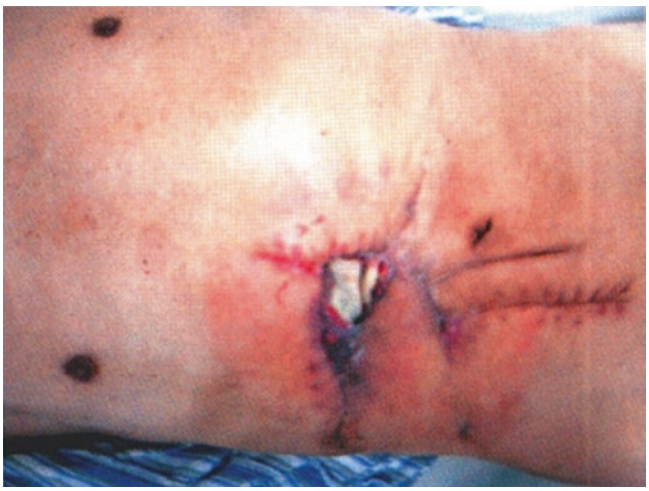


Fig. 16.24 The skin in surgical area was ulcerated, and the patch was exposed to form the defect of the abdominal wall with intestinal fistula

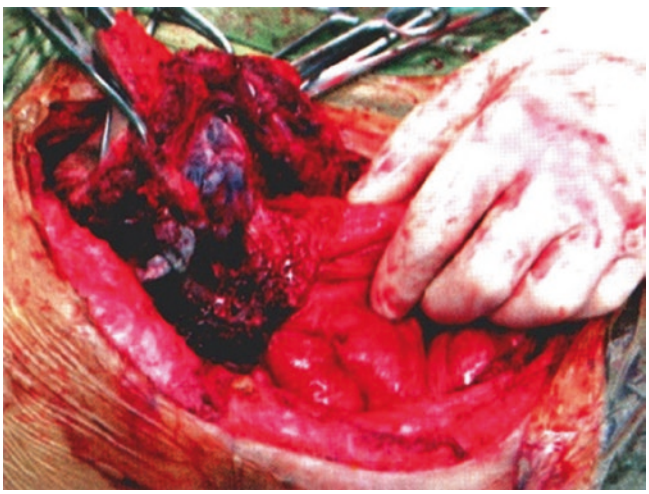


Fig. 16.25 Intestine perforation

It is a hot spot to use the biological patches in repair of the abdominal wall defect in recent years, and they have an anti-tensile strength similar with that of the synthetic patch, but are more flexible, with a strong resistance to infection, and can be applied to the treatment of infected wounds; after implantation in vivo, the vascularization in the patch is rapid, and the tissue remodeling capability is strong and may have the physiological ability to replicate autologous tissue. After being implanted into the abdominal wall, this patch can directly contact with the internal organs and rarely cause adhesion and reduce the complications such as erosion and perforation caused by its friction with the intestinal wall. Currently, the biological patch materials used in clinic mainly include three types such as human acellular dermal matrix (Fig. 16.26), porcine small intestine submucosa (Fig. 16.27), and porcine acellular dermal matrix (Fig. 16.28).

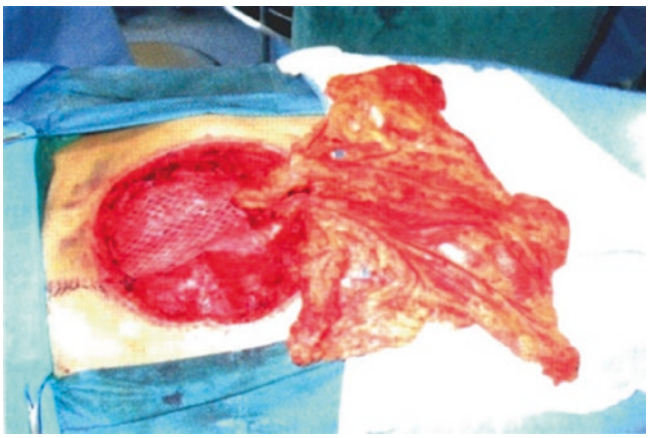


Fig. 16.26 Human acellular dermal matrix

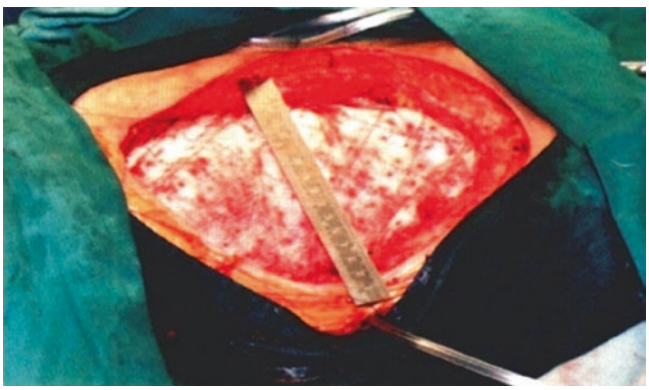


Fig. 16.27 Porcine small intestinal submucosa

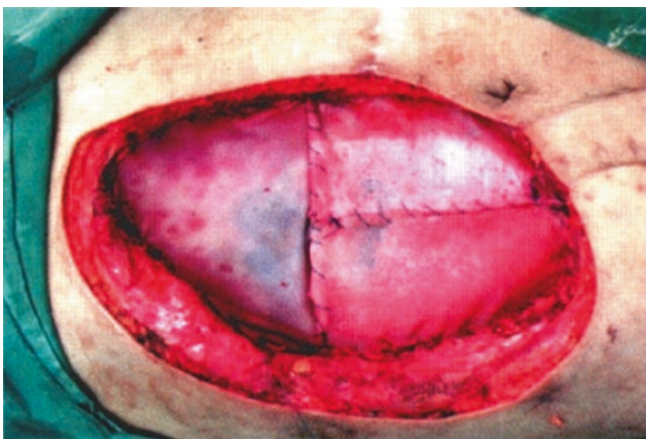


Fig. 16.28 Porcine acellular dermal matrix

4.3.3 Repair Methods

The full-thickness abdominal wall defect must be repaired with transplantation of autologous skin and soft tissue. There are two main methods for autologous tissue transplantation:

1. Skin flap or myocutaneous flap: Various types of technologies for skin flap transplantation are used in repair of the abdominal wall skin and soft tissue, including

local myocutaneous flap transfer and myofascialcutaneous flap with vascular pedicle. Specific skin flaps include local external oblique myocutaneous flap, tensor fascia lata myocutaneous flap with vascular pedicle, or tensor fascia lata myocutaneous flap combined with anterolateral thigh flap. The clinical application of specific skin flap must be determined according to the location, extent, and area of the abdominal wall defect [16–22] .

2. The repair method with sandwich transplantation of greater omentum flap [23, 24]: The sandwich transplantation of greater omentum flap is another effective surgical method different from the skin flap method. This method is to use the rich vascular network and the huge usable area of the greater omentum, the greater omentum is folded into two layers, the patch is implanted between the two layers while the skin graft is transplanted onto the superficial layer of the greater omentum, and the defect in the abdominal wall skin is repaired. This method is mainly suitable for patients with serious condition, poor general condition, and poor tolerance to the surgery which has a large wound and lasts for a long time; or it is used when there is no effective donor site of the skin flap and no blood vessels suitable for anastomosis. The method can also be taken as a remedial measure in cases with failed skin flap transplantation. We summarized a decade of clinical experiences on repair of the abdominal wall defect after malignant tumor resection and formed a set of effective treatment strategies (Table 16.1). The strategies are to adopt different repair methods mainly based on the site, type, and size of the abdominal wall defect. For the defect types indicated in the table, the simple type means that there is only the skin and soft tissue defect and the muscle and fascia tissues are intact or only have a small area of defect. Clinically the cases don't require repair with patches; the complex type refers to the cases with full-thickness abdominal wall defects.

4.4 Defect Repair After Resection of Abdominal Wall Tumors

4.4.1 Overview

For all the abdominal wall defects after radical resection of malignant tumors and some benign tumors in the abdominal wall, it is required to carry out repair and reconstruction of abdominal wall tissue. Common abdominal malignant tumors include dermatofibrosarcoma protuberans, squamous carcinoma, and abdominal wall metastases of intra-abdominal malignant tumors. The surgical resections of these malignant tumors often include full-thickness abdominal wall tissue and sometimes require simultaneous implementation of removal of intra-abdominal diseased organs and therefore have characteristics such as wide surgical range and serious degree of tissue defect with a big area. In addition, some benign tumors, such as abdominal desmoid tumors, although belonging to benign tumors in histocytology, have high local invasive characteristics, are ill-defined, and often require massive radical surgical resection, but there still exists the possibility of recurrence. Especially for the cases with intraoperative suspicion of incomplete resection or limited resection range, after the repair, it is still necessary to consult oncologists for carrying out adjuvant antitumor therapies such as radiotherapy and chemotherapy.

4.4.2 Typical Case

1. Case XVIII Repair of tissue defects after resection of recurrent abdominal wall fibrosarcoma with local external oblique myocutaneous flap.

   The patient, male, 48 years old, underwent partial tumor resection in a tumor hospital 3 months ago due to skin and soft tissue mass in left hypochondriac region, and the wound was directly sutured. The mass was diagnosed as abdominal wall fibrosarcoma by pathological examination, and the postoperative wound healed at the first stage. At 2 months after surgery, the nodule-like scar hyperplasia appeared at the healed wound site. At that time, the hyperplastic scar

Table 16.1 Repair strategies for defects after abdominal tumor resection

Defect site	Defect type	Defect length	Repair method
Upper abdominal wall	Simple	≤7 cm	Local skin flap or myocutaneous flap
	Simple	≥8 cm	Skin transplantation or free skin flap
	Complex	≤7 cm	Local skin flap or plus biological patch
	Complex	≥8 cm	Microvascular free myocutaneous flap or skin flap plus biological patch
			Patch plus greater omentum plus skin transplantation
Lower abdominal wall	Simple	≤7 cm	Local skin flap or myocutaneous flap
	Simple	≥8 cm	Skin transplantation or thigh skin flap with vascular pedicle
	Complex	≤7 cm	Local myocutaneous flap or skin flap plus patch
	Complex	≥8 cm	Thigh myocutaneous flap with vascular pedicle or skin flap plus patch
			Microvascular free myocutaneous flap or skin flap plus biological patch
Inguinal groove			Thigh skin flap with vascular pedicle or myocutaneous flap

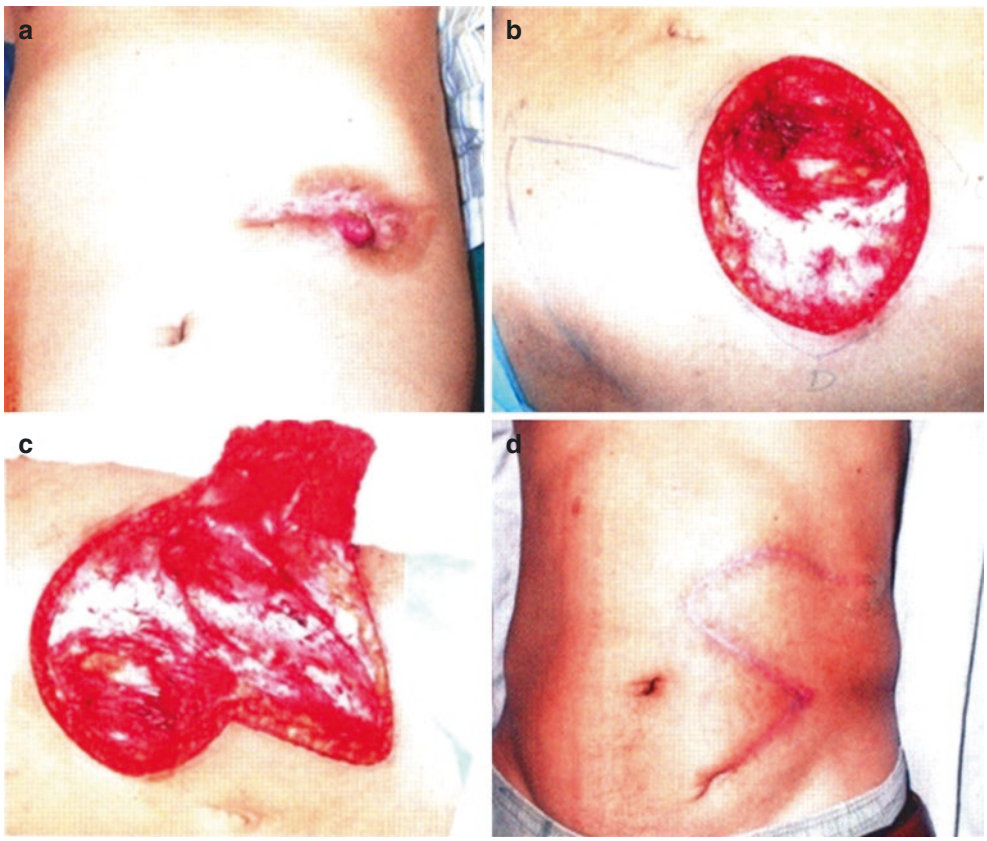


Fig. 16.29 Case XVIII. (**a**) Manifestation of recurrence of abdominal wall fibrosarcoma in left hypochondriac region. (**b**) After extended tumor resection, the full-thickness defect occurred in partial abdominal wall, and after the circular wound was trimmed into the diamond shape, the diamond-shaped external oblique myocutaneous flap was designed. (**c**) The skin flap was dissociated at the deep surface of the sheath of rectus abdominis muscle, and the anterior sheath and external oblique muscle were included. (**d**) One-year follow-up was carried out after surgery, and there were no significant complications

was treated with fluorouracil and triamcinolone injection within the scar in outpatient clinic, but the nodule-like masses continued to grow and have an increased number. At 3 months after surgery, the patient visited the outpatient clinic of our department and was suspected to have fibrosarcoma recurrence. The preoperative examination after admission showed that the patient had good general health and nutrition, and the laboratory examination indicated that various indexes were normal, and therefore, the expanded fibrosarcoma resection was performed under the general anesthesia. The resection range had a distance of 3 cm from the periphery of the original sutured wound and reached deeply to the peritoneum. A 7 × 8 cm abdominal skin and aponeurosis defect was formed after massive tissue resection. The removed tissue was diagnosed as fibrosarcoma recurrence by frozen section examination, and the incisal margins in the periphery and bottom were negative.

After the defect shape was trimmed into the diamond shape, the external oblique myocutaneous flap with the same diameter at its bottom was designed, and the skin flap contains the anterior sheath of the rectus abdominis muscle and the external oblique aponeurosis. After the skin flap was dissected and dissociated, it was transferred to the defect site without tension, and the aponeurosis and skin were sutured by layers. The postoperative wound healed at one stage (Fig. 16.29). One-year follow-up showed no any complications; the patient could take part in the normal physical labor.

2. Case XIX Repair of defects after resection of huge abdominal wall dermatofibrosarcoma protuberans with the greater omentum, biological patches, and free tensor fascia lata myocutaneous flap.

The patient, male, 63 years old, underwent abdominal tumor resection in a hospital in other place 2 years ago and was diagnosed as dermatofibrosarcoma protuberans by the pathological examination. At 6 months after surgery, the tumor recurred in the original resection site and gradually increased, and when the patient visited the hospital outpatient where the authors worked, the tumor volume had increased to 17 × 14 × 15 cm. The preoperative examination showed that the patient lost weight and the spirit seemed fine. Laboratory tests revealed that the serum albumin was lower and other indicators were normal. The regional examination showed that the skin at the surface of the tumor was not ulcerated, the surgical scar was observed at the original transverse incision, the skin clung to the tumor and could not be pushed and moved, and the border was still clear. After the hypoproteinemia was corrected, the expanded tumor resection was performed under general anesthesia; a part of the xiphoid process and costal cartilage was removed, which caused huge full-thickness abdominal wall defect and the cavity under the xiphoid process. Intraoperatively the greater omentum was used to fill in the cavity, and the porcine acellular dermal matrix was implanted between the greater omentums to enhance the tensile strength of the abdominal wall. Then the tensor

fascia lata myocutaneous flap with the same area as that of the defect was designed in the left thigh, which was freely transplanted to cover the skin defect on xiphoid process, and the transverse branch of lateral circumflex femoral vessel in the myocutaneous flap was anastomosed with the internal mammary vessel in the receptor site. The postoperative condition was stable, all skin flaps survived, and the wound healed at the first stage (Fig. 16.30). The patient was followed up for 1 year, and the patient lived a normal life and had no complications and tumor recurrence.

3. Case XX Repair of the defects after extended resection of recurrent fibrosarcoma in the lower abdomen and groin with the propene polymer patch and autologous tensor fascia lata myocutaneous flap with vascular pedicle.

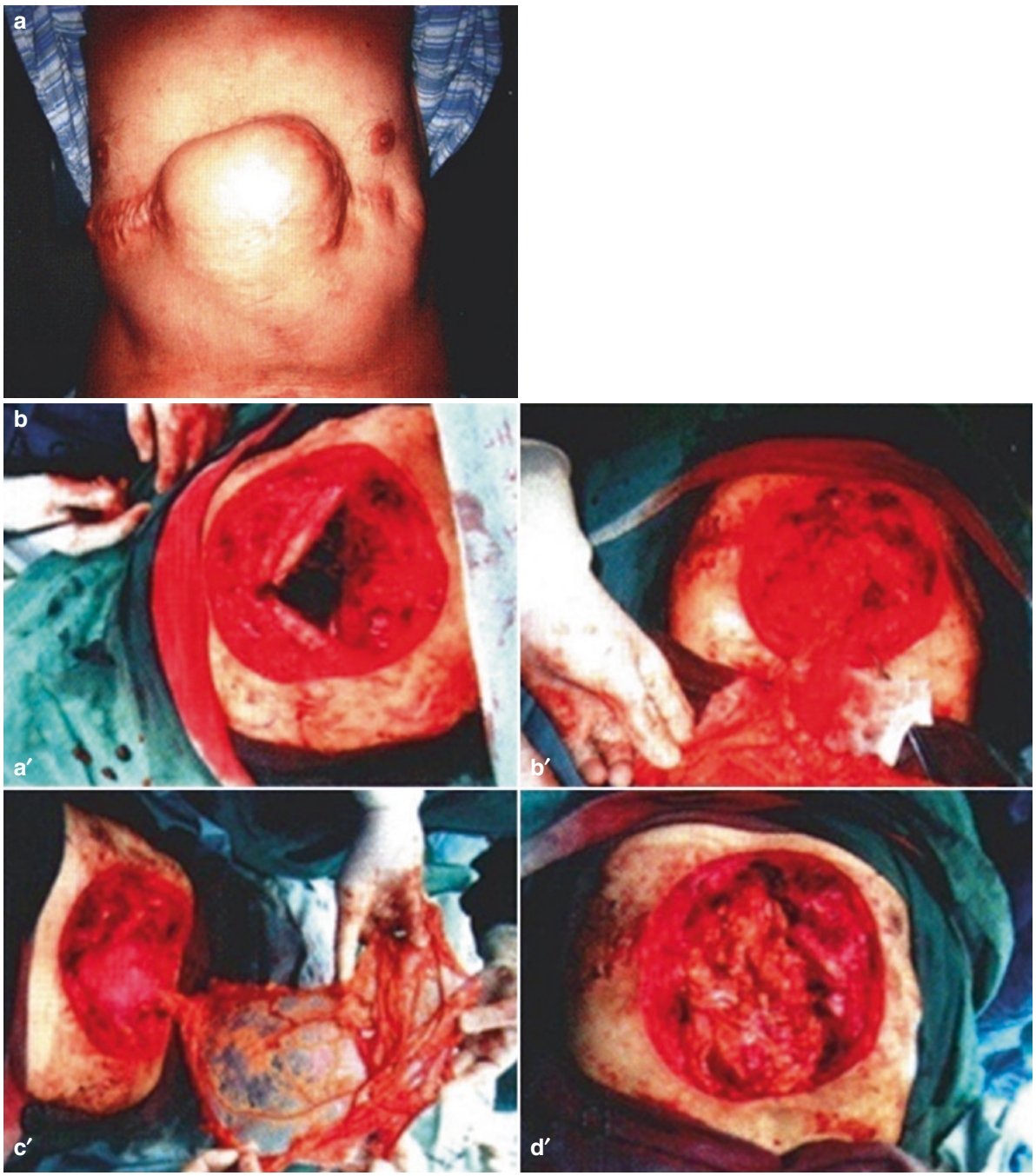


Fig. 16.30 Case XIX. (**a**) The recurrence after resection of dermatofibrosarcoma protuberans, the volume was 17 × 14 × 15 cm. (**b**) *a'*: The full-thickness defect in thoracoabdominal wall after expanded tumor resection and the huge cavity under the xiphoid process. *b'*: The greater omentum flap was filled into the abdomen. *c'*: The porcine acellular dermal matrix was used to repair the abdominal wall aponeurosis. *d'*: The abdominal wall aponeurosis repair was completed. (**c**) The design of tensor fascia lata myocutaneous flap combined with the anterolateral thigh flap. (**d**) When the skin flap was dissociated, the vascular pedicle and fascia lata could be found. (**e**) At 10 days after surgery, all skin flaps survived, and the wound healed at one stage

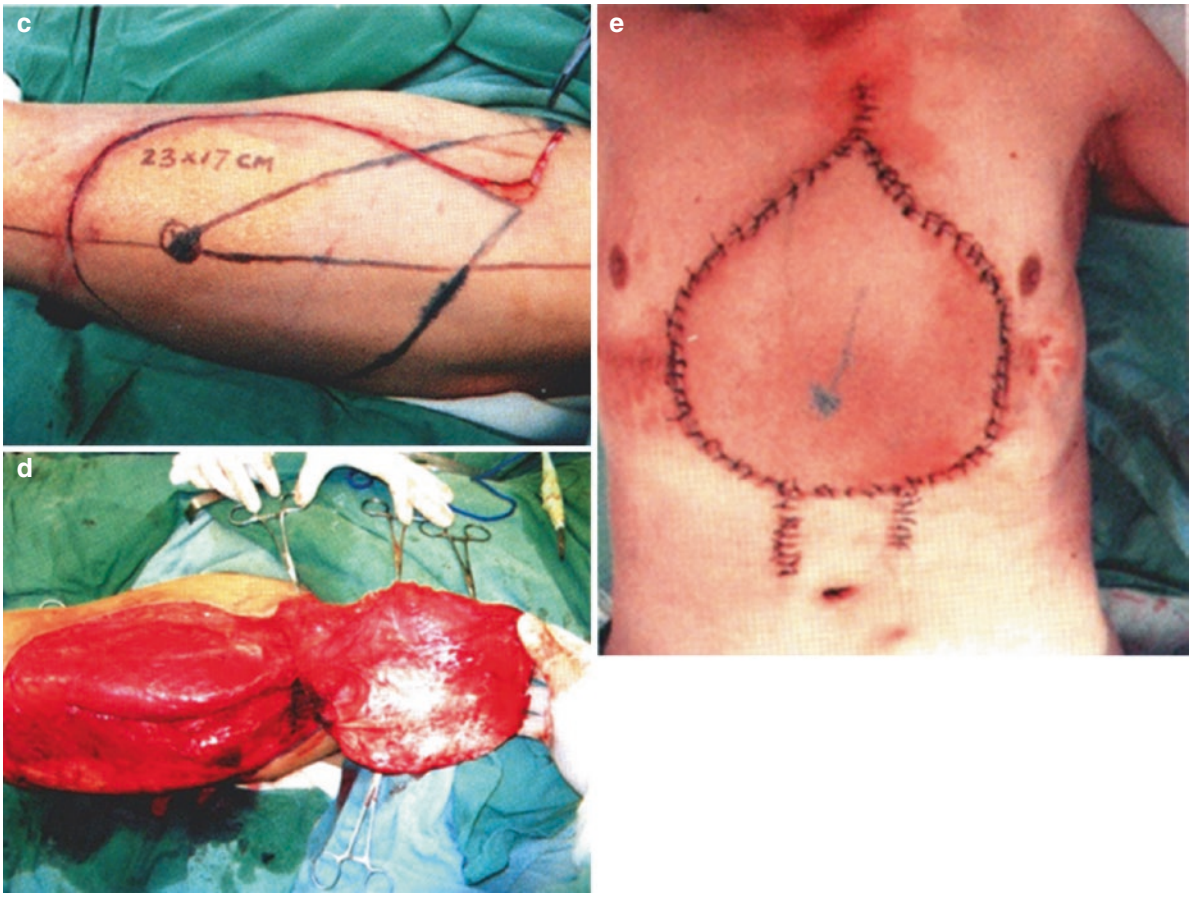


Fig. 16.30 (continued)

The patient, female, 52 years old, underwent multiple partial resections of the fibrosarcoma of the lower abdominal wall 2 years ago; the diseased region was gradually expanded after each resection, finally leading to fibrosarcoma recurrence in areas such as bilateral lower abdominal walls and groins; and the incisional hernia occurred in right lower abdominal wall near to the groin. After the patient was admitted to the hospital, the physical examination and laboratory examination showed no systemic disease, and the health condition was good; therefore, the patient underwent extended resection of tumors in the abdominal wall and groin under general anesthesia. During surgery, the full-thickness tissue in lower abdominal wall was resected, and the lower right inguinal lymph nodes were dissected, which resulted in full-thickness defects in the lower abdominal wall and groin, and the intra-abdominal tissues were exposed. After the greater omentum was used to repair the peritoneum, the propene polymer patch was implanted onto the greater omentum to repair the lower abdominal wall aponeurosis, and then the tensor fascia lata myocutaneous flap with vascular pedicle was designed in the right thigh and was transferred to repair the lower abdominal wall defect. The postoperative condition was stable, and all transferred skin flap survived without complications (Fig. 16.31). The patient was followed up for half a year and had no abdominal hernia and tumor recurrence.

4. Case XXI Repair of the full-thickness defects in the whole upper abdominal wall with the greater omentum, biological patch, and autologous skin graft.

The patient, female, 51 years old, had secondary adenocarcinoma in the abdominal wall. The patient had acceptable general physical condition, and the preoperative imaging examination showed that the ulcer wounds were connected to internal organs. The expanded resection of upper abdominal wall tissue was performed under general anesthesia, and after the adhesive and free diseased tissues were separated, the epigastric abdominal viscera were exposed. The blood vessels surrounding the defect were explored, and it was observed that there was no blood vessel in receptor site available for anastomosis. Taking into account the fact that the abdominal full-thickness defects involved the whole upper abdominal wall, the area was huge, and therefore, it was decided to carry out sandwich transplantation of the greater

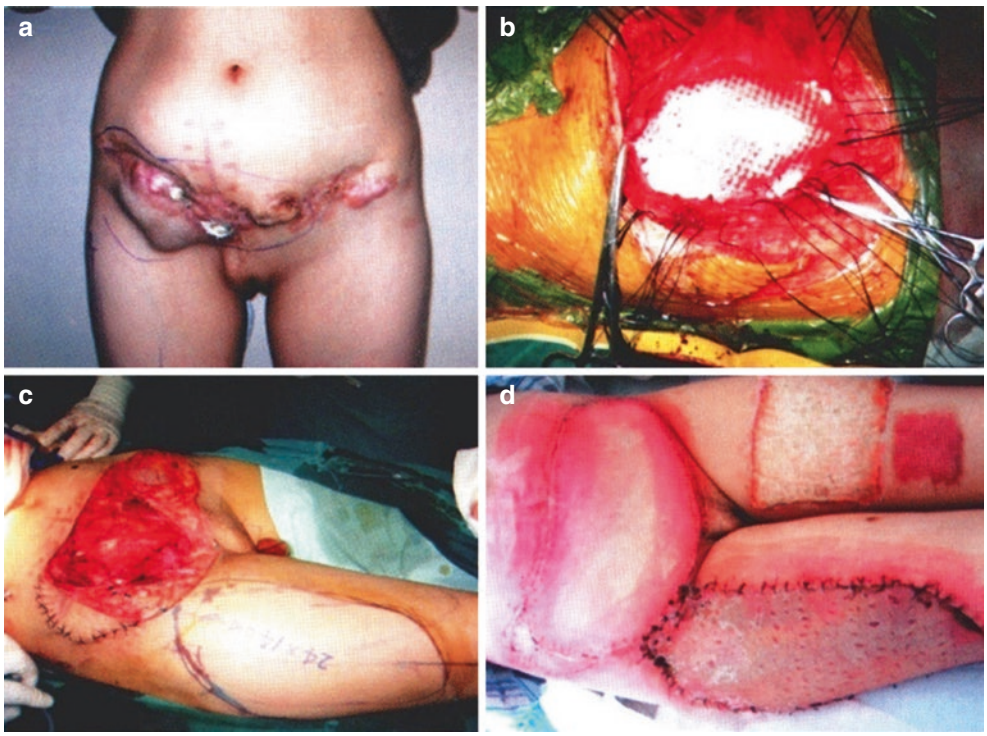


Fig. 16.31 Case XX. (**a**) Recurrence after resection of lower abdominal wall fibrosarcoma, the lesions involved the bilateral groins. (**b**) Full-thickness abdominal wall defects after expanded tumor resection, the propene polymer patch was used to repair the lower abdominal wall aponeurosis. (**c**) The tensor fascia lata myocutaneous flap with vascular pedicle was designed in the right thigh. (**d**) At 2 weeks after surgery, both the myocutaneous flap and the donor site skin graft survived

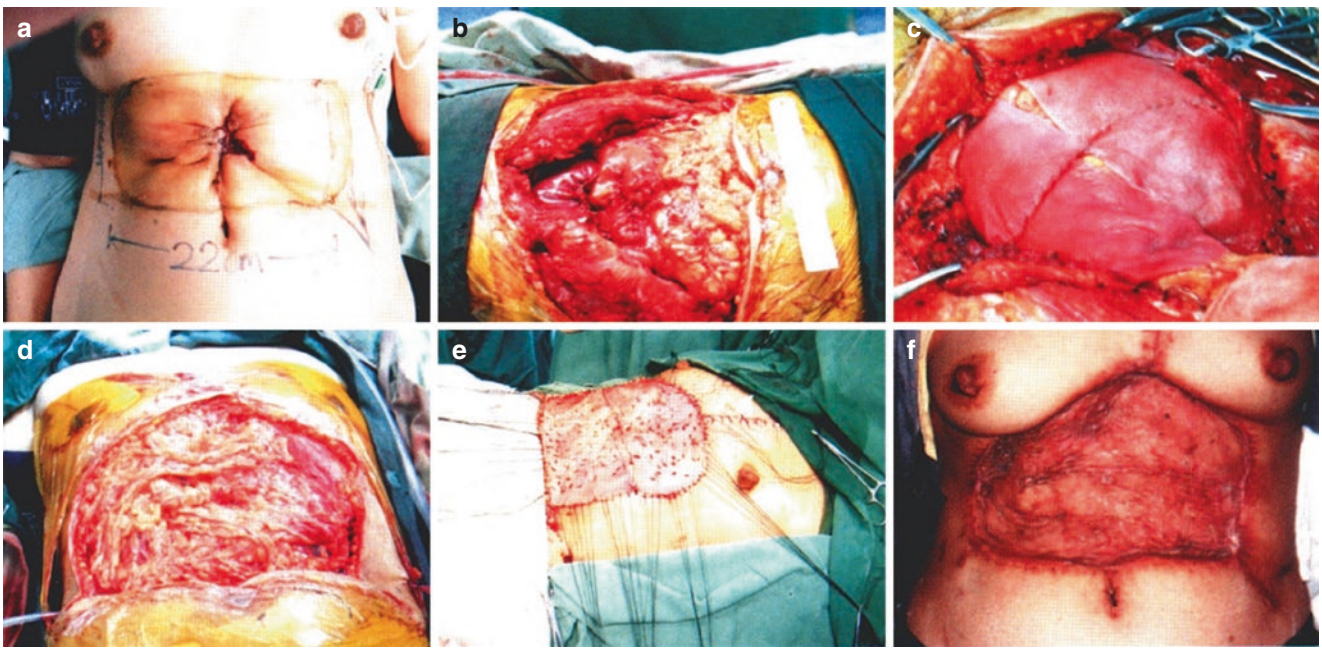


Fig. 16.32 Case XXI. (**a**) Before surgery. (**b**) The full-thickness defect after extended resection of abdominal wall tumor. (**c**) The human acellular dermal matrix was used to repair the fascia of abdominal wall. (**d**) The greater omentum was used to completely cover the patch. (**e**) The autologous split-thickness skin graft was transplanted onto the greater omentum. (**f**) The follow-up was performed at 6 months after surgery, and no skin ulcers and hernia occurred

omentum, biological patch, and free skin graft for repair. The human acellular dermal matrix was used to cover the abdominal organs and repair the fascia of the abdominal wall, and then the greater omentum was used to cover the patch, and the autologous split-thickness skin graft was transplanted to repair the skin wound. All tissues survived after surgery, and the wound healed at one stage. The patient was followed up at 6 months after surgery, and it was observed that the wound healed well without skin ulceration or other complications (Fig. 16.32).

All surgical photographs published in this chapter have been approved by the patients themselves.

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Defect Repair After Resection of the Upper Limb Malignant Tumor

17

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1 Overview

It is often required to use the plastic surgery techniques to repair the defect after resection of the body surface tumor in the upper limb; the relevant theories and measures can be referred to in Sect. 1.14 of Chap. 1. This chapter focuses on the discussion on the diagnosis and treatment of some malignant tumors in the hands, upper limbs, and soft tissues and the repair and reconstruction after tumor resection. The tumors in the hands, upper limbs, and soft tissues account for about 1% of all malignant tumors, a kind of malignant tumor with different histological and clinical characteristics. Because most tumors cause no pain or slight pain, the patients and the medical staff do not pay attention to them; therefore, there is a certain rate of missed diagnosis and misdiagnosis before surgery. The soft tissue malignant tumor is also known as soft tissue sarcoma and mostly occurs in the limbs, trunk, and retroperitoneal space; the most common soft tissue sarcomas are fibrosarcoma, synovial sarcoma, rhabdomyosarcoma, liposarcoma, leiomyosarcoma, and stromal sarcoma; the most common metastatic site is the lung [1].

The courses of disease of the tumors in the hands, upper limbs, and soft tissues are very inconsistent, which is related to the growth rates and symptoms of the tumors and the tolerances of the patients; some malignant tumors have a very short course of disease of more than 10 days or only a few months; because the symptoms appear early, and the vigilance against the tumor is high, the patients seek medical treatment very early; and some malignant tumors have a long course of disease of several decades of years because of various reasons. In general, the superficial tumors in the hands, upper limbs, and soft tissues are easy to detect; but the malignant tumors in the deep areas are difficult to detect early. Once the symptoms appear, or they are detected by the accidental physical examination, the volumes of tumors are already very large. There is no necessary synchronous relationship between the course of disease and the degree of malignancy of the tumor; in other words, the tumors with long course of disease are not always benign; the tumors with short course of disease are not necessarily malignant and vice versa. Based on the medical history and clinical manifestations, it is not difficult to distinguish between the tumors and non-tumor masses, and even the histological origins of tumors can be estimated. If the tumor is suspected as the soft tissue sarcoma, the inspection technique should be gentle, and the forceful squeeze massage should be avoided by all means, so as not to cause iatrogenic spread [2, 3].

The imageological examinations of the tumors in the hand and upper limbs, in addition to detecting the presence, size, and location of the lesion, should make an approximate deduction about its histological type; they are of great significance for the choice of surgical treatment especially in the differential diagnosis of benign and malignant lesions, but they all have limitations [4]. For example, (1) X-ray plain film provides relatively limited information in the diagnosis of tumors. (2) CT perfusion imaging can provide parameters reflecting the early blood supply of the tumor, thereby can better reflect its blood supply situation than the conventional enhanced scan and thus further provide a reliable basis for the qualitative diagnosis of tumor. (3) MRI is obviously superior to CT in reflecting the imaging characteristics of soft tissue; its advantages include high tissue resolution, direct multiplanar imaging, and having signal differences in different tissues under the condition of different pulse sequences and different imaging parameters, which are very conducive to distinguishing the characteristics of different tissues. (4) The ultrasound is a conveniently used, inexpensive, and noninvasive imaging method, but shows no specificity for most tumors. (5) The digital subtraction angiography (DSA) is the most effective imaging method for detection of soft tissue sarcomas before the appearances of CT and MRI,

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but it is difficult to discriminate between benign and malignant lesions with DSA since the diagnostic effect of DSA for most tumors of the hands and upper limbs is very small. (6) PET has a high sensitivity to the malignant tumors; the thallium chloride is valuable in identification of soft tissue tumors. The sensitivity is 95%, the specificity is 50%, and the accuracy is 82.7%, but the specificity is low and the examination cost is high, which limit its application in the clinic. In the diagnosis of malignant tumors of the hand and upper extremity, the pathological and immunohistochemical examinations and the examination of DNA content in tumor cell membranes are often used as final evidences.

The malignant tumors in the hands and upper limbs need comprehensive treatment. The early detection and early treatment are the keys, and whether the desired effect is achieved depends on the correctness and thoroughness of the initial treatment. The local recurrence and distant metastasis can be controlled only in this way, and the limb function can be preserved to the largest extent.

The scope of tumor resection is often determined according to the size, scope, anatomic site, and physiological type of the tumor. Some limb salvage surgeries are compared with the amputation surgeries; there are no significant differences in local recurrence rate and survival rate between two surgical methods; this view has been confirmed by the prospective study carried out by the US National Cancer Institute. The surgical aim is that the tumor is completely removed and the incisal margins are negative. When the soft tissue tumors are removed, 2–3 cm normal tissue should be included. The preoperative interventional imaging combined with local chemotherapy can reduce tumor volume, reduce the difficulty of operation, and improve the survival rate after surgery, even for the patients with local recurrence, and the topical chemotherapy plus surgical resection should still be used as the treatment method. In terms of the present stage, the surgical operation is the main method of treatment of soft tissue tumors. Given the high recurrence rate of soft tissue tumors in the past, the scope of surgical resection is continuously expanded, but the effect is still not satisfied. Under the trend of comprehensive treatment in recent years, the surgical treatment tends to preserve the function, namely, under the premise of preserving the body function as maximum as possible, the most appropriate surgery is carried out to ensure the quality of life of the patient.

The soft tissue reconstruction techniques are of important significance in various aspects such as appearance improvement, functional reconstruction, and wound repair. The resections of tumors in the hands, upper limbs, and soft tissues often cause greater soft tissue defects; it is required to repair the wound, reconstruct the function, and improve the appearance through soft tissue reconstruction. In the surgical treatment of bone and soft tissue tumors, the soft tissue reconstruction must follow the principles of the oncological plastic surgery.

The preoperative or postoperative radiotherapy is an important factor to be considered in soft tissue reconstruction after the resection of tumors in the hands, upper limbs, and soft tissues. The wound after local radiotherapy has a higher incidence rate of complications, such as wound disunion and infection. For the patients receiving preoperative radiotherapy, when necessary, the soft tissue muscle flap or myocutaneous flap with vascular pedicle is selected for reconstruction, in order to reduce the postoperative incidence rate of wound disunion or infection. For the larger wounds after radiotherapy, the vascular pedicled free skin flap with rich blood supply or with thicker diameters of feeding artery must be used for wound repair. Kunisada et al. retrospectively analyzed 43 patients undergoing soft tissue sarcoma resection after radiotherapy, of whom the patients undergoing the first-stage soft tissue reconstruction accounted for 34.9% and the postoperative wound complication rate was 44%. For the patients receiving preoperative radiotherapy at surgical site, the first-stage repair with muscle (myocutaneous) flap should be actively considered.

For patients with larger resection range and simultaneous use of a large segment of metallic implant or allogeneic bone graft, the effective soft tissue reconstruction can significantly reduce the incidence rate of complications such as infection. For allogeneic bone reconstruction, the infection is the main complication, and the adequate soft tissue coverage can reduce the incidence rate of infection and improve the limb salvage rate. The muscle (myocutaneous) flap has played an important role in limb-sparing surgery; for the patients undergoing amputation surgery, both the good soft tissue coverage and soft tissue reconstruction of the stump have positive effects on postoperative functional recovery and wearing prosthesis. In addition, it is reported in the literature that a large area of free myocutaneous flap can be obtained from the residual limb to repair the giant surface wound after amputation.

In recent years, the application of vacuum sealing drainage (VSD) for healing wound is significantly increased; it can significantly promote the formation of granulation tissue, keep the wound dry, and provide better conditions in receptor site for second-stage skin or soft tissue transplantation, so as to improve the success rate of the soft tissue reconstruction. If high-risk patients cannot undergo one-stage complex soft tissue reconstruction, it can be considered that VSD is used to cover the wound and provide better soft tissue bed for second-stage reconstruction. VSD also has an important effect on infected wounds, and the debridement and VSD coverage combined with antibiotics can control the infection better and provide a better soft tissue condition for second-stage soft tissue reconstruction. Due to increased secretion in the infected wound, the VSD sponge is prone to obstruction, thus it can be considered that the VSD with

flushing device is used for coverage. The status of the skin flap should be closely observed after surgery; the reconstruction may fail due to reasons such as hypertonia, poor blood flow, torsion of the pedicle, hematoma, and (or) infection and sometimes may fail due to blood coagulation disorders, poor nutritional status, and anemia. The hematoma can cause skin flap swelling, affect the venous return, and lead to skin flap necrosis. The complete hemostasis should be carried out to prevent hematoma. If it is suspected that the hematoma has been formed, the hematoma should be explored and removed as soon as possible. The partial skin flap necrosis, skin graft failure, or nonhealing wounds also occasionally occur. In general, the wounds are mostly healed through conservative treatments such as changing dressings and improving the general nutritional status.

In summary, when the tumor in the upper limb is removed, some plastic surgery techniques can be used in the surgical incision design; the postoperative scar is hidden as far as possible. The comprehensive grasp of microsurgical techniques and plastic surgery techniques has more important significance for the completion of defect repair after resection of upper limb tumors and the repair and reconstruction at late stage.

Typical case: The patient, male, 46 years old, had recurrence at 6 months after resection of malignant melanoma in the right elbow. The physical examination showed that an ulcer of 3 cm × 2 cm was observed in the right elbow, with irregular margins, and multiple scattered satellite lesions were observed around the ulcer. There was no axillary lymph node enlargement. There was no surgical contraindication. After preoperative preparation, the patient underwent the extended resection of the right elbow lesion under general anesthesia, the parumbilical skin flap pedicled with inferior epigastric artery and vein was used for repair (Figs. 17.1, 17.2, and 17.3), and the postoperative immunotherapy was carried out.

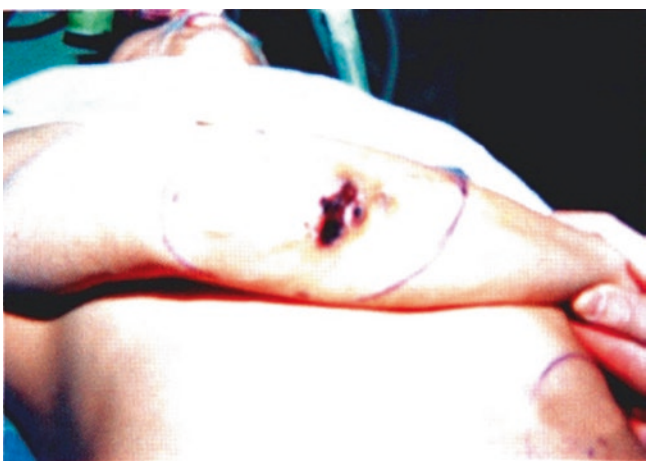

Fig. 17.1 Design of preoperative elbow lesion and incision

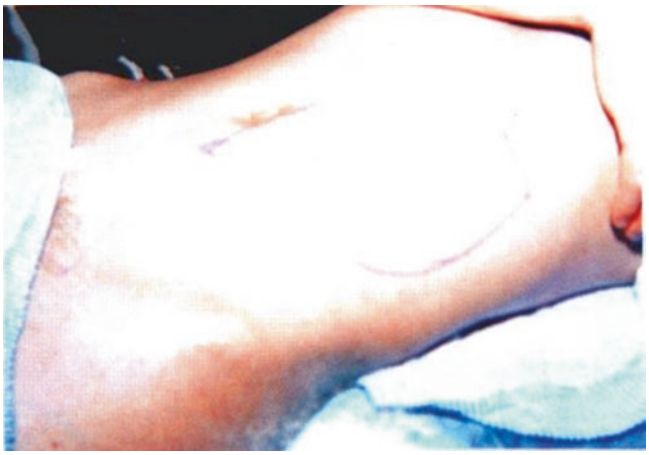

Fig. 17.2 Design of the parumbilical skin flap pedicled with inferior epigastric artery and vein

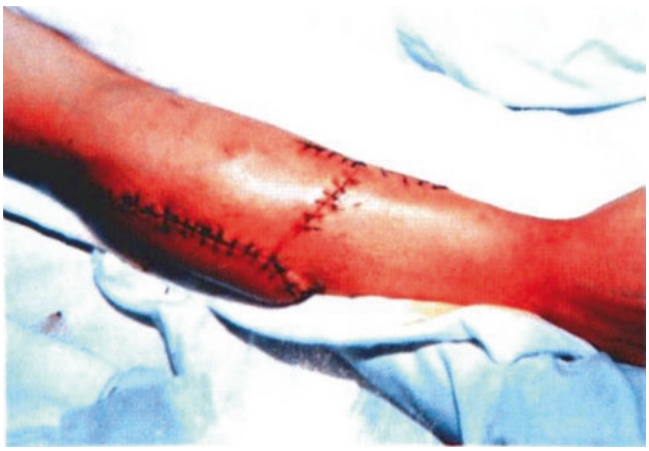

Fig. 17.3 The status after the completion of the surgery

2 The Osteosarcoma of Upper Humeral Shaft

2.1 Overview

Osteosarcoma is the most common type of primary malignant tumor. According to the literature, osteosarcomas account for 22% of malignant tumors and have a relatively high degree of malignancy; the prognosis is very poor, and the pulmonary metastasis occurs a few months later; the survival rate at 3–5 years after amputation is only 5–20%.

Osteosarcoma is the most common primary malignant bone tumor in childhood and adolescence. The osteosarcoma tends to occur in the long bone metaphysis, and now the osteosarcoma with lesions located in the diaphysis is called the diaphysial osteosarcoma; its incidence rate is low, accounting for only 0.52–9.50% of all osteosarcomas. The diaphysial osteosarcoma tends to occur in the long bones of limbs; most of them are found in the femur, followed by the

humerus, fibula, and tibia. The osteosarcoma tends to occur in 15–20-year-old adolescents, while the age of onset of the diaphysial osteosarcoma is higher than that of other osteosarcoma, and the age of onset mostly exceeds 20 years.

2.2 Pathological Manifestation

In the 2002 WHO bone tumor classification, according to the pathological classification and pathogenic site, the osteosarcomas are divided into the general central type (including chondroblastic type, fibroblastic type, osteoblastic type, and eight subtypes derived from these three types), telangiectasia type, small-cell type, low-grade central type, cortical type, secondary type, juxtacortical type, periosteal type, and highly malignant superficial type; the pathological types of diaphysial osteosarcomas are also classified into the abovementioned respective subtypes. The osteosarcoma classification is more complex; the basic elements of the pathological diagnosis are the malignant sarcoma tumor cells and the neoplastic osteoid and bone formed directly by sarcoma cells, and the various subtypes have their characteristic pathological manifestation. The osteosarcomas in the humeral shaft can be divided into osteolytic type, osteoblastic type, and mixed type according to the manifestations of the bone damage on X-ray and MRI, and the osteoblastic type is commonly seen [5].

2.3 Clinical Characteristics

The osteosarcoma in the upper limb shaft has a lower clinical incidence rate, and the humerus is one of its most common locations of disease onset. The symptoms of osteosarcoma include progressive local pain, swelling and dysfunction, body weight loss, and anemia; the physical signs include tenderness, hard and tough masses, dark skin and varicose veins, and affected limb dysfunction. The laboratory tests show elevated alkaline phosphatase (1.5–4 Brinell units or 5–12 Guinness units in normal persons), and the higher value indicates more severe symptoms. The main clinical manifestations include pain and limb dysfunction. The main manifestations of X-ray and MRI include extensive bone damage, periosteal reaction, and easily observed soft tissue mass; the tumor bone and tumorlike calcification are still the main basis for imaging diagnosis. Comprehensive analysis of clinical X-ray, MRI, and pathological manifestations can accurately determine the diagnosis.

2.4 Diagnosis and Differential Diagnosis

Various subtypes of diaphysial osteosarcomas have their own characteristic pathological manifestations, but there are still similarities among them. The bone damages of the diaphysial osteosarcomas are more extensive, generally greater than 10 cm. The diaphysis has rich red bone marrow and more abundant blood supply. The tumor is more likely to spread within the medullary cavity of the diaphysis; therefore, the scope of tumor invasion is more extensive even the entire length of the diaphysis is involved. The diaphysial osteosarcomas are prone to periosteal reaction, and the tumor bone has many forms of manifestation, including spotlike, flocculent, needlelike, or ivory manifestation. Just like the metaphyseal osteosarcoma, the tumor bone and tumorlike calcification are still the main basis for the diagnosis of the diaphysial osteosarcoma with X-ray plain film. Andresen et al. divided the X-ray manifestations of the low-grade central osteosarcomas into four types: (1) osteolytic bone damage containing thicker bone crests; (2) osteolytic bone damage containing less incomplete slender bone crests; (3) simple osteosclerotic lesion; and (4) simultaneously combined with osteolytic bone damage and osteosclerosis. The low-grade central osteosarcoma is rare, accounting for only 1.96% of osteosarcomas, and is rarely located in the diaphysis; it is more difficult to diagnose relying solely on clinical and imaging manifestations, and it is required to integrate the histological manifestations of the characteristics of the benign lesion (spindle cells arranged in sarciniform and plexiform, rare mitotic figures, unobvious cell atypia) to make the diagnosis.

Most small-cell osteosarcomas show mixed bone damage, accompanied with periosteal reaction and soft tissue mass; the intramedullary and soft tissue ossifications are slighter and are easily misdiagnosed as Ewing's sarcoma; the main identification points are that there exists characteristic regional bone-like tissue in pathologically damaged bone of the small-cell osteosarcoma. X-ray and MRI of the small-cell osteosarcoma show the osteolytic bone damage in the middle segment of the femur, thickened endosteum, layered periosteal reaction, needlelike tumor bone, and soft tissue mass. Because the needlelike tumor bone, periosteal reaction, and soft tissue mass are not the characteristic manifestations of the osteosarcoma, Ewing's sarcoma may also have needlelike new bones with relatively consistent thickness and length; therefore, this type needs to be distinguished from Ewing's sarcoma in onset age, location, imaging, and pathology. The onset age of low-grade central osteosarcomas is later than that of the general central osteosarcoma, and it is between 30 and 40 years old. The medical history is longer, and it can sustain for months to years.

Differential diagnosis of the diaphysial osteosarcoma: (1) Ewing's sarcoma: It mostly occurs before the age of 30 years. Ewing's sarcomas with small onset age mostly locate in tubular bones in the four limbs, and the femur is also the most common location of disease onset. The main imaging signs include intramedullary bone damage, periosteal reaction, and soft tissue mass; when the reactive bone sclerosis or residual

bone fragments and needlelike new bone occur within the bone, it is difficult to distinguish it from the diaphysial osteosarcoma, especially the small-cell osteosarcoma; the identification between both depends on pathological examination. (2) Atypical osteomyelitis: It occurs mostly in children and young people; with the lack of obvious infection history, the medical history is usually longer. It mostly occurs in long bone diaphysis in the lower limbs, and is expanded and extended to the diaphysis, but it does not have dead bones, or the manifestation of dead bones is not obvious in most cases; the soft tissue swelling is also not obvious, and the surrounding bone and periosteal proliferation is slighter, or there is no periosteal proliferation. (3) Conventional intramedullary chondrosarcoma in long bones: The endosteum has scallop-shaped changes, and the arcuate or annular calcification and the surrounding partition-like enhancement pattern have certain characteristics. (4) Osteofibrous dysplasia: It is more difficult to distinguish it from the low-grade central osteosarcoma in the diaphysis in pathological and X-ray findings, but the osteofibrous dysplasia is less likely to break through the bone cortex and form a soft tissue mass; the invaded range in the bone marrow cavity is relatively limited, and the peritumoral soft tissue edema is relatively rare.

2.5 Treatment

2.5.1 Indications and Contraindications of Limb Salvage Surgery

1. Main indications
   (1) Enneking stage IA, IB, and IIA patients and some stage IIB chemotherapy-sensitive patients; the major blood vessels and nerves are not affected.
   (2) If the local soft tissue conditions permit, the extensive resection can be achieved.
   (3) There is no metastatic lesion or the metastatic lesion can be cured.
   (4) The general condition is good, and the patient has a strong desire for limb salvage.
2. Contraindications: The recurrent tumors have huge tumor body, poor differentiation, and bad soft tissue condition, or when the major blood vessels and nerves surrounding the tumor are invaded by the tumor, it is advisable to perform amputation surgery.

2.5.2 Surgical Methods

The surgery may be carried out by means of extensive resection of proximal humerus alone, and when the lesion is close to the articular surface, a huge chunk of humerus together with scapula glenoid can be resected. The reconstruction methods vary with each individual. Young people need analgesia and stabilization, and thus the arthrodesis of shoulder may be considered, while the flail shoulder may be considered in elderly people.

The osteosarcoma patients undergoing surgery will be inevitably associated with the problem of tissue reconstruction. Currently the reconstruction techniques mainly include (1) bone tumor resection and arthrodesis, (2) bone transplantation, (3) tumor bone inactivation and reuse, (4) prosthesis replacement, and (5) composite limb salvage surgery. The selection of reconstruction materials is determined according to the experiences and habits of doctors, and the objective conditions, for example, the tumor bone shells in younger patients, are more complete and have a certain strength; the devitalized tumor bone shell and bone cement can be used for filling reinforcement, and the allogeneic bone stored in the bone bank at low temperature can also be selectively used for transplantation, but the patients should be informed that it's prone to having an allograft reaction and leading to the limb salvage failure; the elderly people may select the artificial joint replacement. The soft tissue repair is most important; the wound infection and the necroses in the skin flap margin and skin flap should be reduced as far as possible; all these can lead to limb salvage failure. (6) When the osteosarcoma involves a large area of the skin, the pedicled or free skin flap can be used for repair, such as the latissimus dorsi myocutaneous flap and pectoralis major myocutaneous flap.

2.5.3 Postoperative Evaluation

The prognosis of traditional treatment methods (amputation and radiotherapy) is poor, and 5-year survival rate does not exceed 20%. The most important factor affecting the prognosis of osteosarcoma patients is the reaction degree of the tumor tissue to chemotherapy drugs, namely, the necrosis rate of tumor cells after chemotherapy, for patients with a necrosis rate of less than 90%; even if the chemotherapy regimen is changed, the prognosis is poor. Some scholars have reported that the patients with a tumor size of more than 150 mm^3 have poor prognosis; the preoperative alkaline phosphatase and lactate dehydrogenase levels are also important for prognosis.

For the osteosarcoma patients without lung metastases, after preoperative and postoperative chemotherapy and appropriate surgical treatment, the cure rate is up to 60–80% at abroad; for the osteosarcoma patients treated in China, 5-year survival rate is 52%; 60% of patients have undergone limb salvage surgery, and the recurrence rate after limb salvage surgery is 12.5%.

2.6 Evaluation Method of Treatment and Its Standard

Surgery is the primary means for treatment of osteosarcoma. The purpose of surgical treatment is to safely resect the tumor and preserve the function as far as possible. For osteosarcoma patients, the local recurrence must increase the risk

of metastasis, and therefore the selection of treatment scheme must consider the risk of local recurrence at first. To achieve the safety of the operation range, the surgical boundary should reach the extensive resection defined by the Enneking, including total resection of tumor tissue (should include biopsy channel) as well as the surrounding normal tissues within appropriate range which are not invaded, and the inadequate resection boundary will lead to increased local recurrence rate.

3 The Chondrosarcoma of the Upper Limb

3.1 Overview

The chondrosarcoma occurs in the soft tissue and originates from the chondrocyte or the malignant bone tumor of mesenchymal tissue differentiating into the cartilage, and its incidence rate accounts for about 20% of malignant bone tumors. Stout reported seven cases of chondrosarcoma and listed it as a separate disease entity at first in 1953. Istituto Ortopedico Rizzoli, Bone Tumor Center, summarized the data of 513 cases of chondrosarcoma encountered within 80 years; among them, there were only nine cases of chondrosarcoma within the ectosteal soft tissues, accounting for 1.7%, and the domestic literatures are mostly case reports.

This tumor tends to occur in middle-aged men, mostly in the lower limbs, especially in the thighs. Other frequent-onset locations include the calf, knee, hip, shoulder, ankle, hand, foot, groin, forearm, upper arm, and elbow.

3.2 Pathological Manifestation

The chondrosarcoma is the malignant bone tumor of mesenchymal tissue originating from the chondrocyte or differentiating into the cartilage, and it is often accompanied by matrix and myxoid degeneration, calcification, or ossification. It is mostly primary in origin, and it is secondary to enchondroma, osteochondroma, osteofibrous dysplasia, and Paget's disease only in a few cases. It is divided into central (intramedullary) type and peripheral type according to pathogenic site, and the former is more common. It is divided into five types such as ordinary type, mesenchymal type, dedifferentiated type, myxoid type, and hyaline chondrocyte according to histology. It is divided into grade I–III according to the degree of differentiation: grade I is low-grade malignant, grade II is medial-grade malignant, and grade III is high-grade malignant. Grade I commonly shows cartilage calcification or ossification; relatively grade II shows less cartilage calcification or ossification; and grade III basically shows no cartilage calcification or ossification.

The pseudocapsule of mesenchymal chondrosarcoma is incomplete, the surface is lobulated or nonlobulated, the section surface is substantial, and it is dispersedly distributed with translucent cartilage lesions. It is mainly composed of undifferentiated mesenchymal cells and more maturely differentiated cartilage islands under microscopy; there is a clear boundary between the two, but the transient phenomenon of cell components is observed in some regions; that is, from undifferentiated mesenchymal cells to small spindle cells, the cartilage island is gradually formed. Under the electron microscope, the mesenchymal chondrosarcoma originates from undifferentiated mesenchymal cells, some are maintained in an undifferentiated stage, and some are differentiating toward the cartilage. Casadei considered that the myxoid chondrosarcoma has a complete pseudocapsule, and the section surface is gray-brown and transparent jellylike and may have bleeding and necrosis lesions; small, round, or long elliptic cells are observed under microscope, the nuclear chromatin is deeply stained, and the mitotic figure is rarely seen. The cells are separated by varying amounts of myxoid matrix. Under the microscope, it is observed that the dedifferentiated chondrosarcoma has a poorly differentiated sarcoma area on the basis of well-differentiated hyaline chondrosarcoma; there are a variety of histopathological types, such as fibrosarcoma, osteosarcoma, or malignant fibrous histiocytoma, and this type is rarer. The immunohistochemistry shows that S-100 protein and vimentin are positive, and the cytokeratin is negative.

3.3 Clinical Characteristics

The chondrosarcoma of the upper limb is usually demonstrated as a slowly growing painless mass at first; usually the patient only visits the hospital after the mass is significantly increased, and the patient feels pain a few weeks or a few years later.

Clinically, the onset age of chondrosarcoma is 11–60 years, the onset peak is 30–60 years, and the male to female ratio is 1.8:1. The onset age of dedifferentiated type is older, which tends to occur between 45 and 59 years in middle-aged and elderly people; the onset age of mesenchymal type age is smaller, which tends to occur between 10 and 29 years, with a median age of 26 years; the onset age of ordinary type tends to occur between 30 and 59 years; the patients less than 20 years are rarely seen; and the mucoid type occurs mainly in middle-aged men.

The clinical symptoms are mainly caused by local compression or invasion, including compressive and obstructive symptoms in the cavity-containing organs, an uncomfortable mass with no pain or dull pain in superficial parts, and no skin redness and swelling. The secondary lesion is that the painless mass is increased in short term and the pain occurs.

3.4 Diagnosis and Differential Diagnosis

3.4.1 Diagnosis

X-ray film shows soft tissue mass, and the calcification rate is 30%. The most common X-ray and CT signs of the mesenchymal type are the oval soft tissue masses with a clear boundary which contains a large number of irregular calcification, and the calcification is demonstrated as dotted and flocculent shapes, which is different from the granular or nodular calcification occurring in bone chondrosarcoma. The mucoid type has no calcification, with a lack of typical X-ray manifestations, and it is hard to be differentiated from other soft tissue masses in the plain film; due to rich mucus, CT shows a low density homogeneous mass. In some cases, CT can not only find the soft tissue mass and determine the invasion range but also find calcification-ossification shadows which cannot be shown on X-ray film, which are mostly point-like, circular, or semicircular; CT is now considered as the most effective means of imaging in early diagnosis of this disease. In recent years, MRI is also widely used to diagnose bone tumors and shows the muscle signal on T1-weighted image and high signal on T2-weighted image, of which both the calcification and ossification are low signals. When the angiography is carried out, the outline of the mucoid chondrosarcoma and the relationship of the reactive vascular proliferation in the adjacent soft tissue with the blood vessels and nerves can be clearly shown, and the tumor itself is not obviously developed, while the mesenchymal chondrosarcoma shows excessive proliferation of tumor blood vessels. Some patients may have signs of erosion of adjacent bone [6].

3.4.2 Differential Diagnosis

The chondrosarcoma should be differentiated from the following diseases:

1. Enchondroma. The ordinary chondrosarcoma in tubular bones should be differentiated from the enchondroma. The enchondromas tend to occur in the short tube bones and are often multiple, the bone cortex is expanded and thinned, the typical case has candied fruit-like changes, and the enchondroma occurring in the long bone is mostly demonstrated as the limited calcification without corrosive destruction of the bone cortex. No soft tissue mass is formed around the enchondroma, and there is often no pain symptoms.
2. Osteoclastoma and chondroblastoma. The clear-cell chondrosarcoma should be differentiated from the osteoclastoma and chondroblastoma. The osteoclastoma mostly has bubble-like bone destruction and has no hyperostosis, osteosclerosis, and calcification; the fluid-fluid levels may occur on MRI; the onset age of chondroblastoma is younger; the chondroblastoma mostly occurs in the vicinity of the epiphyseal plate; and the size is generally less than 5 cm.
3. Chordoma and meningioma. The chondrosarcoma occurring in the skull, especially the myxoid chondrosarcoma, should be differentiated from the chordoma and meningioma. The chordoma tends to occur in the slope and is located in the middle area and mostly shows osteolytic and expansive bone damage, in which the residual bone instead of bone calcification is observed; and the chondrosarcoma mostly biases toward one side and occurs in the binding region of the skull, and there may be typical calcification; the small interatrial septum-like enhancement is observed within the tumor after enhanced scan.
4. Osteosarcoma and neurogenic tumors. The chondrosarcoma occurring in the parosteal area and soft tissue should be differentiated from the osteosarcoma and neurogenic tumors. The onset age of the osteosarcoma is mostly younger, and the periosteal reaction is heavier, the Codman triangle and the tumor bone often appear, the soft tissue masses mostly have equal density, and the clinical symptoms are more obvious. The chondrosarcoma is mostly the low-density mass, the characteristic calcification is commonly seen, the periosteal reaction is lighter, and some neurogenic tumors may have calcifications, but that are mostly flocculent and patchy calcifications, which is different from the calcification characteristics of the cartilaginous tumors.
5. Others. The extraskeletal chondrosarcoma should be differentiated from the soft tissue chondroma, chondromyxoid fibroma, chondromyxoid fibroma, chordoma, myxoid lipoma, malignant hemangiopericytoma, and myositis ossificans. Because the incidence rate of this tumor is low, there is a certain degree of difficulty in diagnosis.

3.5 Treatment

3.5.1 Indications and Contraindications of Limb Salvage Surgery

1. Main indications
   (1) Enneking stage IA, IB, and IIA patients; some stage IIB chemotherapy-sensitive patients, and the major blood vessels and nerves are not affected.
   (2) If the local soft tissue conditions permit, the extensive resection can be achieved.
   (3) There is no metastatic lesion or the metastatic lesion can be cured.
   (4) The general condition is good, and the patient has a strong desire for limb salvage.
2. Contraindications. The recurrent tumors have huge tumor body, poor differentiation, and bad soft tissue condition, or when the major blood vessels and nerves surrounding the tumor are invaded by the tumor, it is advisable to perform amputation surgery.

3.5.2 Surgical Methods

Although the non-characteristic clinical and X-ray manifestation can delay the diagnosis and treatment, the treatment method is also an important prognostic factor. The tumor is mainly treated by surgical resection, the recurrence rate after intracystic or marginal resection is very high (30–100%), and the rate of postoperative recurrence and metastasis is 20–60%.

The important measure of the surgical resection is that the tumor is resected en bloc at the best surgical boundary outside the tumor. The selection of resection plane during surgery must be determined according to preoperative Enneking staging. After chemoradiotherapy, the tumor is shrunk, and the boundaries are clear, which helps achieve the goal of radical resection of tumor. The range of extensive resection should include the tumor body, envelope, reaction zone, and the surrounding adjacent 10-cm-thick normal tissue, and the resection should be performed in this normal tissue structure as far as possible. For the tumors with highly aggressive biological behavior, which don't receive chemotherapy or are insensitive to chemotherapy, the cuneiform plane should be at 6 cm outside the lower boundary of the tumor (determined according to preoperative MRI), and the resection range of the soft tissue should be 2–3 cm outside the reaction zone. The tumor patients who are sensitive to chemotherapy can be treated with resection with smaller surgical boundary; the femoral resection should be carried out at 3 cm under the lower boundary of the tumor, and the soft tissue resection is performed at 1 cm outside the tumor. Generally, it is believed that the myxoid chondrosarcoma is a low-grade malignant tumor; it grows slowly and has a good prognosis. The metastasis rate is low, even if lung metastasis occurs; the metastasis focus can be resected, and the extensive resection can be performed; while the malignancy degree of the mesenchymal chondrosarcoma is high, it can be easily metastasized to the lungs through blood channels; in a few cases, it is metastasized to the regional lymph nodes, the prognosis is poor, and the radical resection should be carried out. Because the tumor site is mostly located outside the compartment, therefore it is often difficult to carry out limb salvage surgery in the patients with mesenchymal chondrosarcoma. When the tumor involves the skin, the pedicled or free skin flap can be used for repair.

3.5.3 Postoperative Evaluation

The statistics by Amir showed that the recurrence may take place at 2 months to 15 years after surgery (with an average of 2.6 years) and the metastasis may take place at 4 months to 17 years after surgery, namely, some patients may have recurrence and metastasis many years later; therefore, the tumor patients must be followed up for a long time. Although the chemotherapy and radiotherapy may be used as adjunctive therapy of this tumor, their exact effects are not yet clear.

3.6 Evaluation Method of Treatment and Its Standard

The chondrosarcoma is a malignant bone tumor with relatively slow clinical progression and low metastasis rate, and the purpose of clinical basic treatment is to remove the tumor as thoroughly as possible and prevent recurrence; the imageological examination, especially CT and MRI, provides a reliable basis for proper clinical diagnosis, guiding treatment, and postoperative reexamination.

4 The Clear-Cell Sarcoma of the Upper Limb

4.1 Overview

The clear-cell sarcoma (CCS) occurring in the limbs is a clinically extremely rare soft tissue malignant tumor and is also known as soft tissue melanoma. Enzinger firstly proposed the clear-cell sarcoma in 1965. In the new edition of WHO soft tissue tumor classification, the soft tissue clear-cell sarcoma is used and listed as the tumor with an uncertain classification.

The clear-cell sarcoma occurs mainly in the tendon and aponeurosis of the distal limb in young and middle-aged people. Related studies have found that the vast majority of clear-cell sarcomas contain melanin; Chung and Enzinger also called it as the soft tissue malignant melanoma in 1983. It is a malignant soft tissue sarcoma with a lower incidence rate, accounting for about 1% of soft tissue sarcomas, and the mortality rate is between 39% and 74%.

4.2 Pathological Manifestation

There are two kinds of views on the histological origin of clear-cell sarcoma: one view is that the tumor cells are similar to the synovial membrane; therefore, it is considered as a kind of synovial sarcoma, and another view is that the tumor cells contain melanin; thus, it is considered that the clear-cell sarcoma derives from the neural crest. Clinically, this tumor is more commonly seen in young and middle-aged people. The incidence rate of this kind of tumor in Asian populations is relatively lower, and therefore there are few domestic reports on clear-cell sarcoma in the four limbs, especially in the upper limbs.

4.3 Clinical Characteristics

The clear-cell sarcoma in the upper limbs occurs mainly in the distal limbs; it is rarely seen in the head, neck, and trunk,

and it is mainly located in the deep tissues, involving the tendons and aponeurosis, generally not involving the skin, but the larger tumors can invade the skin. The onset of tumor is insidious; sometimes the tumor develops slowly and often has no accompanying symptoms. When the patient seeks treatment, frequently it has been a while since the onset of the tumor. Approximately 50% of patients have a history of trauma at the tumor site.

The main clinical manifestation is the local mass in the upper limbs, which may have pain and tenderness, with less redness and swelling. The tumor texture is harder, with clear boundary. This tumor is often solitary, and may also be multiple, often adheres to the tendon, and is prone to recurrence and metastasis; the regional lymph node metastasis is commonly seen, the lymph node metastasis in early stage is one of the characteristics that makes it different from other soft tissue sarcomas; as the sites of distant metastasis, the lung is most commonly seen, followed by the liver, bone, and brain.

The mode of the metastasis of clear-cell sarcoma is mainly the lymphatic metastasis; the patients who are found with regional lymph node invasion before surgery should also undergo regional lymph node dissection. The patients after tumor resection are prone to recurrence, and the local recurrence rate is 50–84%. The emergence of regional lymph node metastasis is more common than other soft tissue sarcomas, and the regional lymph node metastasis rate in ordinary soft tissue sarcomas is about 8%, while the regional lymph node metastasis rate in clear-cell sarcomas is 33–53%. The most common site of distant metastasis is the lung, and the occurrence rate is 44–53%. The sentinel lymph node biopsy is definitely helpful in early detection of tumor metastasis.

4.4 Diagnosis and Differential Diagnosis

At present, the diagnosis of clear-cell sarcoma mainly depends on the pathological examination, which is characterized as follows: it is observed by the naked eye that the texture is generally harder, nodular, or lobulated; in most cases, it closely adheres to the tendons and aponeurosis, and it is commonly seen that the surrounding muscle or subcutaneous adipose tissue is invaded, but the local skin is generally more complete. The section surface of the tumor is gray-white, and sometimes the spots or glue-like mucus degeneration is visible. The epithelioid and spindle cells can coexist in the same tumor, and the transition is observed. Microscopically, most tumor cells are irregularly polygonal or spindle-shaped and are arranged densely in pieces or nests and are separated by fibrous tissue. The cells are round or spindle-shaped, with clear nuclear membrane and large and obvious nucleoli, and the cells are basophilic; in the cytoplasm, there is an aggregation of a lot of glycogen, swelled mitochondria, and vesicles with interface membrane, and a large number of ribosomes, polysomes and rough endoplasmic reticulum, and the melanosomes in different periods are observed. Some tumors contain polynuclear giant cells, which are focally distributed, with a rosette-like arrangement. Under the electron microscope, some tumor cells contain melanin granules. The most applied immunohistochemical indicators are S-100 and HMB-45 staining, the positive rate of S-100 expression is higher, and the specificity of HMB-45 staining is higher.

The clear-cell sarcoma has unique clinical pathological characteristics, but it is easily misdiagnosed as other epithelial-like soft tissue sarcomas because of its varied histomorphology. It is required to differentiate the clear-cell sarcoma from the following diseases: (1) synovial sarcoma – although it tends to occur clinically in the vicinity of large joints, the hands are one of the predilection sites of the synovial sarcoma. (2) Malignant giant cell tumor of tendon sheath – it tends to occur in the distal extremities, it can be caused by repeated attacks of benign giant cell tumor of tendon sheath, but it can also be primary. (3) Metastatic clear-cell carcinoma from kidney or lung – the metastatic lesions are mostly demonstrated as the tumor cells gathering into groups, which are separated by less interstitial fibrous tissue. For the clear-cell tumors in less common parts and the undetermined clear-cell tumors, the molecular biology detection technology can be used; it is feasible to use RT-PCR technology to detect the expression of EWS-ATF1 fusion gene mRNA in paraffin-embedded tissue of the clear-cell sarcoma, which can be used as a powerful tool for diagnosis and differential diagnosis of clear-cell sarcoma.

4.5 Treatment

4.5.1 Indications and Contraindications of Limb Salvage Surgery

1. Main indications
   (1) Enneking stage IA, IB, and IIA patients and some stage IIB chemotherapy-sensitive patients, and the major blood vessels and nerves are not affected.
   (2) If the local soft tissue conditions permit, the extensive resection can be achieved.
   (3) There is no metastatic lesion or the metastatic lesion can be cured.
   (4) The general condition is good, and the patient has a strong desire for limb salvage.
2. Contraindications. The recurrent tumors have huge tumor body, poor differentiation, and bad soft tissue condition, or when the major blood vessels and nerves surrounding the tumor are invaded by the tumor, it is advisable to perform amputation surgery.

4.5.2 Surgical Methods

The main treatment method for the clear-cell sarcoma of the upper limb is still the surgical resection. The surgery mainly includes local resection, radical resection, and amputation. The radical resection must be performed within the normal tissue surrounding the tumor; the resection is carried out at 3 cm distance from the base of the tumor, and it is required to undermine the subcutaneous tissue again toward the outer side by 4–5 cm or more widely, in order to perform the intermuscular resection. When the nerve is squeezed and displaced or adheres to the tumor, the epineurium should be resected along with the tumor. Because most tumors are adjacent to the joints, tendons, and ligaments, to retain the abovementioned structures often affects the thoroughness of the surgery; they are prone to recurrence. Another characteristic of this tumor is the extremely high rate of local recurrence; the survival rate of extensive resection or amputation is higher than that of the simple local resection. When the tumor involves the skin, the pedicled or free skin flap can be used for repair [7].

4.5.3 Postoperative Evaluation

The clear-cell sarcoma is very prone to local recurrence and metastasis; when the patient is treated by surgery, to ensure negative surgical margin is very important for the prognosis of the patient. The method of metastasis of the clear-cell sarcoma is mainly the lymphatic metastasis, but so far whether the clear-cell sarcoma patients without metastasis undergo lymph node dissection is inconclusive, the sentinel lymph node biopsy is important for early detection of tumor metastasis. The effects of chemotherapy and radiotherapy are not yet clear.

4.6 Evaluation Method of Treatment and Its Standard

For the prognosis of clear-cell sarcoma, it is generally considered that the tumor size and the surgical range are important influencing factors. At present, most scholars believe that the amputation is the best choice when the removal of the limb tumor cannot achieve the negative pathological result of tumor tissue in the surgical margin; for the sites with adequate margin (>3 cm), the compartment resection or extensive resection is entirely feasible. The postoperative radiotherapy and chemotherapy can be used as the common adjuvant therapy means. Kawai et al. followed up 75 patients with clear-cell sarcoma, and then found that the 5-year survival rate was 47% and 10-year survival rate was 36%, suggesting a poor prognosis. Lucas et al. reported that the 5-year survival rate was 67%, but the 10-year survival rate was reduced to 33%. Sara et al. reported that when the tumor was less than 5 cm, 5-year survival rate was 70%; when the tumor was more than 5 cm, the 5-year survival rate was 15%, indicating that the prognosis of patients with tumors more than 5 cm is significantly poorer than patients with tumors less than 5 cm. The early confirmation of pathological results and implementation of extensive resection of tumor may have a positive influence on the prognosis.

The incidence rate of soft tissue clear-cell sarcoma is low, the degree of malignancy is high, and the prognosis is poor. The extensive surgical resection combined with postoperative radiotherapy and chemotherapy is a good treatment plan for patients with soft tissue clear-cell sarcoma [8, 9].

5 The Malignant Fibrous Histiocytoma of the Upper Limb

5.1 Overview

Malignant fibrous histiocytoma (MFH) was firstly discovered and described by O'Berien and Stout in 1964 and then was known as malignant fibrous xanthoma. Stout and Latters firstly named this type of tumor as MFH in 1967. In the past, it was believed that MFH is a highly malignant rare soft tissue sarcoma. With the rapid development of technologies in clinical studies, histopathology, and immunohistochemistry, and deeper understanding of the disease, now most people think that MFH has an unknown etiology; mainly occurs in the limbs, trunk, retroperitoneal area, and other parts; and is demonstrated as common soft tissue sarcoma with an invasive growth, easy recurrence after surgery, and poor prognosis [10].

5.2 Pathological Manifestation

Scholars have different opinions on understanding of the natures, origins, and differentiation characteristics of various cellular components in malignant fibrous histiocytoma. In general, there are three kinds of views:

1. It originates from the histiocytes; some differentiate into fibroblast cells.
2. It originates from the primary mesenchymal cells and differentiates bidirectionally into fibroblasts and histiocytes.
3. It originates from the primary mesenchymal cells and differentiates partially into fibroblasts; either the origin or differentiation has nothing to do with the histiocytes.

The immunoenzyme mark is made with ABC method, in MFH cells, which belong to the real tumor components

and which reactive components are explored. The analytical research shows that MFH cells (fibroblast-like, histiocyte-like, and mononuclear polynuclear tumor giant cells) are the parenchymal cells of the tumor, Touton giant cells and histiocytes belong to reactive components, and the belonging of osteoclast-like giant cells can still not be determined.

Analyzing from the point of view of histogenesis, the vimentin is positive in three MFH cells, indicating that they are mesenchyme-derived; after the specific strong CD68 (KP-1, PG-M1) is used to carry out marking and then it is found that 20% fibroblast-like MFH cells are positive, 40% histiocyte-like MFH cells are positive, indicating that MFH is a primitive mesenchymal cell-derived sarcoma and has bilateral differentiation ability such as differentiating into fibroblasts and histiocytes. For the pathologically complicated and difficult cases with suspected specific tendency of myogenic, neurogenic, fat, or epithelial differentiation, it is very important that a series of antibody markers and the electron microscope are used for positive and negative confirmations.

5.3 Clinical Characteristics

The malignant fibrous histiocytoma is a highly malignant soft tissue tumor, the recurrence rate is high, it is prone to metastasis, and the prognosis is poor. It occurs mainly in 50–70-year-old people, and it occurs more commonly in males. The literatures report that the tumor tends to occur mostly in the lower limbs, followed by upper limbs and retroperitoneal area.

The malignant fibrous histiocytoma of the upper limb is usually demonstrated as a painless mass with sustained growth; when it involves the major nerves, the dull pain can occur in the corresponding site. The tumor is mostly solitary, the tumor is located within skeletal muscle in about a third of the cases, and the tumor is located in the subcutaneous tissue in a few cases.

5.4 Diagnosis and Differential Diagnosis

5.4.1 Diagnosis

The malignant fibrous histiocytoma has a complex composition and varied morphology, and it is difficult to be diagnosed. The tumor cells have obvious polymorphism; the fibroblasts, histiocyte-like cells, and abnormal giant cells in the tumor exist mixedly in different proportions. Usually the following diagnostic criteria are used: (1) multifarious tumor cells; (2) the heterogenic fibroblasts and histiocyte-like cells coexist; (3) abnormal mitotic figures; (4) there is a lot of collagen tissue; (5) there exist reactive inflammatory cells; and (6) there are fibroblasts with wheel-shaped arrangement (of which items (1)–(4) belong to the necessary conditions). According to different components within the tumor, the malignant fibrous histiocytoma is divided into different subtypes, mainly including the ordinary type, myxoid type, giant cell type, inflammatory type, and vascular tumorlike type.

5.4.2 Differential Diagnosis

The X-ray, CT, and MRI imaging manifestations of the malignant fibrous histiocytoma are characteristic, namely, the primary tumor in the bone is mainly manifested as bone damage and soft tissue swelling and mass, the expansion of affected bone and periosteal reaction are rare, the calcification in lesion site is observed, and the primary tumor in soft tissue is manifested as a nonspecific mass. The adjacent bone is normal or involved, and the periosteal reaction is commonly observed, of which the CT and MRI examinations in aspects of determining tumor size and invasion degree are obviously superior to ordinary X-ray. Dai Jingrui analyzed the CT manifestations of 45 patients with MFH and then considered that the CT manifestations of MFH are mainly demonstrated as soft tissue mass; when the lesion is smaller, the margin is smooth, and the density is uniform; the morphology of increased tumor is irregular, often accompanied by necrosis and calcification, and the adjacent organs and tissues are involved. And the recurrent tumor has CT manifestations similar to that of the primary tumor.

In view of the fact that there are many reports on primary MFH of bone and relatively less imaging reports on MFH of limbs and soft tissue, Zhou Jianchun et al. retrospectively analyzed MRI imaging data of MFH of limbs and soft tissue and then considered that it mainly has the following characteristics: (1) The T1WI and T2WI signals of irregular masses with clearer boundary are uneven. (2) T2WI often shows multiple nodular mass with varied high signal intensity, and the nodules are separated from each other by the cord-like low signal shadow. (3) The use of different azimuth imaging and different imaging parameters can determine the exact ranges of most MFH of limbs and soft tissue; in some patients with postoperative recurrence combined with cicatricial adhesion, biopsy bleeding, and surrounding tissue edema, the range of abnormal signal on MRI does not match the actual size of the tumor, after the fat suppression techniques for imaging are applied or the Gd-DTPA is intravenously injected for enhanced scan, and the actual size of the tumor can be clearly displayed. (4) According to the MRI imaging features of the bone tissue and bulky blood vessels, the relationship between the tumor and the surrounding tissues can be better understood.

5.5 Treatment

5.5.1 Indications and Contraindications of Limb Salvage Surgery

Since most of malignant fibrous histiocytomas are highly malignant tumors, the tumor stages are stage II A and II B; the limb salvage surgery is suitable for patients with stage II A tumors and stage II B tumors sensitive to chemotherapy, the large blood vessels and nerves around the lesions are not involved, and the better functions can be achieved through complete resection in safe boundary and implementation of reconstruction.

5.5.2 Surgical Methods

The malignant fibrous histiocytoma of the upper limb is treated mainly by surgical treatment, and the extensive and radical resection should be performed. If the tumor is too widespread with violations of major blood vessels, nerves, bones, and joints, the amputation should be considered. When the tumor involves the skin, the pedicled or free skin flap can be used for repair. The initial symptom of the disease is the painless mass; in most cases, the course of the disease varies, and the disease is easily misdiagnosed, thus losing the best time for treatment.

The radiotherapy and chemotherapy are often taken as the adjuvant therapies of the surgery, which can improve the efficacy. The postoperative radiotherapy can reduce tumor recurrence, and the postoperative chemotherapy can control the distant metastasis of the tumor. Much importance is attached to comprehensive treatment to reduce recurrence and metastasis and prolong the survival rate.

5.5.3 Postoperative Evaluation

In the limb salvage surgery, since the prosthetic design itself has limitations at the early stage, the prosthesis is seldom used; the tumor bone resection combined with inactivation of the tumor bone shell and reimplantation as well as the tumor resection with autogenous bone transplantation or allograft bone transplantation are mainly carried out; the postoperative complications mainly occur after the inactivation of tumor bone and reimplantation, including recurrence and nonunion bone. But in recent years, with the improvement of prosthetic design technology and concepts, the scope of application of the prosthesis is greatly expanded, which is becoming the mainstream of limb salvage surgery.

5.6 Evaluation Method of Treatment and Its Standard

Malignant fibrous histiocytoma is a highly malignant tumor. Among 200 patients with malignant fibrous histiocytomas reported by Weiss, the local recurrence rate was 44%, and the metastasis rate was 42%. The places where the tumor is easily transferred into are the lungs, lymph nodes, liver, and bones in turn. The factors closely associated with the prognosis include the size, depth, location, histological type, and treatment method of the tumor. Some literatures make statistics on the relationships of tumor size, location, and treatment method with the prognosis: the recurrence and metastasis rates in patients with tumor diameter less than 5 cm are significantly lower than those in patients with tumor diameter more than 5 cm; the recurrence and metastasis rates in patients with tumors in limbs are significantly lower than those in patients with retroperitoneal tumors; and the recurrence and metastasis rates in patients undergoing surgery plus adjuvant treatment are significantly lower than those in patients undergoing simple surgery. Recently, the radiotherapy and chemotherapy of the malignant fibrous histiocytoma are gradually taken seriously and have achieved a certain effect. The postoperative radiotherapy is a practical and feasible method to reduce the chance of recurrence. The chemotherapy, especially high-dose chemotherapy, has been widely used in treatment of the malignant fibrous histiocytoma; the chemotherapy adopts the combined use of drugs, and the commonly used chemotherapy regimens include ifosfamide (IFO) + adriamycin (ADM), cisplatin (DDP) + doxorubicin, cyclophosphamide, vincristine, doxorubicin, and dacarbazine (CYVADIC). The preoperative chemotherapy is conducive to limb salvage and in reducing the surgical range [11].

5.7 Clinical Cases

Typical case: The patient, male, 52 years old, 2 weeks after incomplete resection of malignant fibrous histiocytoma in the right elbow. There was no axillary lymph node enlargement. There was no surgical contraindication. After preoperative preparation, the patient underwent extensive lesion resection plus the repair with the lateral upper arm skin flap under general anesthesia (Fig. 17.4).

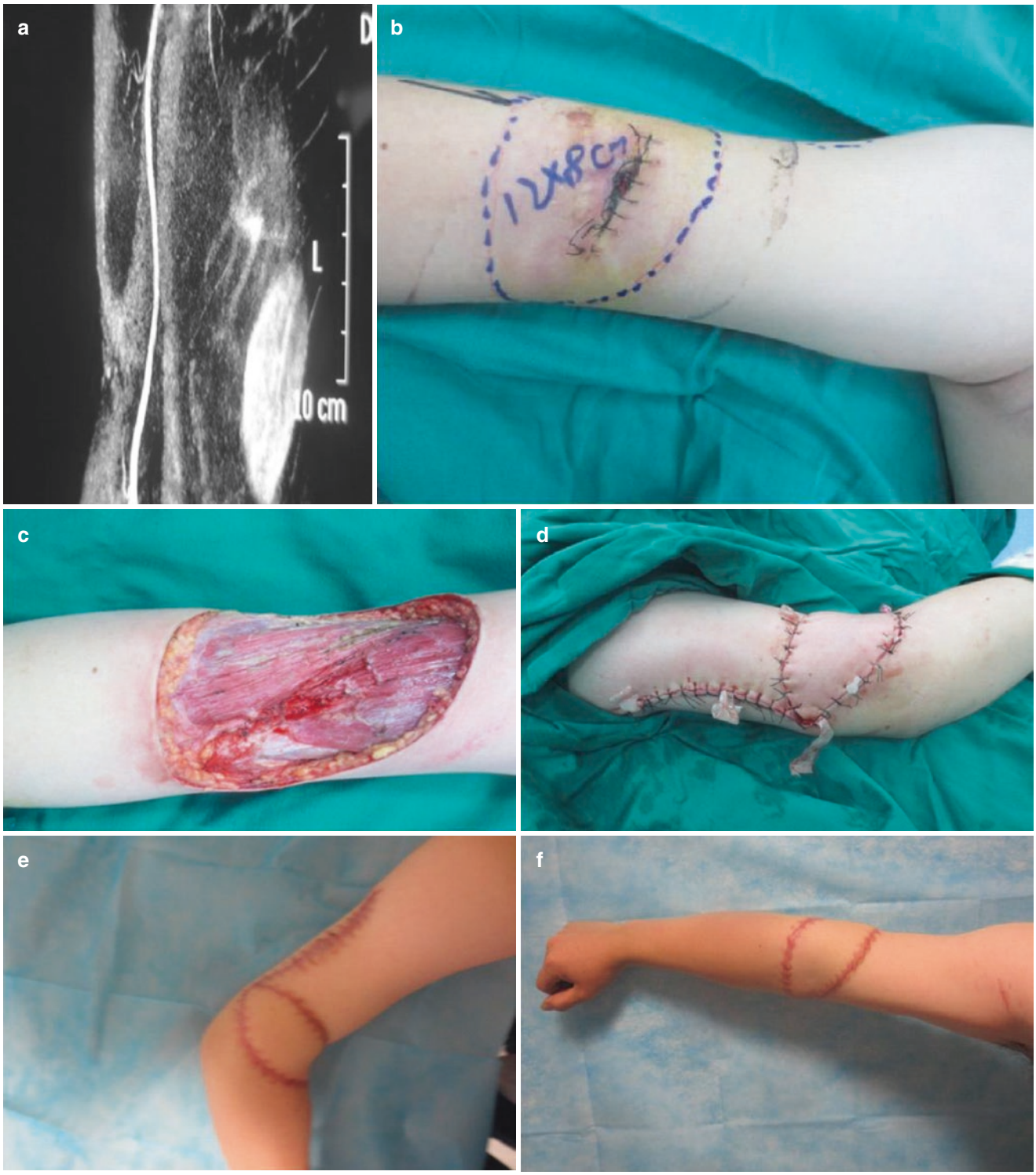

Fig. 17.4 The patient with recurrence after resection of malignant fibrous histiocytoma in the right elbow. (**a**) the recurrence after resection of malignant fibrous histiocytoma in the right elbow. (**b**) Preoperative lesion. (**c**) Tissue defect after extended resection of tumor. (**d**) Tissue defect was repaired with the upper arm skin flap. (**e**) The elbow joint examined in flexed position at 6 months after surgery. (**f**) The elbow joint examined in straight position at 6 months after surgery

6 The Osteoclastoma of the Upper Limb

6.1 Overview

The osteoclastoma is an aggressive primary benign bone tumor which is composed of proliferative mononuclear cells and osteoclast-like multinucleated giant cells and has a tendency to local recurrence, because it can have distant (lung) metastasis, and is also considered as the intermediate or low malignant bone tumor. The chondroblastoma, chondromyxoid fibroma, simple bone cyst, brown tumor of hyperparathyroidism, nonosteogenic fibroma, aneurysmal bone cyst, and some osteosarcomas are giant cell-rich primary bone tumors. In the Enneking surgical staging, they are usually defined as stage III tumors; the lesions with strong invasiveness often are defined as stage I tumors.

The osteoclastoma of the upper limb bone usually occurs in patients with maturely developed bone, the age of predilection is 20–40 years, and a very few people have this disease before epiphyseal closure. The female incidence rate is slightly higher than the male incidence rate, accounting for 56.4%. In the group below 20 years of age, the female incidence rate is significantly higher than the male incidence rate, accounting for up to 72%. The giant cell tumor of the upper limb bone mainly involves the bone epiphyseal ends in adults; and when it occurs in children before the epiphyseal closure, it mainly involves the metaphysis.

6.2 Pathological Manifestation

The typical sites invaded by the osteoclastoma are the epiphyses of long bones and the metaphyseal regions; the articular subchondral bone is almost always invaded and the cartilage is intact. If the timely treatment is not carried out, because the tumor is too large, the diaphysis may be involved. The tumor is usually eccentric to the long axis of the bone. In a few patients with unclosed epiphysis, the tumor can penetrate through the epiphyseal plate from the metaphysis and invade the diaphysis. The medial cortex bone is absorbed, the margin of the bone is invaded by the tumor, the periosteal new bone appears, the regenerated new bone forms the sheath surrounding the tumor, and there is often a layer of fibrous tissue or bone response in the outer layer of the metaphysis. The tumor is gray and reddish brown and consists of soft blood vessels and fibrous tissue. The tough part is the grayish yellow and is the area of fiber and collagen; the bone-like substance may be the result of previous fractures and degeneration. The necrosis and hemorrhage areas may lead to tumor cystic degeneration. This performance is very obvious, and sometimes it can be similar to aneurysmal bone cyst. The histological patterns, imaging characteristics, and clinical characteristics of the osteoclastoma in hand and foot short bones are similar with the giant cell reparative granuloma, and it is difficult to distinguish between the two.

6.3 Clinical Characteristics

6.3.1 Symptoms

The symptoms of the osteoclastoma of the limb are mainly demonstrated as different degrees of pain and may be associated with swelling and limitation of activity; the course of disease ranges from a few weeks to several months, with no specific performance, and it is difficult to be distinguished from other bone tumors from the aspects of symptoms. The osteoclastoma is mostly a single lesion and often occurs in the bone epiphyseal ends of the long bones, commonly seen in the distal radius; it is also seen in the proximal humerus, occasionally in the small bones of hands and feet.

6.3.2 Imageological Examination

1. X-ray plain film. For the imaging examination of the osteoclastoma, X-ray plain film is the radiological examination means with the most valuable diagnostic value. The X-ray plain film of osteoclastoma shows osteolytic damage in bone epiphyseal ends, which can invade the metaphysis, extend toward the joint, and invade partial or total bone cortex under the adjacent articular cartilage. The size of the tumor is related to the size of the diseased bone. The tumor invasion range along the long axis of the affected limb bone is often less than the tumor invasion range along the horizontal axis; the sievelike changes can be observed at the side of the diaphysis, while the obvious bone cortical expansion and thinning can be observed around the bone epiphyseal end. There are varying degrees of osteolytic changes within the lesions, and there is mostly no periosteal reaction outside the cortex; when the pathological fracture occurs, the periosteal reaction can be observed. It can be usually observed that the subperiosteal new bone is interrupted, the periosteum is maintained intact, and there may be a clear boundary at the marginal part of the affected cancellous bone. The osteoclastoma has no tumor matrix mineralization, the joint effusion is rarely seen, but it is often associated with the occurrence of pathological fracture. The osteoclastoma in the places outside the long bone has no characteristic manifestation on X-ray plain films, and there is no difference compared with other osteolytic lesions. The osteoclastoma of the long bone has its unique imaging manifestations and typical occurrence sites; in most cases, a definite diagnosis can be made with X-ray plain films; however, before surgical treatment, the histological diagnosis is still necessary, because similar logical manifestations can also be found in other diseases, such as malignant fibrous histiocytoma, osteosarcoma, and other tumors.

2. CT. CT is superior to X-ray plain film in determining the scope of the tumor, which can accurately determine the scope of the tumor in the cortex, the relationship between the tumor and other structures, whether the cortex is intact, and the invasion range of the tumor. On CT plain film, part of the reactive changes and edema in the cortical surface and synovial membrane resemble a part of the tumor. In addition, non-reinforced CT cannot distinguish between the tumor and the muscle, because both have the same attenuation coefficient. CT can show the damage degree of the subchondral bone only through the way of reconstruction. The liquid-liquid planes can be observed within the tumor, which are caused by the osteoclastoma combined with the aneurysmal bone cyst.
3. MRI. For the osteoclastoma, magnetic resonance imaging (MRI) is the best imaging method, which has a high-quality contrast and resolution, and the multiplanar imaging can be carried out. CT cannot determine the scope of the tumor outside the cortex, and MRI also cannot, because the tumor has the same attenuation coefficient as that of the adjacent muscles. It is better to use CT to determine the small cortical damage, because MRI has a poor resolution in space existence.
4. Bone scan. The bone scan is also used for the diagnosis of osteoclastoma. In the place invaded by the osteoclastoma, the uptake of 99mTc radionuclide is increased. The increased radionuclide uptake may be dispersed, and the blood concentrates at the marginal part, while the concentration in the central part is lower. The radionuclide uptake may exceed the tumor boundary, and therefore, the bone scan cannot be used to properly judge the invasion range within the medullary cavity. The tumors located in soft tissue have a very low radionuclide uptake, and the bone scan also cannot be used to determine the tumor invasion range outside the bone. The increase of radionuclide uptake can occur in the joints adjacent to the tumor, and the joints without tumor invasion can also have radioactive concentration. The bone scan can neither confirm the diagnosis of osteoclastoma nor determine the tumor invasion range; therefore, the application is limited. The bone scan can exclude or help diagnose the multiple lesions.

Furthermore, the angiography is rarely used as a diagnostic means and is only used to determine the relationship between the huge tumor and the main blood vessels.

6.4 Diagnosis and Differential Diagnosis

Confirming the diagnosis of osteoclastoma of upper limb before treatment is a basic prerequisite for proper treatment. After imageological examination and preoperative preparation, it is required to carry out biopsy. For osteoclastoma, the aspiration biopsy can make a definite diagnosis for the vast majority of cases and can also reduce the possibility that the local soft tissue is contaminated and implanted by the tumor cells.

6.5 Treatment

6.5.1 Indications and Contraindications

The amputation is only suitable for patients with grade III cancerization and recurrence (refer to Sect. 17.2 of this chapter).

6.5.2 Surgical Methods

The selection of surgical incision is determined according to the local anatomy and the site damaged by the tumor. The incisal exposure range should include the reaction zone and the surrounding normal bones; these parts can allow windowing and removing lesions. An enough bone window is opened to expose all lesions within the bone, so as to avoid incomplete curettage due to the covering of the bone or soft tissue. After the tumor curettage, the appropriate material should be selectively used to fill in the bone defect to restore the strength of the articular subchondral bone in the shortest possible time. If the lesion is small, the autogenous bone transplantation can quickly solve the problem; the reconstruction of blood supply of bone defects filled with allogeneic bone is slower than that with autologous bone. If the bone defect is too much, the autogenous bone cannot meet the needs of the filling; the combined implantation of autologous and allogeneic bones can be carried out; at the moment, the autologous bone should be placed directly in the area under the joint cartilage, and the allogeneic bone is placed in the area which is unimportant for bone repair. The bone cement (polymethylmethacrylate) is infused under tourniquet to play the effect of polymerization in the absence of blood. After complete hemostasis, the wound is closed with absorbable suture line layer by layer, and the drainage tube is routinely placed. If the patient with bone cement treatment after a period of recovery has indeed no performance of recurrence, the implantation of the autologous bone under the joint cartilage combined with the use of allogeneic bone can be applied to replace the bone cement. If after the marginal resection or expanded local resection is carried out, the local recurrences in admission passage site or other parts are derived from the soft tissue pollution caused by the resection or biopsy. The results of treatment of osteoclastoma with marginal resection or extensive resection are associated with the biological characteristics of the tumor.

The functional recovery after surgical treatment is related to the resection range and reconstruction means. The complication incidence rate in patients with allogeneic bone graft is

higher, but approximately three fourths of the patients can achieve acceptable functions. The complication rate of the autogenous bone transplantation in distal radius is as high as that of the arthrodesis, but most patients can achieve satisfactory results. The scraping method for tumor resection is significantly associated with local recurrence. The complications of the effective curettage plus physical and chemical adjuvant treatment are mainly demonstrated as the complications of the wound and the fracture of the diseased bone; after appropriate treatment, the results can still be satisfactory. For the huge limb osteoclastoma with a wide invasion range, if the resection or effective reconstruction cannot be carried out under a safe surgical boundary, the amputation is also an effective treatment method. When the tumor involves a large area of the skin, the pedicled or free skin flap can be used for repair.

The effect of chemotherapy on osteoclastoma is not satisfactory, and the chemotherapy drugs should be carefully selected. For the patients with distant metastases, either preoperative or postoperative metastasis, the progression of the disease should be controlled before the metastatic tumor is resected. The radiotherapy on osteoclastoma can cause the secondary sarcoma in the pathogenic site. For a few clearly diagnosed benign osteoclastomas, primary or secondary lesions which cannot be removed by surgery, the high-voltage radiotherapy can be carried out. Malignant osteoclastoma refers to that the patient with osteoclastoma has recurrence after several years of treatment, especially after radiotherapy and clinical imaging, and histological manifestations present as the sarcoma. It is malignantly transformed into osteosarcoma, malignant fibrous histiocytoma, or fibrosarcoma; their treatment methods are the same as that of the primary malignant bone tumor.

6.5.3 Postoperative Evaluation

Through timely and regular treatment, most osteoclastomas can be cured. The results of the fracture after appropriate treatment can still be satisfactory. The recurrence rate after expanded curettage of the huge limb osteoclastoma with a wide invasion range is less than 10%, and the reoperation can also be carried out after recurrence. The treatment of 3–6% of patients with metastasis is more difficult and is a difficult problem which is currently met.

6.6 Evaluation Method of Treatment and Its Standard

Osteoclastoma is a stage I tumor, according to treatment principles for the Enneking staging of musculoskeletal system; the surgical treatment with incisal margin greater than surgical boundary should be carried out. The traditional standard treatment of the osteoclastoma is that the tumor is curetted, and the small pieces of autogenous iliac bone containing cortical and cancellous bone are used to fill the cavity left by tumor curettage. This method of intratumoral resection can only reach the intracystic surgical boundary, and the small lesions can be left within the bone. No matter how careful and thorough the curettage is, some small lesions may be left. If this method of tumor curettage plus bone transplantation is used for treatment of the osteoclastoma, the local recurrence rate can be as high as 40–60%, and therefore, it is necessary to carry out marginal or extensive resection of osteoclastoma. The complete resection reduces the recurrence rate of the tumor, but it also brings some problems on defect repair and functional recovery. The ideal treatment method should be the surgical curettage plus the adjuvant therapy, so as to achieve the purpose of the marginal or extensive resection, not only reducing the recurrence rate of the tumor but also greatly limiting the retention of limb function. The chemical or physical methods can help achieve this goal; the chemical methods include the application of phenol solution or anhydrous alcohol to smear the inner surface of the cavity after tumor curettage and the application of cytotoxic substances (e.g., topically applied chemotherapeutic drugs) onto the surface where the local recurrence may occur. The physical treatment methods include freezing or heat treatment. The freezing of the cavity after tumor curettage can effectively control the recurrence, but the incidence rates of postoperative local damage and bone complications are higher. The heat generated when using the bone cement to fill the cavity after intratumoral resection is used to prevent the recurrence, namely, the pyrogenic reaction of bone cement causes the local heating, and so the residual tumor tissue is necrotized, while the normal tissue is not damaged. Theoretically, it is possible that the bone cement produces chemical cytotoxic effects on local area in the polymerization process, but it is not reliable; the main advantages of bone cement filling should be that the early weight-bearing is permitted and it is easy to observe the recurrence. The direction of the treatment of osteoclastoma should be to directly control the lesion without affecting the joint function.

Another characteristic of the osteoclastoma is the rich blood supply, and the use of the tourniquet is very helpful for surgical treatment. For the lesion which cannot be treated using a tourniquet and has rich blood supply, the preoperative arterial embolization can be carried out on the day before surgery or the day of surgery; the gelatin sponge or polyvinyl alcohol ball is selectively placed into the artery branch supplying blood to the tumor, when the intratumoral resection or marginal resection is carried out; this method can significantly reduce the bleeding. If the extensive or marginal resection is the ideal method, the junction of the normal cortex and the lesion must be exposed during the surgery, so as to confirm the transition of normal tissues to pathological tissue. The characteristics of the osteoclastoma confirm that the mass has grown very large before diagnosis, because the margin is not clear; the surgeon may be misled into tumor during blunt dissection and thus cause the

pollution, which should attract attention. At any time before tumor resection, for the patients with joint space pollution caused by neoplastic fracture or open biopsy, the extra-articular resection should be considered. If there may be residual tumor cells, the synovium of joint should be carefully examined, and the extensive resection should be carried out. The osteoclastoma affects the epiphyseal ends of long bones, and may cause loss of joint function, and it is required to carry out joint reconstruction. The fibular autologous bone graft is used for reconstruction of the distal radius; it is required to resect two carpal bones, and the carpal joint formed by this kind of bone transplantation can provide a functional upper limb. Most osteoclastoma can be treated with the method such as curettage plus local adjuvant therapy [12].

7 The Epithelioid Sarcoma of the Upper Limb

7.1 Overview

The epithelioid sarcoma (ES) is a rare soft tissue malignant tumor of uncertain histological origin. The literatures have referred to this type of tumors as the synovial sarcoma and the giant cell sarcoma of tendon sheath. Berger described correctly the pathological characteristics of the epithelioid sarcoma in 1938, but which is regarded as a type of synovial sarcoma. De Santo described it as atypical synovial sarcoma in 1941, and Bliss and Reed called it as the large cell sarcoma of the tendon sheath in1968. In 1970, based on the summary of 62 cases, Enzinger described the epidemiology, pathological characteristics, and clinical manifestation of this tumor in detail and then named it as the epithelioid sarcoma. Although the epithelioid sarcoma is rare, it has leaped into the top three primary soft tissue malignant tumors in hand; moreover, the recurrence rate is high, and the prognosis is poor.

The epidemiology shows that the male-to-female incidence ratio is 2:1; 20–40 years is the age segment of predilection. The patients don't have a clear history of trauma; only a very small number of patients have a history of trauma, and the length of the period from getting injured to finding the tumor is irregular. The tumors are mostly located in the limbs, predominantly in the hands.

7.2 Pathological Manifestation

The distal ES is characterized by the formation of multiple granulomatous nodules (pseudo-granuloma), the boundary is more clear, and the shape is irregular. The necrosis often occurs in the nodule center, it is often combined with hemorrhage and cystic degeneration, and the chronic inflammatory cell infiltration can also be observed. The necrotic nodules in multiple centers can be integrated with each other to form the map-like necrosis. There are epithelioid tumor cells surrounding the nodules; the volumes are larger, polygonal or circular, and oval; the cell nuclei are circular or oval; the cell atypia is mild; there is nuclear vacuolization; and small nucleoli are observed. The mitotic figures are rarely seen, often less than 5/10HPF. The intercellular collagen deposition is obviously observed. Some tumor cells have abundant eosinophilic cytoplasm and are called as eosinophilic epithelioid cells, similar to the striated muscle cancer cells or malignant rhabdoid tumor cells. Some tumor cells are spindle, and the cell bodies are relatively fatty, similar to fibrosarcoma cells. Some ESs show significant spindle cell proliferation, but the cell atypia is lower; they are embedded in abundant collagen-rich extracellular matrix and are called as fibroma-like type. Sometimes the epithelioid tumor cells and the spindle cells are mixed together, similar to biphasically differentiated synovial sarcoma. Sometimes the adhesion force between tumor cells is decreased, accompanied by the hemorrhage within tissue, which may appear similar to manifestations of the angiosarcoma. If the fat droplets within the tumor cells are dissolved, which are similar in appearance to the lumens within cells, the tumor can be regarded as epithelioid hemangioendothelioma. Sometimes the tumor often grows along the neurovascular bundle; the perivascular or perineural infiltration of tumor cells is commonly observed. A few tumors can have dystrophic calcification and bone formation (10–20%).

7.3 Clinical Characteristics

The epithelioid sarcoma of the upper limb most commonly occurs in the extensor side of the forearm, palms, and the palmar surfaces of fingers; the lesions may be located under the skin and may also be located in the deep tissues. When the lesions are located under the skin, the lesion is often single or multiple hard lumps; if it has skin invasion, it is often combined with ulceration; the lesions locating in deep tissue often invade the muscle tendon, tendon sheath, or fascia tissue and are larger and ill-defined masses. There are no obvious self-conscious symptoms in most cases at the initial stage; only the fixed skin or subcutaneous nodules can be touched. Fifty percent of cases have multiple lesions; sometimes multiple nodules can merge into each other; its long diameter is greater than 20 cm, and the tumors often invade the deep fascia and deep tissue, but rarely involve the skin; therefore, the skin color in the tumor surface is mostly normal. If the skin is involved, the skin color will be changed into brown-red; other cases have a single lesion, its long diameter is greater than 5 cm even up to 10 cm, along with the progress of the disease course, and the ulcer can occur in the central part of the tumor. Compared with other malignant tumors in the limbs, its growth rate is relatively slow.

The literature statistics showed that the follow-up duration varied, the results were that 30% patients died, 70%

patients had recurrence, both occurred within 12 months, and a few patients had recurrence up to three times. This tumor could be metastasized via lymph node metastasis or hematogenous metastasis, and the longest survival time was 11 years after surgery [13].

7.4 Diagnosis and Differential Diagnosis

7.4.1 Diagnosis

The misdiagnosis rate of the epithelioid sarcoma of the upper limb is higher, and it is often misdiagnosed as benign tumors, such as inflammatory granuloma, fibroma, and nodular fasciitis, and is also often misdiagnosed as malignant tumors such as synovial sarcoma, squamous cell carcinoma, malignant melanoma, and malignant schwannoma. Therefore, the lack of specific clinical manifestations is the characteristic of the tumor, and therefore, the final definite diagnosis should still be determined according to the pathological examination results. Although the epithelioid sarcoma has been identified as the malignant tumor, because the onset of the disease is slow, there are fewer symptoms, and the disease in some patients lasts more than 10 years or even repeatedly occurs; the repeated resection is carried out for more than ten times, and it is sometimes easy to be misdiagnosed as the benign tumor. At the time of diagnosis, the clinical data, tumor tissue morphology, and immunohistochemistry results must be combined with each other for overall consideration.

7.4.2 Differential Diagnosis

The epithelioid sarcoma should be distinguished from the following diseases [14–17]:

1. Benign lesions. The epithelioid sarcoma has a long course of disease and grows slowly, with mild symptoms or no symptoms, sometimes accompanied by skin ulcers in the diseased region; it is displayed as the granulomatous lesion under the microscope, and therefore, the superficial single nodule or multiple nodules can be misdiagnosed as benign inflammatory lesions such as necrotizing granulomas, lipid necrobiosis, and rheumatoid nodules. But the epithelioid features of epithelioid sarcoma, typical nodular arrangement and cytokeratin (CK), and positive epithelial membrane antigen (EMA) staining are conducive to its differentiation from benign lesions.
2. Epithelioid angiosarcoma. Histologically, both are composed of large epithelioid cells and have cytoplasmic vacuoles and positive CD34; sometimes the epithelioid sarcoma may be manifested in the form of pseudo-artery sarcoma. However, the epithelioid sarcoma has positive CK and the endothelial-like characteristics such as negative factor VII-related antigen and CD31. While the epithelioid angiosarcoma is characterized mostly by the cytoplasmic vacuolation in single tumor cell and the formation of the original vascular lumen, 10% of tumors may contain red blood cells, no central necrosis, negative CK, and positive factor VII-related antigen and CD31.
3. Synovial sarcoma. The immunohistochemical expressions of CK and vimentin can be positive in both. The synovial sarcoma is more common in the vicinity of the knee joint and other large joints; the skin in tumor surface has no ulcer; under the microscope, it generally shows no nodule-shaped distribution, there is a clear dividing line between the epithelioid tumor cells and spindle-shaped tumor cells, the morphology of two-way differentiation is formed, and CD34 is negative. The epithelioid sarcoma is more common in the forearm, hand, and fingers, and the skin in tumor surface can have ulcers; there is a transitional phenomenon between the spindle-shaped tumor cells and the epithelioid tumor cells under the microscope, and most patients have positive CD34.
4. Epithelioid malignant peripheral nerve sheath tumor. Sometimes the epithelioid malignant peripheral nerve sheath tumor can be confused with the epithelioid sarcoma, but the former has positive S-100 and negative CK and EMA, while the epithelioid sarcoma has negative S-100 and positive CK and EMA. In addition, sometimes the epithelioid sarcoma invading the skin with ulceration requires differentiation from ulcerative squamous cell carcinoma, and the epithelioid sarcoma lacks keratin beads and has dyskeratosis in adjacent epithelia, but the metastatic epithelioid sarcoma can sometimes be mistaken for squamous cell carcinoma in cytologic examination.

The aspiration biopsy and electronic microscope examination can be carried out for auxiliary diagnosis, but there are reports that the biopsy shows no definite tumor cells, and the electron microscope also shows no specific microstructure features. In the aspect of immunohistochemistry, four items of CK, vimentin, EMA, and S-100 protein are regularly examined; the cytogenetic studies, chromosome analysis, and DNA blot examination can also be performed for the molecules in epithelioid sarcoma cell line; and the results of the experiment suggest that this tumor is related to the chromosomal structural abnormality of del (3) (q21.1) and the change in PCCB genes.

7.5 Treatment

7.5.1 Indications and Contraindications of Limb Salvage Surgery

1. Main indications
   (1) Enneking stage IA, IB, and IIA patients and some stage IIB chemotherapy-sensitive patients; and the major blood vessels and nerves are not affected.
   (2) If the local soft tissue conditions permit, the extensive resection can be achieved.

(3) There is no metastatic lesion or the metastatic lesion can be cured.
(4) The general condition is good, and the patient has a strong desire for limb salvage.

2. Contraindications. The recurrent tumors have huge tumor body, poor differentiation, and bad soft tissue condition, or when the major blood vessels and nerves surrounding the tumor are invaded by the tumor, it is advisable to perform amputation surgery.

7.5.2 Surgical Methods

Surgical methods include:

1. The tumor and surrounding reactive tissue can be resected by means of marginal resection, and the intraoperative pathological examination can determine whether the tumor cells are retained in the margins.
2. The tumor and all tissue structures in the fascia compartment where the tumor is located or the surrounding 3 cm (minimum) normal tissue are extensively resected.
3. All tissues outside the joint adjacent to the tumor are radical resected, or the amputation is carried out. Most foreign scholars believe that the epithelioid sarcoma is treated appropriately with extensive resection or radical resection; the combined use of radiotherapy may increase the efficacy.
4. The repair with pedicled or free skin flap. When the tumor involves the skin, the pedicled or free skin flap can be used for repair.

7.5.3 Postoperative Evaluation

Currently the surgical treatment is still the main treatment measure, and it is divided into local resection, extensive resection, and radical resection. Due to the small average age of onset of ES and the high requirements for quality of life, therefore the limb salvage surgery at the early stage is the preferred surgical approach. The range of the limb salvage surgery can generally only meet the requirement of extensive resection, but requires soft tissue reconstruction and coverage; nonhealing wounds and skin flap necrosis may occur after surgery. But some reports confirm that, for the treatment of soft tissue sarcoma, the limb salvage surgery has no significant correlation with the local recurrence rate and the survival rate. The surgical target of the soft tissue sarcoma is that the tumor is resected totally, and the frozen biopsy of the margin is negative; if possible, the removal of the tumor should include 2–3 cm normal tissue.

7.6 Evaluation Method of Treatment and Its Standard

The epithelioid sarcoma grows slowly, its clinical manifestations are not prominent, the physical signs lack specificity, it has a high recurrence rate after surgery, and the prognosis is not ideal. The disease is prone to lymphatic metastasis; the lymph nodes adjacent to the lesion should also be dissected as far as possible, supplemented by postoperative chemotherapy and radiotherapy, but the effects of chemotherapy and radiotherapy are still not accurate. The large-dose radiotherapy on the surgical site may have auxiliary value.

8 The Tendon Sheath Fibroma of the Upper Limb

8.1 Overview

The fibroma of tendon sheath (FTs) is a rare dense fibrous nodule, and it mostly originates from the tendon or tendon sheath tissue of the limbs. The typical morphological feature is that the fibroma is consisted of a small amount of spindle-shaped cells with mild appearance and dense collagen fibrous stroma, containing varying amounts of crack-like vascular compartments. The fibroma of tendon sheath was first proposed by Geschickter and Copeland in 1936, and the disease could get to be known again until Chung et al. reported 136 cases in 1979.

8.2 Pathological Manifestation

The fibroma of tendon sheath is a relatively rare benign soft tissue tumor, and it has now been confirmed that the fibroma of tendon sheath is a proliferative lesion of fibroblast and (or) myofibroblast through researches on its morphology, enzyme histochemistry, immunohistochemistry, and ultrastructure. The lesion mostly occurs in the tendon and tendon sheath, it originates from the synovium of joint in a few cases, and it involves the subcutaneous tissue in individual cases. Therefore, the fibroma of tendon sheath is also known as the synovial fibroma of tendon sheath.

Under microscopy, the perimeter of the tumor tissue is clear, and the tendon or tendon sheath may be residually left. The invagination of small nerve bundle can be observed around a few lesions, which may be one of the causes of lesion tenderness and pain. A few cystic cavities in partial lesion margin or parenchyma are covered with synovium, suggesting that lesion may also occur in the synovial tissue. The typical histological manifestations include: the lesion is separated into multiple lobules by the long and narrow fissure-like vascular compartments, and each leaflet is consisted of tightly surrounded spindle-shaped cells and dense collagen fibrous stroma. Some lesions have histological diversity such as focal interstitial edema, mucoid degeneration, cystic degeneration, and cell composition with a variable density and have no manifestations of tumor necrosis, pathological mitotic figure, and nuclear atypia [18].

8.3 Clinical Characteristics

The typical fibroma of tendon sheath of the upper limb shows slow growth of the mass in local area, a few cases may be accompanied by pain or tenderness, the disease is more common in adult males, the incidence rate of male-to-female ratio is 3:1, and the peak incidence is between 30 and 50 years. The most common incidence sites are the fingers, hands, and wrists, especially that the right index finger and middle finger are more commonly seen. The fibromas of tendon sheath occurring in the hands account for 75–82% of all cases and account for 3% of all soft tissue tumors occurring in the hands. The typical manifestation is the small, hard, painless, and slowly increased nodular mass which attaches to the tendon and tendon sheath, and it may be associated with symptoms such as carpal tunnel syndrome and ulcers. Clinically, it is often diagnosed as ganglion cyst. About 15% of cases have a relationship with the local history of trauma.

Although there are no characteristic imaging manifestations on MRI, CT, and B-ultrasound, the location, size, and texture of the lesion, and its correlation with the surrounding tissues can be clearly shown. There is no X-ray abnormality in most cases, but when the tumor compresses the surrounding muscle, fat, and bone tissues, the translucent soft tissue mass shadow and bone invasion shadow can be displayed. The lesions are not of uniform size. The section surface is lobulated and may have myxoid degeneration and cystic degeneration.

8.4 Diagnosis and Differential Diagnosis

It is not difficult to diagnose most fibromas of the tendon sheath, but it is easiest to diagnose especially when the lesion is closely connected with the tendon or tendon sheath, and histologically the lesion is only consisted of the dense collagen matrix and fewer spindle-shaped cells. However, when the lesions appear in the atypical sites and morphologically the performance heterogeneity appears, these tumors may lead to diagnostic confusion, and therefore, they still need to be differentiated from the following diseases:

1. The giant cell tumor of the tendon sheath. The giant cell tumor of the tendon sheath morphologically consists of histiocyte-like monocytes, osteoblast-like multinucleated giant cells, foam cells, chronic inflammatory cells, hemosiderin-laden macrophages, and collagen-based matrix which are mixed in different proportions; while the fibroma of tendon sheath doesn't have foam cells and hemosiderin-laden macrophages, occasionally only a few multinucleated giant cells are observed, and the differentiation between both is not difficult.
2. Nodular fasciitis focal. The cell-rich focal areas of some tendon sheath fibromas show fasciitis-like morphological characteristics; sometimes these areas are difficult to be identified with the nodular fasciitis. However, the fibroma of tendon sheath with fasciitis has more or less typical dense collagenous fibrous stroma, sparse spindle-shaped cells, and fissure-like vascular compartments; both are mutually transitional, mostly occurring in the metacarpophalangeal area. The nodular fasciitis has more mucus; the spindle-shaped cells are generally fatty, showing an arrangement which is the same as that in the medium; there is obvious red blood cell extravasation and inflammatory cell infiltration, which rarely occur in metacarpophalangeal area; and the differentiation between both is not difficult. For terminal nodular sclerotic fasciitis, morphologically there is a lack of fissure-like vascular compartments, and it can be identified with the tendon sheath fibroma.
3. Fibrous histiocytoma. The fibrous histiocytoma is a tumor consisting of fibrocytes and hypertrophic histiocytes, similar to some tendon sheath fibromas with rich cells which show a spiral-shaped arrangement. However, the former lacks the fissure-like vascular compartments and sclerotic collagenous fibrous stroma, and the latter lacks the histiocytes and has the classic histological pattern of the tendon sheath fibroma; both are easy to identify.
4. Desmoplastic fibroblastoma. The desmoplastic fibroblastoma is consisted of sparse spindle- or stellate-shaped fibroblasts and a lot of dense or fibrous myxoid stroma, lacks the narrow fissure-like vascular compartments, and has no cell-rich area.
5. Fibromatosis. When the fibroma of tendon sheath has rich focal cells which are arranged in bundles morphologically, it is similar to the fibromatosis. However, the latter has obscure boundary and shows an obvious invasive growth and has no fissure-like vascular compartments; the spindle-shaped tumor cell nuclei have an expression of β-catenin, and it is easy to be identified with the fibromatosis with clear boundary.

8.5 Treatment

8.5.1 Surgical Indications

For the patients with the fibroma of tendon sheath of upper limb who have been definitely diagnosed and have been excluded with the systemic diseases which cannot tolerate operation or the local infection focus which may lead to postoperative infection, the surgical treatment can be carried out.

8.5.2 Surgical Methods

The marginal resection outside the fibrous capsule is carried out during surgery; generally there is less recurrence, but all recurrences appear after the intracapsular resection of the tendon sheath fibroma. Therefore, a layer of healthy tissue (such as adipose tissue) outside the tumor capsule should be removed together during surgery, in order to reduce the recurrences. If the tendon sheath fibroma is enormous, the pedicled or free skin flap can be designed for repair according to the situation of skin defect wound after resection [19, 20].

8.5.3 Postoperative Evaluation

The fibroma of tendon sheath does not have invasive and metastatic characteristics, and its treatment is mainly the surgical resection, in order to preserve function and alleviate the symptoms. The recurrence rate of the fibroma of tendon sheath varies in literature reports. The observations show that the site where the lesion is closely linked to the tendon or tendon sheath, namely, the initial growing point of the lesion, is closely embedded within the tendon or tendon sheath like a mushroom; if only the lesion tissues outside the growing point are dissected, and the initial growing point of the lesion still remains within the tendon or tendon sheath, this is bound to increase the recurrence rate of the tendon sheath fibroma. Therefore, we hypothesize that the recurrence of the lesion may be related to the incomplete resection of the lesion, and thus, it is recommended that at the same time of trying to protect local function, the appropriately extensive resection of the tendon or tendon sheath attached to the initial growing point of the lesion is essential to reduce the recurrence rate.

8.6 Evaluation Method of Treatment and Its Standard

In short, the fibroma of tendon sheath is a proliferative lesion of benign fibroblasts and (or) myofibroblast; it occurs mostly in adults; it is more commonly seen in the upper limbs, especially most commonly seen in metacarpophalangeal area; and a few lesions can recur. Despite its varied histological morphologies, there are always typical histological features, which are also the main basis for the diagnosis and differential diagnosis.

All surgical photographs published in this chapter have been approved by the patients themselves.

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Defect Repair After Resection of the Malignant Tumor of the Lower Limb

18

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1 Overview

In terms of the boundaries between the lower limbs and trunk, the front side is the inguinal ligament, the lateral outer side is all iliac crest, the rear side is the lateral margin of the sacrococcygeal bone, and the above interfaces form a continuous boundary to separate the lower limbs and trunk. The lower lateral side of this interface is the lower limb.

The malignant tumors of the lower limbs include skin cancer and malignant melanoma originating from epithelium and soft tissue sarcoma originating from mesenchymal tissue. The oncoplastic surgery mainly involves the malignant tumors in the skin and soft tissues, including some malignant tumors of bones and cartilages which invade the skin and soft tissue. Among the skin and soft tissue malignant tumors, basal cell carcinoma and squamous cell carcinoma occur mostly in the exposed parts of the elderly people, but occur rarely in the lower limbs. Most squamous cell carcinomas of the lower limbs are secondary to chronic skin ulcers or scars. The malignant melanomas occur mainly in the heels and feet, and its incidence rate accounts for half of systemic malignant melanoma. The lower limbs are a high incidence zone of soft tissue sarcoma. According to the statistics from Shanghai Shuguang Hospital, the incidence rate of soft tissue sarcomas of the lower limbs accounts for 49.77% of soft tissue sarcomas in the whole body, of which 5.65% in the hips, 28.85% in the calves, 12.98% in the thighs, and 2.29% in the feet.

The general repair principle after resection of the malignant skin and soft tissue tumors of the lower limbs includes [1]:

1. The limbs are retained and the supporting and walking functions of the lower limbs are recovered as far as possible.
2. The wound after resection of malignant tumor is repaired to provide convenient conditions for further radiotherapy.
3. Given the fact that there are more opportunities for exposure of distal lower limbs compared with the proximal lower limbs, on the selection of local skin flap, the skin flap proximal to the defect is selected as far as possible.
4. Under the condition without affecting the functions, the original morphology of the limb is restored as far as possible.

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2 Malignant Tumors Derived from the Epithelial Tissue

2.1 Skin Squamous Cell Carcinoma

In recent years, along with the prolongation of the life span of people, the aggravation of the environmental pollution, the influence of occupational factors, and the improvement of diagnostic level, the incidence rate of malignant skin tumor is also in a growing trend, and the patients tend to be younger. In China, squamous cell carcinoma is the most common malignant skin tumor, and its incidence rate accounts for 78% ~ 90.9% of malignant skin tumors. Squamous cell carcinoma is closely related to long-term exposure to the ultraviolet light. There are large differences in reports on the component proportion ratio of skin squamous cell carcinoma among domestic hospitals; these differences may be related to sample size and sample selection bias and are simultaneously related to the differences in genetic and natural environmental factors of the populations. Due to the low incidence rate of malignant skin tumor of the lower limb, now there is still a lack of related epidemiologic data.

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2.1.1 Clinical Manifestations

This tumor is mostly solitary, and the tumor size varies from the size of green beans to 8 to 10 cm. Skin squamous cell carcinoma mostly has ulcerative, cauliflower-like, or nodular mass as the main manifestation; other manifestations include scar-like and eczema-like skin lesions. The ulcer margin is wider and is uplifted and turned over outward, sometimes the red granular base has purulent fluid accompanied by the stench, and the surface is often covered by pus scab. The surface of the nodular or cauliflower-like mass is dark red or presents with angiotelectasis, the hyperplasia of horny material is commonly observed in the central part, and the crusta is visible and is closely attached to the base; the forceful dissection will lead to easy bleeding. The early manifestation of squamous cell carcinoma occurring in the external genitalia is a hemorrhagic papillary uplift, resembling the prominent granulation tissue, but the texture is harder, with marginal uplift, and the wide, thick, and hard ulcers are observed at the later stage.

Bowen's disease is a squamous cell carcinoma in situ, and 10% of Bowen's diseases can develop into invasive squamous cell carcinomas.

Marjolin ulcers are often secondary to chronic inflammation and occur in the area where the drainage tube is placed or the scarring area. When the tumor is secondary to the chronic ulcer, the granulation tissue in the ulcer surface will be suddenly increased, the surface becomes dirty, with a fishy smell and continuous bleeding; and when the tumor is secondary to the scar, the scar surface will be ulcerated and have a delayed healing, or the ulcerated site shows an ulcerative and cauliflower-like enlargement (Fig. 18.1). These uncommon lesions have a strong aggressiveness, with a metastasis rate of 50%.

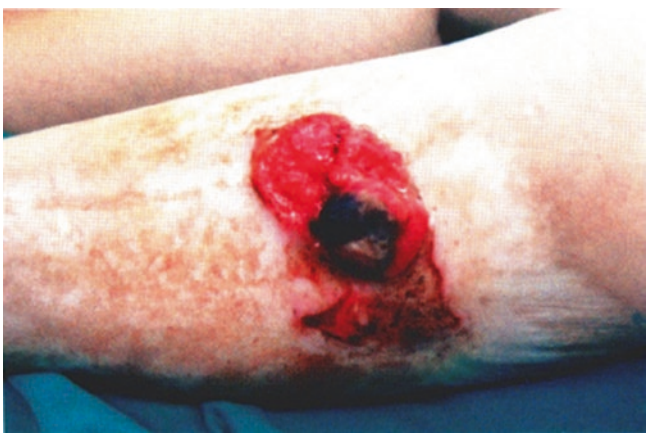

Fig. 18.1 After burn trauma in the upper segment of the left calf, the patient had recurrent ulcers for more than 10 years; the pathological examination showed skin squamous cell carcinoma

2.1.2 Surgical Treatment and Wound Repair

Currently the surgery is the preferred method for treatment of malignant skin tumor [1–4]. For the prevention of postoperative recurrence, the range of the surgical resection should be large enough, which is directly related to the prognosis of the patient and the recovery of the local appearance and function. It is generally required that when skin squamous cell carcinoma is resected, the distance between the incision and the lesion margin should be greater than 1.0–2.0 cm. At the same time, the depth of resection of skin squamous cell carcinoma should be determined according to the depth of tumor invasion.

The repair of wound after tumor resection should follow the sequence for repair of soft tissue defects, the direct suture is considered firstly, and the second consideration involves skin transplantation, local flap, muscle flap, or fascial flap combined with skin grafting, distal flap, and free flap. The distal flap should be carefully selected, which has the possibility to metastasize the tumor to the donor site. The flap is preferably selected in the pretibial area or plantar weight-bearing area, the tissue flaps available to be selected by the former for repair include the retrograde fasciocutaneous flap with sural nerve, posterior tibial artery perforator flap, gastroecnemius myocutaneous flap, gastrocnemius muscle flap, or soleus muscle flap combined with skin grafting, and the medial plantar skin flap is preferably selected by the latter [5].

It is recommended that the prophylactic or selective lymph node dissection is not performed in high-risk patients. For the palpable lymph nodes, if the biopsy confirms the presence of lymph node metastasis, the lymph nodes should be removed. There is still no conclusion on whether the guided sentinel lymph node biopsy is implemented in those patients with high risk of lymph node metastasis.

In short, the early and accurate diagnosis of skin squamous cell carcinoma requires the rich experiences of the clinicians and the support of the pathological diagnosis, thereby reducing the cases of misdiagnosis and missed diagnosis. The timely treatment is very important for the prognosis of the patient.

2.1.3 The Fasciocutaneous Flap with Nutrient Vessels of Sural Nerve and Small Saphenous Vein

The fasciocutaneous flap with nutrient vessels of sural nerve and small saphenous vein is widely used due to the fact that it doesn't damage the main blood vessels, the survival rate of the skin flap is high, and most donor sites can be directly sutured. In 1992, Masquelet et al. carried out anatomical studies on the calves in perfused fresh corpses and found that the nutrient arteries of the saphenous nerve, superficial peroneal nerve, and sural nerve not only feed their accompanying nerves but also gives off a number of cutaneous branches into the superficial fascia on the superficial surface of the

nerve. These nutrient arteries may be an artery and may also be an arterial network woven by small arteries. Moreover, these arteries are also anastomosed with the perforators of the well-known deep arteries. Based on this discovery, they put forward the concept of neurocutaneous island flap and use it in repair of soft tissue defects of the calf, of which the retrograde fasciocutaneous flap with nutrient vessels of sural nerve and small saphenous vein has attracted more widespread interest.

1. Surgical design: The retrograde fasciocutaneous flap with nutrient vessels of sural nerve and small saphenous vein is the neurocutaneous flap taking the sural nerve nutrition blood vessels as the supply vessels; the axis line of the skin flap is the connecting line between the Achilles tendon and the midpoint of the lower boundary of the popliteal fossa; the axis point can be set on the axis line at 5–10 cm above the lateral malleolus. The upper boundary of the skin flap does not exceed the junction of the upper and middle third of the posterior calf. To ensure the blood supply of the skin flap, most physicians will make the pedicle of the skin flap into the nerve and fascia pedicle with deep and superficial fascias, and the pedicle width is not less than 3 cm; therefore, this skin flap is also called as retrograde sural nerve fasciocutaneous flap. Since the nutrient vessels of the sural nerve are anastomosed with perforating branches of the peroneal artery at the ankle level, Doppler detector is used to detect around the designed axis point before surgery; sometimes the echo of blood flow can be heard; at the moment, the axis point should be changed to the site with the echo of blood flow as far as possible, in order to ensure the blood supply of the skin flap (Fig. 18.2).
2. Surgical methods: The tourniquet is used to stop bleeding in the lower limbs. The skin, subcutaneous tissue, and deep fascia are incised according to the design. Between the deep fascia and the muscle membrane, the separation is performed from both sides of the skin flap to the central axis. In the proximal skin flap, the small saphenous vein and sural nerve are explored and ligated. The skin flap is lifted up from the near to the distant; the skin flap is formed into neural and fascial pedicled island flap; the skin flap is transferred to the receptor site through the tunnel between the skin flap and the receptor site (or the skin is incised). The donor site is directly sutured or is implanted with the intermediate-thickness skin graft.
3. Typical cases
   (1) Case I: The patient, male, 72 years old, had a chronic ulcer complicated with squamous cell carcinomas on the posterior side of the ankle of the left calf; the wound after skin flap resection was covered with the fasciocutaneous island flap with nutrient vessels of sural nerve and small saphenous vein (Fig. 18.3).
   (2) Case II: The patient, male, 54 years old, had squamous cell carcinoma above the medial malleolus of the left calf; the wound after tumor resection was covered with the fasciocutaneous island flap with nutrient vessels of sural nerve and small saphenous vein (Fig. 18.4).
   (3) Case III: Skin squamous cell carcinoma in the left popliteal fossa was treated with the extensive resection of the left popliteal fossa lesion plus the repair with free latissimus dorsi skin flap (Fig. 18.5).
4. The advantages and disadvantages of the skin flap: The main advantages of the retrograde fasciocutaneous flap with nutrient vessels of sural nerve and small saphenous vein are that the blood supply is reliable, the rotating radian of the skin flap is large, the surgical operation is simple, and there is no damage to the well-known vessels.

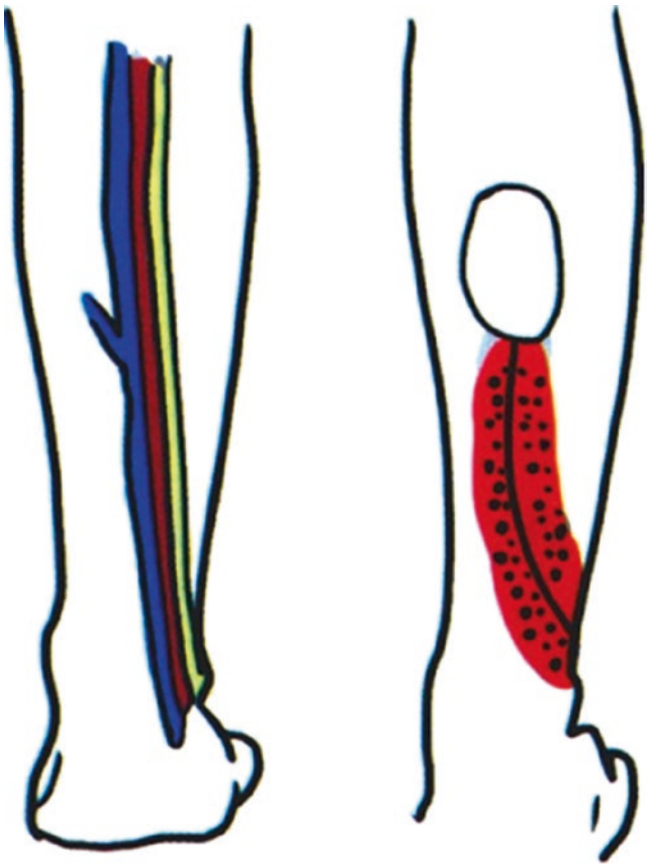

Fig. 18.2 Design of sural nerve and its nutrient vessels and skin flap

The main disadvantage of this skin flap is the discomfort caused by the lateral foot numbness after surgery. But the

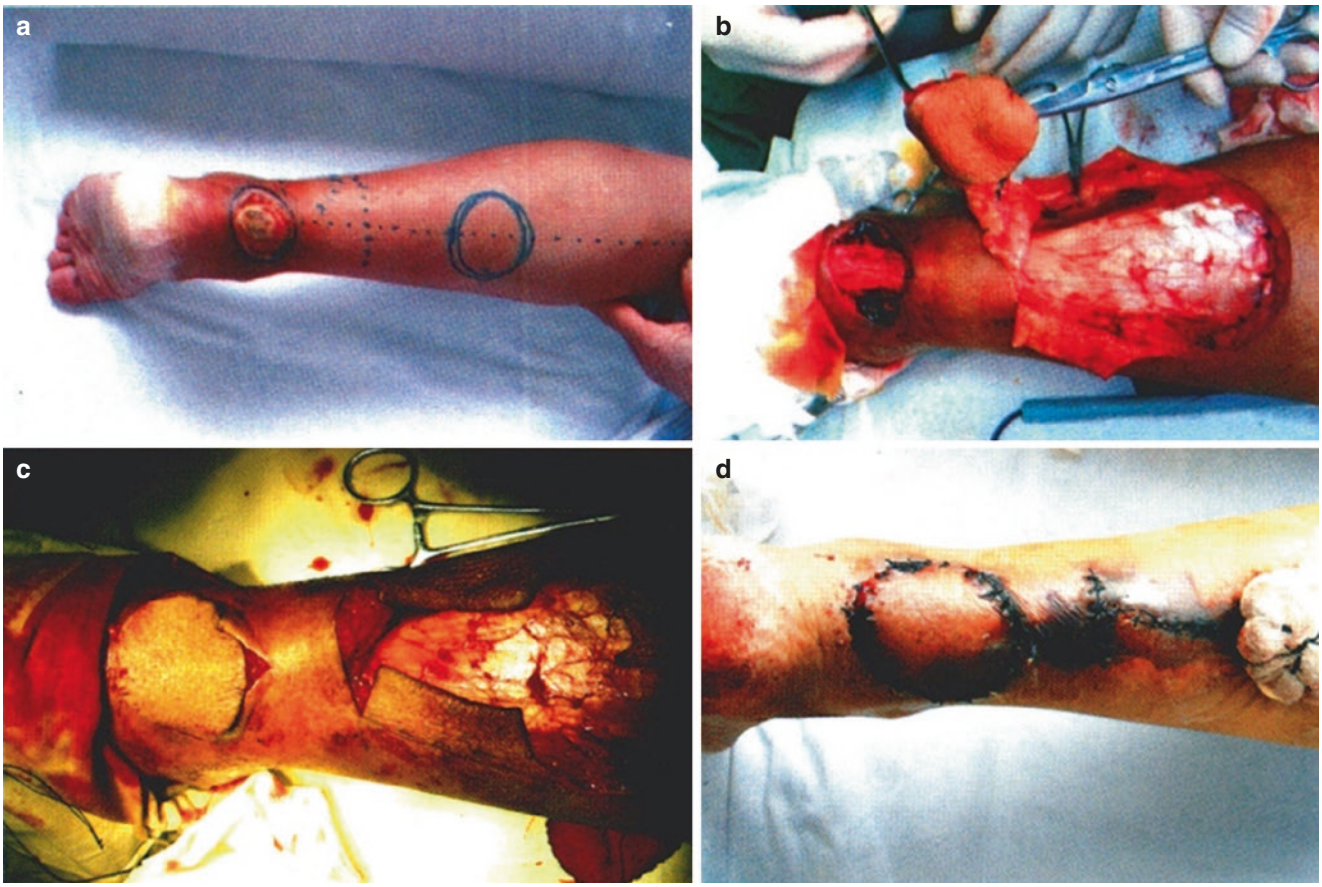

Fig. 18.3 Case I. (**a**) Skin flap design. (**b**) Lifted up the skin. (**c**) The skin flap was transferred into the receptor site. (**d**) At 1 week after surgery

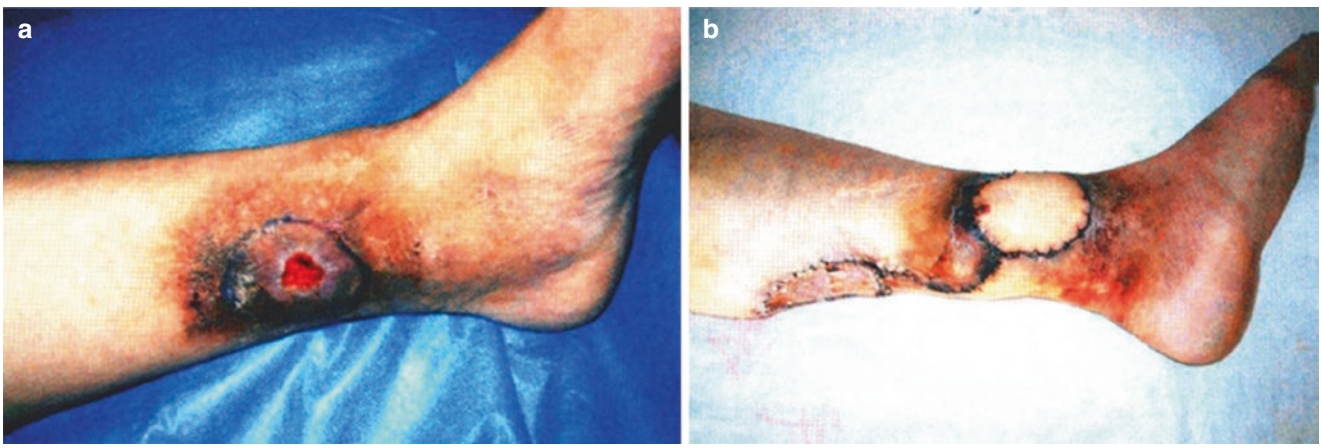

Fig. 18.4 Case II. (**a**) The lesion site of squamous cell carcinoma in the upper part of the left calf before surgery. (**b**) The wound was covered with the fasciocutaneous island flap with sural nerve

follow-up carried out by Costa-Ferreira et al. showed that both the lateral foot numbness and the nerve edema have been improved at 12 months after surgery. Another disadvantage is that it does not apply to the wound with a larger area. Ayyappan et al. extended the upper boundary of the skin flap to the upper one third of the posterior calf and designed the oversized fasciocutaneous flap with sural nerve with the maximum area of 17 × 16 cm. We also carried out a trial on this, but an oversized fasciocutaneous flap with sural nerve with an area of 18 × 6 cm was mostly necrotized due

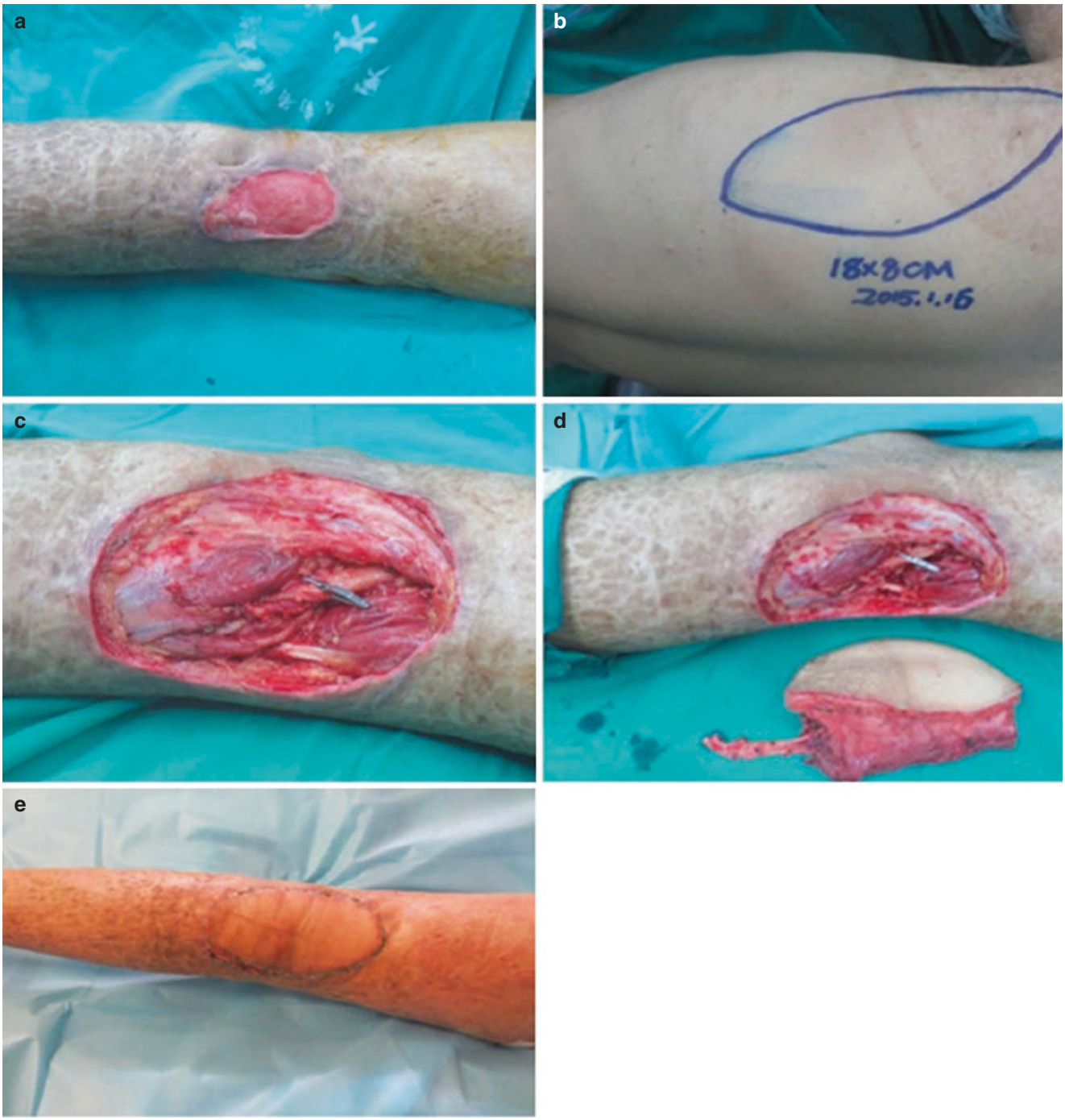

Fig. 18.5 The patient with skin squamous cell carcinoma in the left popliteal fossa. (**a**) Before surgery. (**b**) Design of latissimus dorsi myocutaneous flap. (**c**) The tissue defect after extensive resection of the left popliteal fossa lesion. (**d**) The extensive resection of the left popliteal fossa lesion plus the repair with free latissimus dorsi skin flap was carried out. (**e**) The patient was reexamined at a month after surgery

to venous congestion with infection, and therefore, we believe that before there is enough evidence suggesting that the sural nerve artery can provide nutrition for the skin flap with super large area, one should be careful to use the oversized fasciocutaneous flap with sural nerve.

2.2 Malignant Melanoma

The malignant melanomas only account for 5% of the annually diagnosed skin cancers, but the mortality rate accounts for 75% of all skin cancers. Due to wide development of health

education work, the level of awareness for the hazards of malignant melanoma in the masses is greatly improved; when the primary tumor is still confined to the skin, many patients have obtained the diagnosis and treatment. Malignant melanoma most commonly occurs in the skin of the lower limbs in women. In Asia, it often occurs in the plantar skin or the nail bed.

2.2.1 Clinical Manifestations

The early clinical symptoms of skin melanoma can be summarized as ABCDE rule; this rule helps to identify the lesions similar to malignant melanoma, namely, A. asymmetry, B. irregular margin, C. uneven color, D. the lesion with diameter and pigment spot diameter of more than 5–6 mm can be considered suspicious, and E. uplift. The only disadvantage of this rule is that the speed of melanoma development, namely, the trend of significant change occurring within weeks or months, is not taken into consideration. Therefore, attention should be paid to the growth and variation trend of pigment spots.

In addition, any pigmented lesions have satellite lesions; the color intensity is increased or decreased, there exists itching, bleeding, rapid tumor growth, hair loss or hair growth, all suggesting that the cell proliferation within the lesion is active; sharp vigilance should be maintained at this point.

Any suspected lesions require surgical resection and pathological examination, so as to definitely diagnose the suspected cases and accurately determine the thickness of the tumor, thus providing the basis for further treatment.

The advanced patients usually present with larger black tumor body in plantar skin surface. Part or all of the tumor body protrudes out of the skin, or the skin is ulcerated with a prolonged healing and has black exudates. The patients cannot walk and see the doctor mostly due to the influence of the tumor body. Most patients still have no enlarged lymph nodes in the groin.

2.2.2 Pathological Classification and Prognosis

The study found that the thickness of the skin invaded by the malignant melanoma is closely related to the prognosis. At present, there are mainly two methods of classification according to the melanoma thickness:

1. Clark classification: Clark divided the malignant melanoma into five stages according to different depths of the skin invaded by the tumor: (1) Stage I: Intradermal melanoma – it will not be metastasized and is benign. (2) Stage II: The tumor body penetrates through the basilar membrane. (3) Stage III: The tumor body is full of dermal papilla and invades into the reticular dermis. (4) Stage IV: The tumor body infiltrates the reticular dermis. (5) Stage V: The tumor body invades into subcutaneous fat.
2. Breslow classification: Breslow accurately measured the thickness of the tumor in the slice through the optical micro-measurement to classify the malignant melanomas: (1) Stage I: The thickness of the tumor body is less than 0.75 mm. (2) Stage II: The thickness of the tumor body is 0.76–1.50 mm. (3) Stage III: The thickness of the tumor body is 1.51–3.99 mm. (4) Stage IV: The thickness of the tumor body is greater than 4 mm.

Table 18.1 The reference range for resection of the tumor body of malignant melanoma tumor

The thickness of the tumor body (mm)	The resection range of the normal tissue outside the tumor body (cm)
In situ	0.5
≤1	1
1–2	1–2
2–4	2
≥4	2–3

The thicknesses of invaded skins are different; thus, the opportunities of lymph node metastasis and systemic metastasis as well as the prognoses are different.

In terms of the opportunity of lymph nodes and systemic metastasis, when the depth of skin invaded by the tumor is degree I, the incidence rate of regional lymph node metastasis is 2%–3%, and the distant metastasis rate is almost zero; when the depth of skin invaded by the tumor is degree II, the lymph node positive rate is 25%, and the distant metastasis rate is 8%; when the depth of skin invaded the tumor is degree III, the lymph node positive rate is 57%, and the distant metastasis rate is 15%; when the depth of skin invaded by the tumor is degree IV, the lymph node metastasis rate is 62%, and the distant metastasis rate is about 72%.

In terms of prognosis, when the lesion thickness is less than 1 mm, the resection and cure rate is over 99%, 5-year survival rate is 89%–95%; when the lesion thickness is between 1 and 4 mm, 5-year survival rate is 63%–89%; when the lesion thickness is greater than 4 mm, 5-year survival rate is 7%– 63%.

2.2.3 Surgical Treatment and Wound Repair

The surgical resection is still the preferred treatment; the surgical safety margin of the resection depends on the thickness of the tumor body (Table 18.1), but the current evidence-based medical evidence still supports that a safety margin of 2 cm is enough. Whether the wound margin after resection of the tumor body has residual tumor cells can be determined with the method of Mohs surgery.

The resected tissues include the tumor and its surrounding tissue; the depth reaches the deep fascia. Under the condition that the pathological examination confirms no tumor cells on the deep surface of the superficial fascia of the resected tissue block, the deep fascia should be retained; the retained deep fascia can be taken as the barrier for invasion of the tumor into the deep layer.

The repair of wound after tumor resection should also follow the sequence for repair of soft tissue defects. Since the

malignant melanoma occurs mostly in plantar base and foot bottom, if the tumor body is located in a non-weight-bearing zone, the skin transplantation is firstly considered, and the split-thickness skin graft plus packing pressure is more commonly used; if the tumor body is located in a weight-bearing zone, the skin transplantation cannot be considered, and the pedicled skin flap and free skin flap should be used for wound repair. One should be careful to select the distal skin flap, which has the possibility to metastasize the tumor to the donor site. Because the medial plantar skin flap is located in the non-weight-bearing zone of the arch of the foot between the head of metatarsal bone and calcaneus, its anatomical structure is similar to the covering tissue in the weight-bearing zone, with good blood supply and sensation. It is an ideal donor site for repairing the wound in the weight-bearing zone (especially the heel); therefore, the medial plantar skin flap is preferred for repair of the wound in this zone. For the wounds in the bottom of the heel and the posterior heel, the anterograde medial plantar island flap can be selected for repair. For the wound in the anterior margin of the foot bottom, the retrograde medial plantar island flap can be selected for repair. If it is difficult to repair, other skin flaps can be selected, such as the fasciocutaneous flap with nutrient vessels of sural nerve and small saphenous vein, the fasciocutaneous flap with nutrient vessels of saphenous nerve and great saphenous vein, and free skin flap.

1. Medial plantar skin flap
   (1) Related anatomy: The posterior tibial artery is divided into the lateral plantar artery and the medial plantar artery at the bifurcation of the starting point of abductor hallucis, and the medial plantar artery runs frontward between the abductor hallucis and flexor digitorum brevis, is parallel to the flexor hallucis longus tendon, and has 2–9 branches with varying diameters along the way. Of which, at the base of the first metatarsal bone, there is a larger branch running obliquely toward the second and third toes on the anterior outer side, this branch crosses the arch of the foot by about 2 cm, is anastomosed with the branch of the common plantar digital artery of the second and third toes, and is indirectly connected to the arch of the foot. The vascular thickness varies greatly. After giving off this branch, the trunk of the medial plantar artery continues to run forward and gives off inward the first medial plantar digital artery near the first metatarsal head, and then this trunk is anastomosed with the first plantar metatarsal artery; it continuously runs forward into the common plantar digital artery between the first and second toes and is connected with the deep plantar artery from the dorsal pedal artery through the first plantar metatarsal artery, thereby participating in formation of plantar arterial arch jointly by the deep plantar artery and lateral plantar artery; this structure is constant (Fig. 18.6). The medial plantar artery and its branches have their accompanying veins all the way.

Fig. 18.6 The distribution diagram of plantar blood vessels

   (2) Skin flap design: The undersurface of the first metatarsal bone is taken as the base point, namely, the junction area of the weight-bearing zone in the anterior margin of plantar area and the non-weight-bearing zone; a straight line is drawn toward the point of intersection of the medial plantar margin and the continuation line of the anterior margin of the medial malleolus; this line is taken as the central axis to design the skin flap; the distal medial plantar artery or the diagonal branch is selectively used as the pedicle, or both are used jointly; the skin flap area in adults generally does not exceed 8 × 4 cm. The distance from the rotation point to the most distal end of the skin flap should be slightly greater than the distance from the wound to the most distal end. The size and shape of the skin flap are similar to those of the

wound, so that the skin flap after transfer can be sutured without tension.

(3) Surgical methods:

1) Repair of heel with medial plantar island flap through antegrade approach: The distal incision of the skin flap is made on the proximal side of the first metatarsal head, the superficial branch of the medial plantar artery is found at first, and sometimes it needs to be ligated at the distal end of the skin flap. It is separated with the surface of the myolemma of the abductor hallucis under the metatarsal fascia from far and near to the binding area of the superficial blood vessels and deep blood vessels. After the deep blood vessels are ligated, the main trunks of medial plantar vessels and their accompanying plantar medial nerves are dissected in the abductor hallucis and flexor digitorum brevis, the main trunks of the nerves are retained in the original place, but attention is paid to preserving the nerve branches issued toward the skin flap. The blood vessels are separated toward the proximal posterior tibial artery and vein to a sufficient length, and the nerves are separated between beams to obtain a sufficient length, and the surgical dissection is completed (Fig. 18.7). The skin between the pedicle and the receptor site is incised and is transferred to the plantar wound through open approach; it should be avoided that the vascular pedicle is distorted and compressed (Fig. 18.8).

2) Repair of anterior plantar margin with medial plantar island flap through retrograde approach:

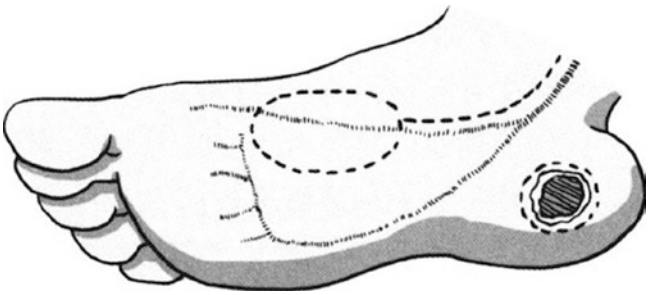

Fig. 18.7 Anterograde medial plantar island flap

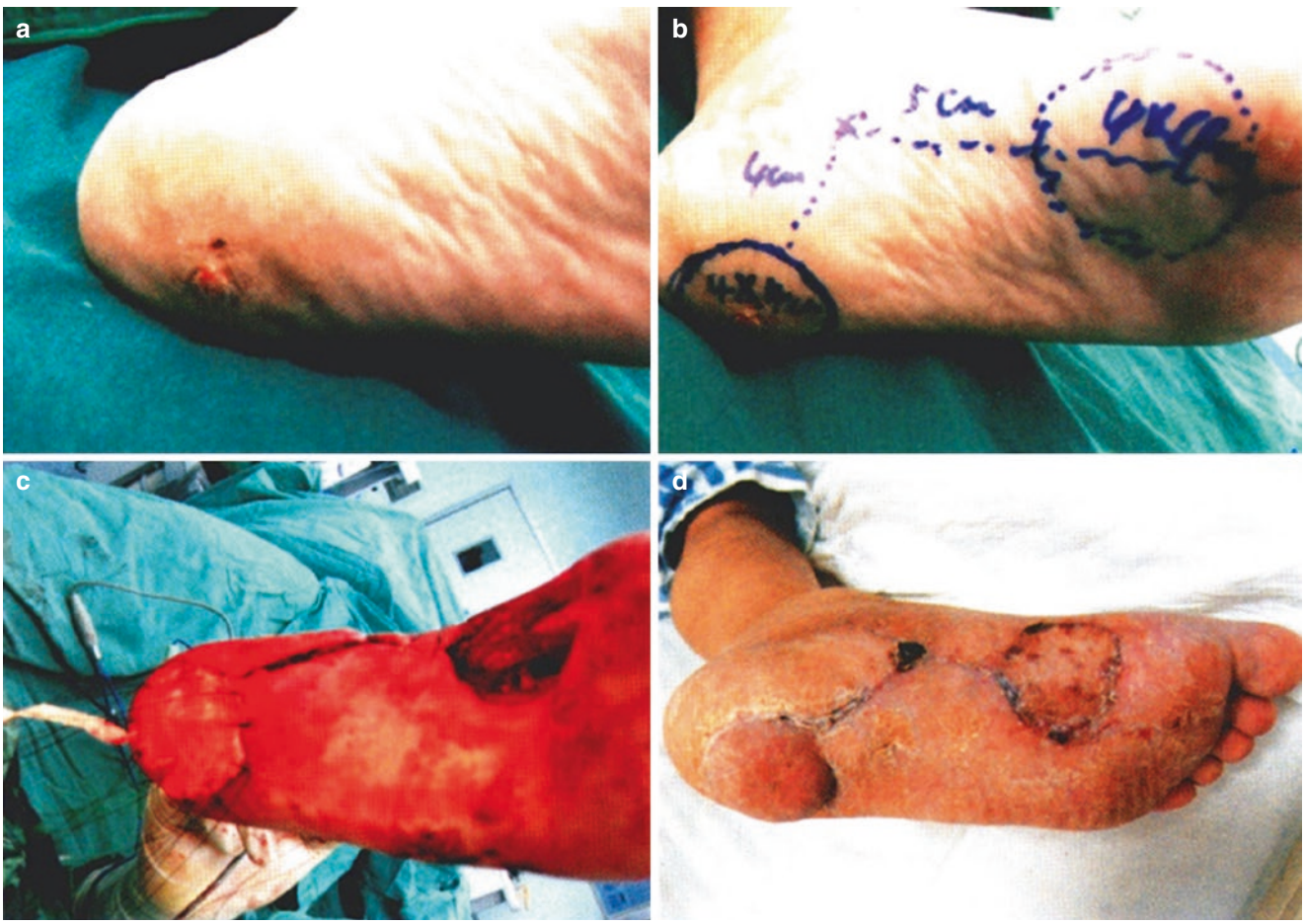

Fig. 18.8 The medial plantar island flap was used to repair heel wound through antegrade approach. (**a**) The melanoma in the heel before surgery. (**b**) The incisal margin of the tumor and the medial plantar island flap was designed before surgery. (**c**) After resection of the lesion, the medial plantar island flap was transferred anterogradely to repair the wound. (**d**) At 2 weeks after surgery

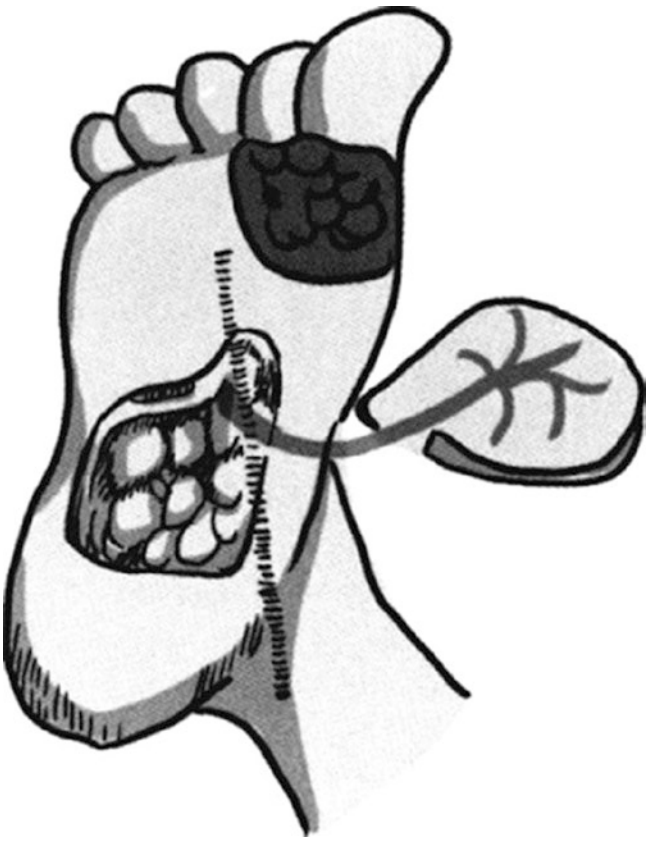

Fig. 18.9 Retrograde medial plantar island flap

The proximal lateral margin of the skin flap is incised at first; the dissection is carried out at the surface of the myolemma of the abductor hallucis from the near to the distant until the superficial branches of the medial plantar blood vessels enter into the skin flap. Then the bilateral margins of the skin flap are incised, as well the skin flap is dissected and dissociated at the surface of the myolemma of the abductor hallucis (Fig. 18.9). Then the skin at the distal side of the skin flap is incised; attention is paid to finding the superficial branch vessels and retaining their surrounding fascia and loose subcutaneous tissue; the pedicle is dissected without exceeding the proximal side of the first metatarsal head. The superficial branch of the artery is occluded at the proximal end with a vascular clamp for 5 min; when the blood supply of the skin flap is good, the proximal blood vessel is cut off; and the surgical dissection is completed. The skin between the pedicle and the receptor site is incised and is transferred to the plantar wound through open approach; it should be avoided that the vascular pedicle is distorted and compressed (Fig. 18.10).

(4) The advantages and disadvantages: The advantage of medial plantar skin flap is that the use of skin flap with a structure consistent with that of plantar skin to repair the heel and the plantar weight-bearing zone can achieve the curative effects of good wear resistance, compression resistance, sensation, and elasticity. The disadvantage is that the venous return of the skin flap venous is poor, attention should be paid to avoiding injuring the veins, and some soft tissues around the blood vessels are preserved as much as possible to ensure venous return; the plantar subcutaneous tissue is more dense and inflexible and has a larger pressure on the pedicle after its transfer; attention should be paid to suture tension and the pressure of the bandaging; if necessary, some subcutaneous tissues may be cut off appropriately; the retrograde transplantation makes this skin flap lose nerve sensation.

2. The fasciocutaneous flap with nutrient vessels of sural nerve and small saphenous vein: The skin flap design, surgical method, and the advantages and disadvantages can be read in the preceding part of the text.

Case III: The patient had the malignant melanoma in the heel with huge ulceration; the heel after tumor resection was repaired with the fasciocutaneous flap with nutrient vessels of the sural nerve and small saphenous vein (Fig. 18.11)

2.2.4 Treatment of Lymph Nodes

1. Treatment of regional lymph nodes: The treatment of the regional lymph nodes is still controversial; a retrospective study suggests that the elective lymph node dissection (ELND) is beneficial to increase the survival rate, while another prospective study does not obtain such in conclusion. Generally it is believed that if there are no clinical signs of regional lymph node metastasis, the thickness of the tumor body is less than 1.5 mm; it is inappropriate to carry out ELND; when the thickness of the tumor body is more than 1.5 mm, or the cytology and histology examinations confirm the presence of local lymph node metastasis, the lymph node dissection should be carried out. If the primary lesion is near the lymph nodes, the tumor body and major lymph node should be dissected together. For example, the malignant melanoma in the mid-thigh and the inguinal lymph nodes needs to be removed together. Conversely, if the lesions are below the knee joint, they cannot be treated in this way. But the examination shows that lymph nodes in the site of femoral canal contain tumor cells; it is often required to carry out deep femoral lymph nodes dissection. If the examination confirms the presence of distant metastases, it is not recommended to carry out routine lymph node dissection.

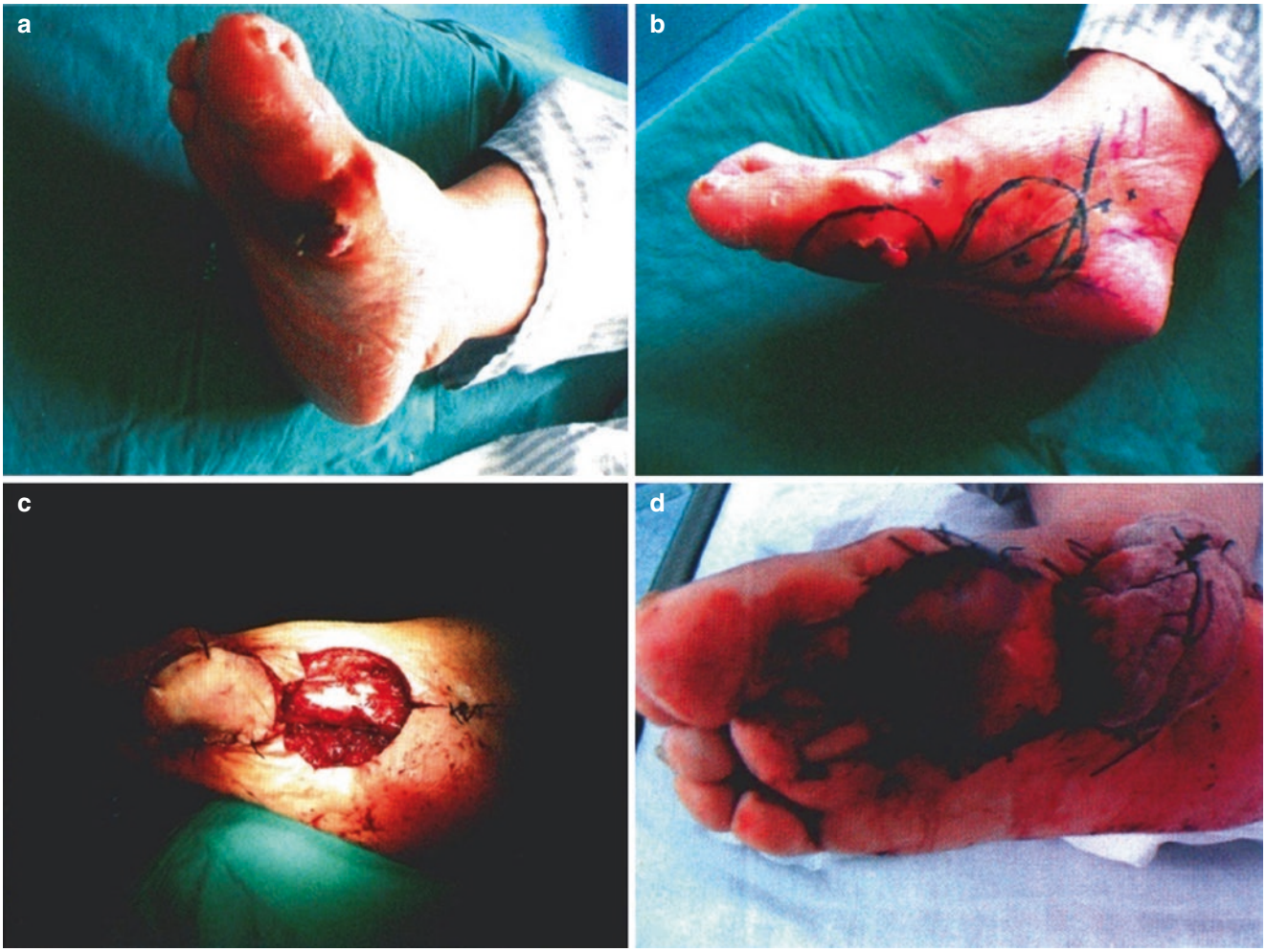

Fig. 18.10 The plantar medial plantar island flap was used to repair the wound in the anterior margin of the foot bottom through retrograde approach. (**a**) The plantar melanoma before surgery. (**b**) The incisal margin of the tumor and retrograde medial plantar island flap were designed. (**c**) After lesion resection, the medial plantar island flap was transferred retrogradely to repair the wound. (**d**) At 1 week after surgery

2. Treatment of sentinel lymph nodes: In 1991, the researchers in UCLA (University of California, Los Angeles) injected the isosulfan blue into lower limb skin of the cat. They found that the injection sites are different and the first colored lymph nodes are different, for example, if the injection is performed in the inner thigh, the central group of the inguinal lymph nodes are always colored, while if the injection is performed in the lateral thigh, the lateral group of the inguinal lymph nodes are always colored. Thereby the concept of the sentinel lymph nodes is proposed. The sentinel lymph nodes refer to the lymph nodes reached firstly by the malignant tumor cells breaking away from the primary location.

   During surgery, the dyes are intradermally injected near the malignant melanoma, and the firstly stained lymph nodes are found according to the direction of the dye drainage. The immunohistochemistry and (or) PCR examination is carried out for the resected lymph nodes; the detection rate of lymph node micrometastasis can be increased by 40%. The best way to get the sentinel lymph nodes is to carry out preoperative and intraoperative subcutaneous injections of the radioactive tracer technetium-99 m, combined with intraoperative dye tracing; the combination of two factors makes the sentinel lymph node-positive detection rate increased to 95% while making its false negative rate reduced to less than 1%. For positive sentinel lymph nodes, the elective lymph node dissection is performed; if the pathological section examination confirms that the lymph nodes have no tumor cells, then it is believed that other lymph nodes also have no tumor cells. The advantage of this approach is that whether lymph node metastases exist can be revealed, and thus, it is not required to carry out lymph node dissection, which reduces the blindness of the elective lymph node dissection and its secondary damage; meanwhile the pathologist is allowed to carry out

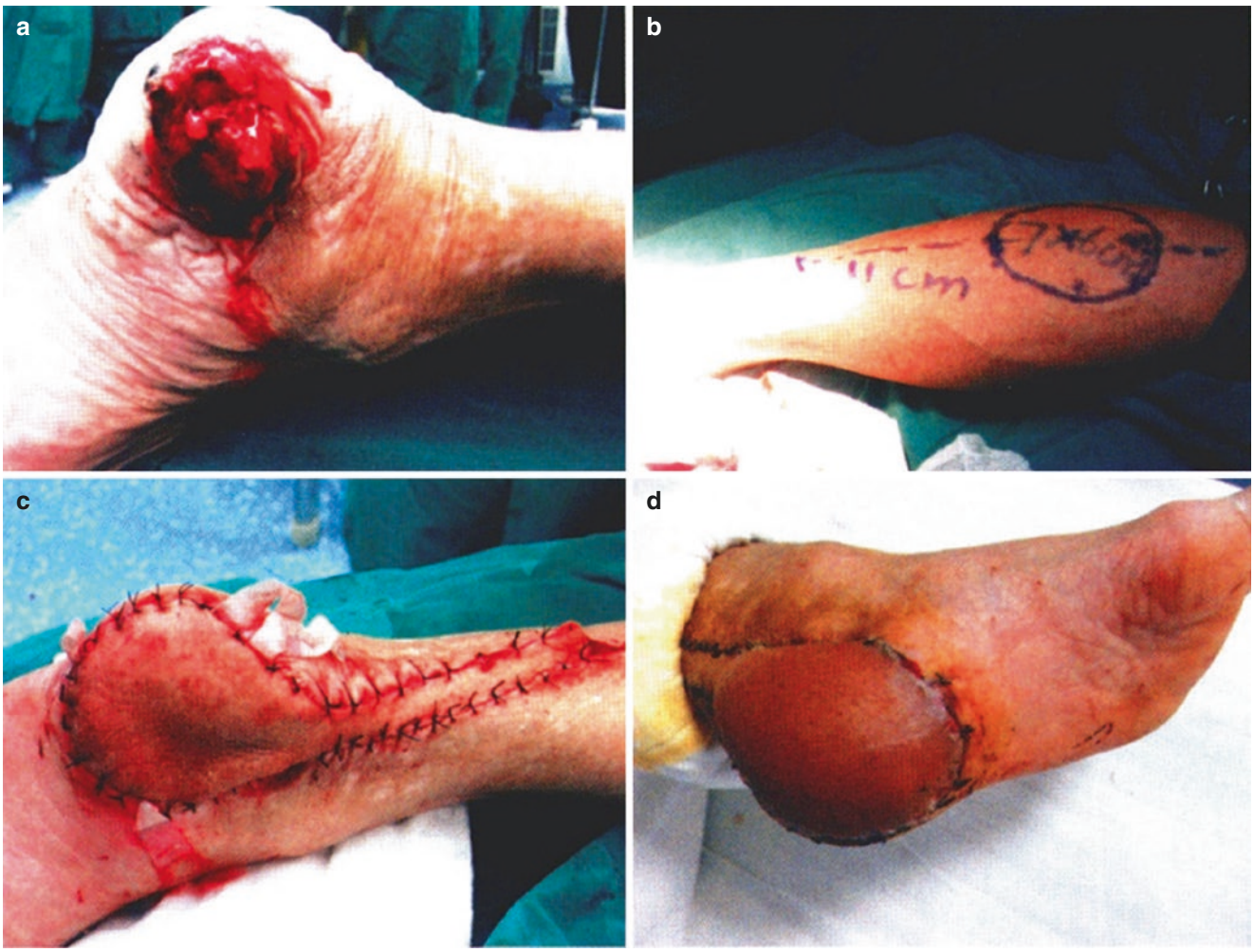

Fig. 18.11 Case III. (**a**) The melanoma in the heel with huge ulceration. (**b**) The fasciocutaneous flap with nutrient vessels of sural nerve and small saphenous vein was designed before surgery. (**c**) After the wound was repaired with the fasciocutaneous flap with nutrient vessels of sural nerve and small saphenous vein. (**d**) At 2 weeks after surgery

multiple stainings for the lymph nodes to increase the diagnostic accuracy.

3. Principles of lymph node dissection
   (1) The regional lymph node dissection is sufficient.
   (2) The involved lymph node must be completely removed.
   (3) In general, the number of lymph nodes which are removed and examined is as follows: ≥10 in the groin, ≥15 in the armpits, and ≥15 in the neck.
   (4) In the groin area, if the clinical finding shows that the number of metastasized superficial femoral lymph nodes is greater than or equal to three, the iliac fossa and obturator lymph nodes are electively dissected.
   (5) If the pelvic imaging suggests or Cloquet lymph node is positive, it is required to carry out iliac fossa and obturator lymph node dissections.

3 Malignant Tumors Derived from the Mesenchymal Tissue

The malignant tumors derived from the mesenchymal tissue, also known as soft tissue sarcomas, are the most common malignant tumors originating from embryonic mesenchymal tissue. These tumors are insensitive to chemotherapy; therefore, the surgery is still the main method of treatment, and the radiotherapy can be used as adjuvant therapy after tumor resection.

The soft tissue sarcomas are the malignant tumors of soft tissues, including the malignant tumors occurring in adipose tissue, fibrous tissue, muscle tissue, blood vessels, and peripheral nerve tissue. But in view of their distribution, the occurrence scope far exceeds the scope of the abovementioned tissues, for example, the leiomyosarcoma can occur in

the skin; this is because the tumor body is derived from the blood vessels of the superficial vascular network or arrector pili muscle in the skin.

3.1 Epidemiological Characteristics

The incidence rate of soft tissue sarcoma is very low, accounting for about 1% of all systemic malignant tumors. The buttocks, thighs, and calves are high incidence areas of soft tissue sarcoma; the soft tissue sarcoma occurring in the three areas accounts for about 40%–50% of soft tissue malignant tumors in the whole body. This kind of tumors rarely has the possibility of canceration of benign malignant tumors. Most soft tissue sarcomas are sporadic.

So far no clear cause has been found. But the studies have found some certain inducing factors, for example, the exogenous rays have the potential to cause soft tissue sarcomas, the radiotherapy can increase the incidence rate of the soft tissue sarcoma by 50 times, the onset time is 3–15 years after radiotherapy, and once the disease onset occurs, the prognosis is poor. Another study found that AIDS patients are susceptible to Kaposi's sarcoma, and the incidence rate is 310 times that of the general population; the incidence rate of angiosarcoma is also 17 times that of the general population. Some studies have also found that certain occupational causes such as long-term exposure to polyvinyl chloride, phenoxyacetic acid herbicides, and chlorophenol wood preservatives will also increase the incidence rate of soft tissue sarcoma. The dioxin, especially the tetrachlorodibenzodioxin, also has the potential to cause soft tissue sarcomas. The possibility of neurofibromatosis type I developing into malignant peripheral nerve sheath tumor is likely to be ten times higher than that in the general population.

Viewing from the layers where the disease onset occurs, if the deep fascia is taken as the boundary between superficial and deep layers, the soft tissue sarcomas occurring in the superficial layers account for about 15%, while the soft tissue sarcomas occurring in the deep layers account for 85%. Five common histological types include malignant fibrous histiocytoma, rhabdomyosarcoma, synovial sarcoma, liposarcoma, and fibrosarcoma, which totally account for 90% of all soft tissue sarcoma.

3.2 Biological Characteristics

3.2.1 Growth Pattern

The epidemiological characteristics show that the soft tissue sarcoma grows mostly in the deep tissues and usually shows a kind of eccentric growth and spherical enlargement. The compression zone and reaction zone appear around the tumor. The reaction zone presents mostly with tissue edema, neovascularization, and the formation of the pseudocapsule of the sarcoma. This pseudocapsule infiltrated by the sarcoma will be finally changed into the sarcoma and become a part of the sarcoma due to the ingrowth and development of the tumor buds. Then a new pseudocapsule is formed, and the above process is repeated. The pseudopodia, jumping tumor foci, or satellite nodules may occur within normal tissues outside the reaction zone and in the compression zone, and therefore in normal tissue of the incisal margin observed by the naked eye, the microscopic invasion of the malignant tumor is likely to have occurred. This process is repeated to form a multinodular tumor. It is clearly wrong to judge whether the tumor is resected completely or not only with the naked eye.

The soft tissue sarcoma is often disseminated along the route of loose tissues with relatively low interstitial pressure and poor defense function. It often parallelly develops along the long axis of the limb, on the surfaces of some fascias, or between muscle bundles. Sometimes the invasion of the tissues such as skin can occur in the vicinity of the main tumor nodule.

3.2.2 Barrier Effects of Special Tissue Structures on the Sarcoma

The dense connective tissues are natural barriers for the sarcoma, such as deep fascia, muscle cavity, aponeurosis, periosteum, and epineurium. Especially when the sarcoma is located in an exertional compartment, in a considerable period of time, the tumor growth is limited in the compartment. Only at the late stage, the sarcoma may break through the compartment and develop outward under the action of external factors through the opening of the compartment, vascular holes, or other weak areas.

3.2.3 Metastasis

The tumor cell metastasis is one of the characteristics of malignant tumors. The tumor cell metastasis is a sequential process; the initial stage involves three aspects: (1) the adhesion of cancer cells to the basement membrane, (2) the degradation of the basement membrane, and (3) the penetration of cancer cells through the matrix into the blood and lymph vessels, of which the movement of tumor cells is the prerequisite for tumor invasion and metastasis.

1. Lymphatic metastasis: The incidence rate of the lymph node metastasis of soft tissue sarcoma is lower than that of the cancer; even if the tumor grows in areas of lymph node concentration, no positive lymph nodes are often observed in the histological examination.
2. Blood route metastasis: The clinical practice has proven that the soft tissue sarcoma is metastasized mainly through blood route; the main target organ is the lung, followed by

the brain, liver, bone, and skin. The blood route metastasis occurs mostly 3–5 years later; the distant organ metastasis often appears only after multiple local recurrences.

The main cause of death of the soft tissue sarcoma is the vital organ metastasis, the targeted therapy for distant metastasis is the key to prolong the survival time, and the efficacy in this respect needs to be further improved.

3.3 Clinical Manifestations

The clinical manifestations of the soft tissue sarcomas vary due to the course of disease and the degree of tumor differentiation. There is no obvious discomfort at the early stage, and a variety of clinical manifestations may appear at the middle and advanced stage:

1. Mass: The mass is often painless, and it can last for more than several months or a year. The mass located in the surface is lowly malignant in most cases, and the mass located in deep area is the highly malignant sarcoma in most cases.
2. Pain: The soft tissue sarcoma is mostly demonstrated as painless mass, but the mass with rapid growth may cause a dull pain. When the tumor involves the nerve, the pain is manifested as the first symptom.
3. Location: The sarcomas have their own different predilection sites; the fibrous tissue-derived tumor occurs mostly in the skin and subcutaneous tissue; the adipose tissue-derived tumor occurs mostly in the hips and lower limbs; the striated muscle-derived tumor occurs mostly in the muscular layers of the limbs.
4. Activity: The activity of sarcoma is related to its occurrence location, pathological type, and the length of the course of the disease. The lowly malignant tumor has a good activity; the highly malignant tumor has a poor activity; the activity of the superficial tumor is better, while the activity of the sarcoma in deep layers is poor.
5. Temperature: The sarcoma has a rich blood supply, and the local temperature can be higher than that of the normal tissue.
6. Regional lymph nodes: The synovial sarcoma and rhabdomyosarcoma often have regional lymph node enlargements, and sometimes the lymph nodes are integrated into groups.

3.4 Treatment

The soft tissue sarcoma is a disease entity with a low incidence, and its biological behaviors are various, as compared with other types of malignant tumor, and it is very difficult to develop a treatment standard which is suitable for all soft tissue sarcoma.

3.4.1 The Factors Affecting the Treatment of Soft Tissue Malignant Tumors of the Lower Limbs

The treatment goals of soft tissue malignant tumors of the lower limbs are to completely and thoroughly remove the tumor tissue, control the recurrence rate and mortality rate of the malignant tumors to a minimum level, and preserve the functions of the limbs to maximum extent. To achieve these goals, at present, the following consensuses have been achieved in aspect of the surgical treatment of soft tissue sarcoma:

1. Whether the incisal margin is appropriate is the only important factor in the decision of local recurrence. In other words, the resection range is closely related to the local recurrence.
2. The anatomical structures in some parts of the human body such as fascia have natural barrier functions. When the sarcoma is located therein, the anatomical structure has certain constraint effects on the sarcoma in a considerable period of time. This type of structure is completely resected along with the sarcoma, which can be regarded as radical local treatment.
3. The limb salvage surgery has an increasing tendency to replace the amputation surgery, because the amputation surgery has no advantage in reducing the recurrence rate of tumors compared to the limb salvage surgery.

3.4.2 The Methods for the Resection of Soft Tissue Malignant Tumor

1. Intracapsular resection: The intracapsular resection (incision biopsy) is the method that part of or all tumor tissues are resected within the psuedocapsule of the sarcoma. After the surgery is performed with this method, a large number of tumor tissues are left, which need to be resected again after definite diagnosis, and therefore, this method is only used in living tissue biopsy.
2. Marginal resection: The marginal resection (resection biopsy) refers to the surgical method that the tumor is completely resected outside the true or false capsule of the tumor, and it is used mostly in tumors with a greater benign likelihood or low-grade huge malignant tumors. Different from the highly malignant tumors, these tumors rarely invade surrounding normal tissues, and therefore, the extracapsular removal of the tumor can significantly delay the time to tumor recurrence while also reducing the complications caused by the removal of a large number of normal tissues. Of course, if the tumor volume is

smaller, under the possibility of reducing the complications, the resection range could be expanded to obtain a safe incisal margin.

This method can also be used in important structures adjacent to the sarcoma under a condition without ideal incisal margin. This surgical method can only remove the tumor bodies seen by naked eyes, and the majority of cases still have microscopic residual tumor tissue. Other additional treatments should be carried out, and otherwise the recurrence rate is high.

3. Extensive resection: Theoretically, the extensive resection refers to complete resection in which the normal tissue with a distance of more than 3 to 5 cm from the tumor is taken as the incisal margin and the tumor is not exposed during surgery. But the extensive resection is based on the assumed safety distance; therefore, the presence of residues of the microscopic tumor and the jumping tumor foci is entirely possible. And that in clinic, there are few cases which truly conform to this incisal margin or allow this resection method. For example, the requirement for 5 cm incisal margin cannot be reached in the distal limb. In such a case, Mohs micrographic surgery can be used to obtain the histologically negative incisal margin after resection of the malignant soft tissue tumor. The margins with multidimensional directions are marked in detail to indicate the sites for the pathologist to draw materials to carry out pathological examination, so that the normal tissues can be retained to maximum extent. It can be called as the extensive resection with the help of Mohs surgery.
4. Chamber resection: The chamber resection is a surgical method based on the concept of chamber which is put forward in recent years. The anatomical structures in some parts of the human body have natural barrier functions, when the sarcoma is located therein, and this kind of barrier has certain constraint effects on the sarcoma in a considerable period of time. This type of structure is completely resected along with the sarcoma, which can be regarded as radical local treatment. The local recurrence rate of the chamber resection is significantly lower than that of the extensive resection. This surgical method is reasonably designed, with an excellent effect. But there are fewer sites in clinic which are suitable for carrying out radical resection, and they account for less than 20% according to literature statistics. At the same time, the tissue damage caused by the chamber resection is very serious, and some functional defects left by the surgery cannot be restored to normal levels even after repair and reconstruction.
5. Amputation: The randomized controlled trials by some researchers show that there is no difference in the postoperative survival rate between the amputation and the limb-sparing surgery with radiotherapy, and then it is proposed that the amputation for malignant tumor is not necessarily a radical cure but is only a surgical method to reach an incisal margin. Therefore, this surgical method is rarely selected. And in this surgical method in modern surgical treatment of tumors, the functions cannot be restored through repair and reconstruction, and this surgical method doesn't belong to the scope of plastic surgery.

3.4.3 Selection of Surgical Method for Surgical Resection

After the diagnosis is determined, an appropriate surgical method is selected, and the local recurrence rate can be significantly reduced. The following principles and sequence can be taken for reference (Fig. 18.12).

1. Chamber resection: According to surgical staging, the chamber resection is firstly selected to achieve complete cure.
2. Extensive resection: The tumor is completely removed with a safe margin of 3–5 cm.
3. Extensive resection with the help of Mohs surgery: When the local conditions cannot meet the requirements of extensive resection, in order to maximize the removal of the tumor, preserve the normal tissue, and reduce the damages to the functions, this type of surgical method can be selected. For patients with positive histological report, the postoperative radiotherapy is additionally performed.
4. Marginal resection plus adjuvant radiotherapy: There is no alternative but to perform marginal resection, and it must be performed simultaneously in combination with radiotherapy; the effect of internal irradiation may be better.

   Case IV: The patient, female, 43 years old, had huge liposarcoma in the left thigh, which adhered to the sciatic nerve; the local radiotherapy was carried out after surgery (Fig. 18.13).
5. Amputation: When the tumor invades the multilayer structure from the skin to the bone, it is required to consider the amputation.

3.5 The Repairing Principles after Resection of Soft Tissue Sarcoma

One of the features of limb-sparing surgery in treatment of soft tissue sarcoma is that a lot of soft tissues with certain functions are resected along with the tumor. Although the resected tissues are significantly less than those in amputation, the corresponding morphology and function damages are still very serious. Thus, the intervention of reconstruction techniques is also logical, and the conventional radiochemical therapy must be replaced.

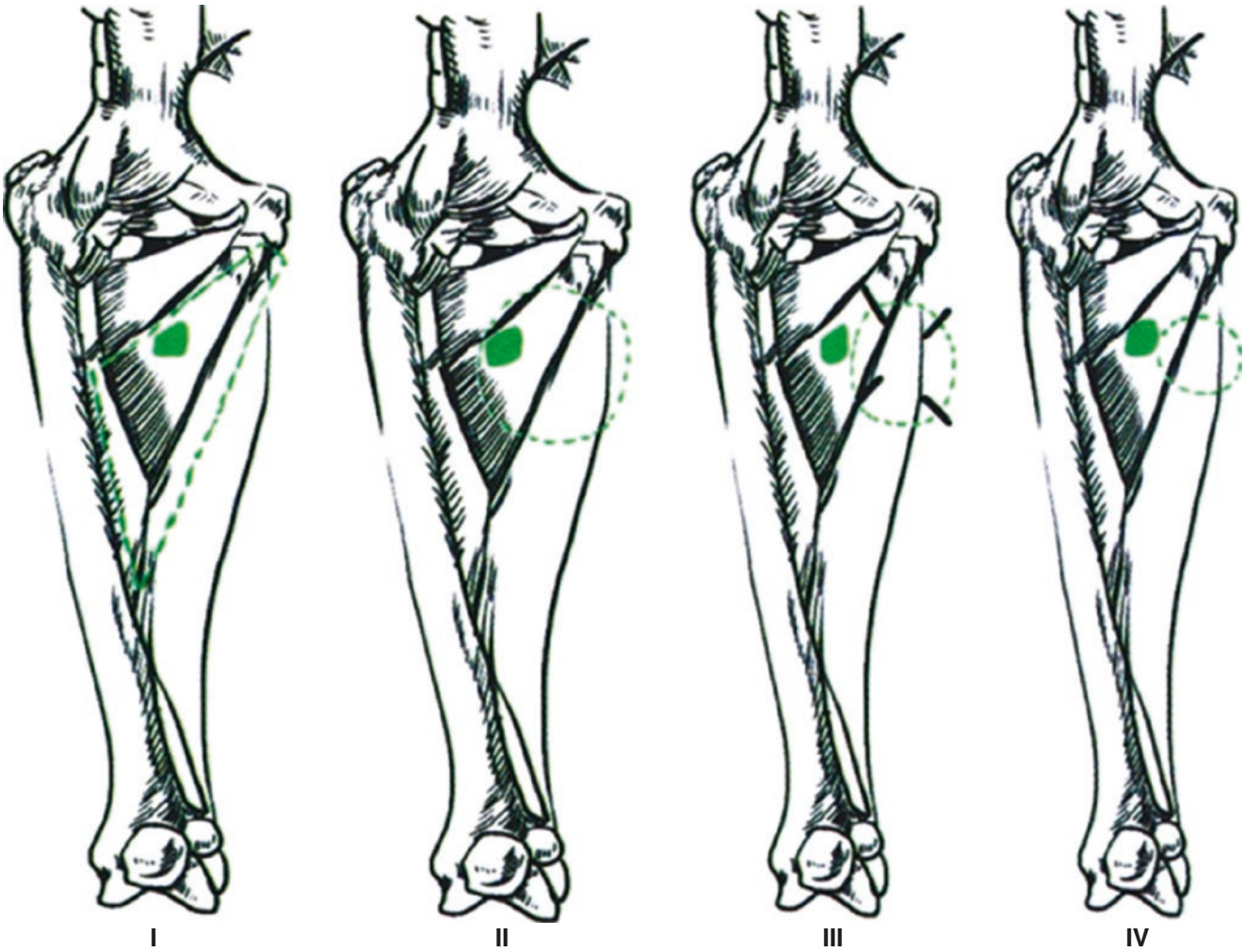

Fig. 18.12 Selection of surgical resection method

3.5.1 Relationship of the Surgical Staging with the Repair and Reconstruction

The surgical staging is the integrated result of multiple clinical indicators, and it should not only guide the tumor resection but also guide the repair and functional reconstruction.

1. Stage I: It is histologically low-grade malignant or locally aggressive. All necessary functions should be restored as far as possible under the condition of complete local resection. It is necessary to use some highly difficult techniques (such as vascularized free tissue transplantation) during surgery, because after receiving ideal surgical treatment, stage I sarcoma can achieve radical cure without any additional other treatments. Thus, functional recovery should be in line with this point, and the functional outcome will affect the patient a whole life long.
2. Stage II: It is the sarcoma with higher malignant degree. If the tumor is located within the chamber (T1), it still can get the chance of radical cure; the contents to be reconstructed should be based on the situation after radical treatment; the closer it is to the healthy side, the better it is. If the tumor is located outside the chamber (T2), the reconstruction program should be designed according to the situation after resection.
3. Stage III: For patients with regional lymph nodes or distant organ metastasis, the contents to be repaired and reconstructed should be comprehensively analyzed. In principle, the required functions should be repaired and recovered mainly with simple surgery, and the main energy should be focused on the systemic tumor control. The survival being prior to the function is still one of the current principles.

3.5.2 Relationship of the Survival Time with the Repair and Reconstruction

According to current literature statistics, 5-year survival rate of comprehensive treatment of soft tissue sarcoma is 40%–70%. How long is the survival time before the

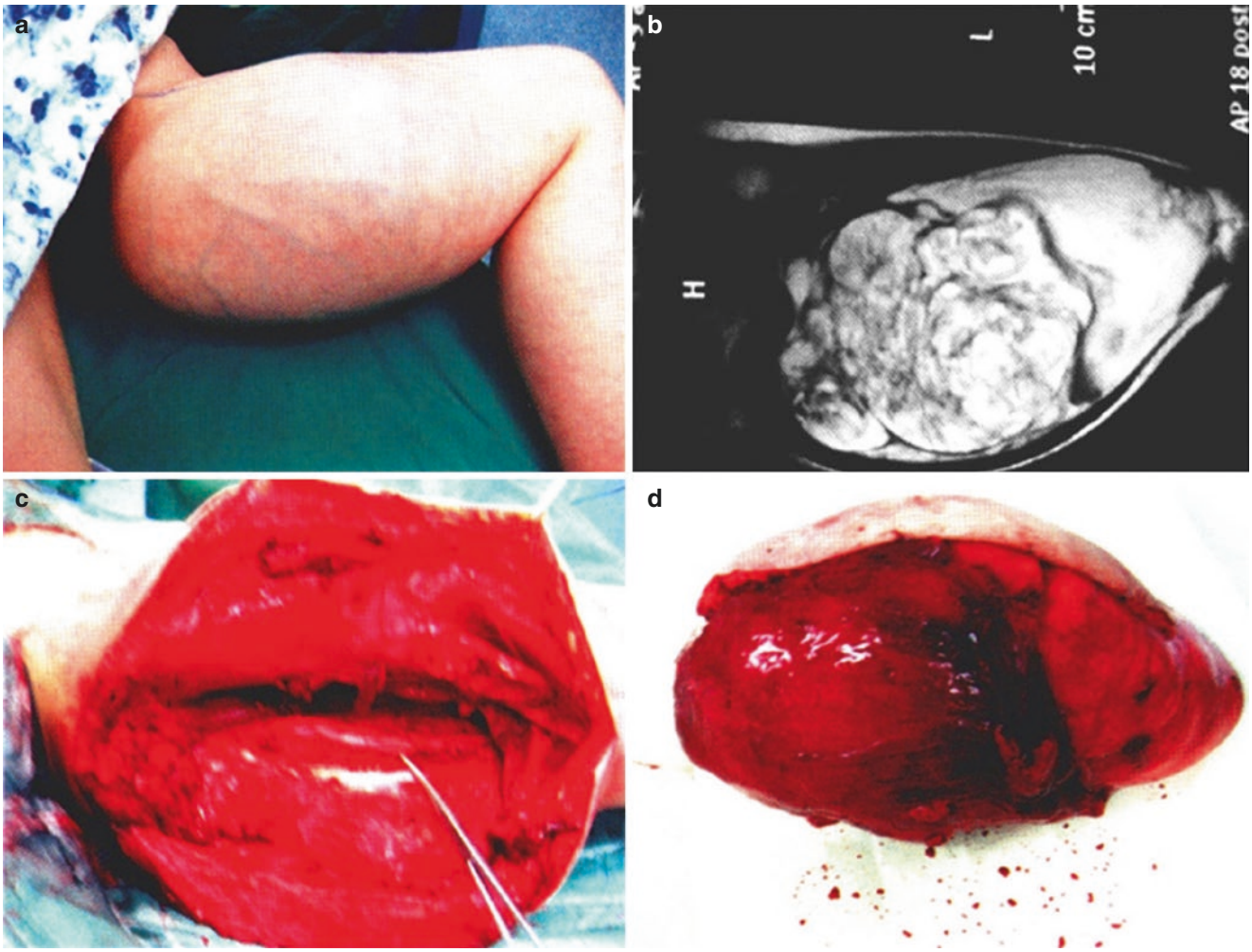

Fig. 18.13 Case IV. (**a**) Huge liposarcoma in the left thigh. (**b**) MRI image of liposarcoma. (**c**) The ischiadic nerve was observed after marginal resection. (**d**) The excised specimen

implementation of repair and reconstruction? Currently it has not been reported in literature. According to clinical experience, after sarcoma resection, repair, and reconstruction, the patients should have a recovery phase; according to different reconstruction contents, if the recovered functions after recovery phase can be used normally for more than 6 months, the patients should undergo repair and reconstruction.

3.5.3 The Timing of Repair and Reconstruction

If various conditions allow, in principle, the repair and reconstruction should be carried out at the same time of sarcoma resection. When special circumstances are encountered during surgery, and the repair and reconstruction cannot be completed at the first stage, they can also be completed at the second stage. Or more functions need to be reconstructed, which contradict with each other; it is required to carry out staged reconstructions.

3.5.4 The Relationship of the Technical Ability and Equipment Condition with the Repair and Reconstruction

The functional reconstruction of the damaged limbs uses the knowledge and skills of some interdisciplinary subjects, such as orthopedic surgery, plastic surgery, microsurgery, and rehabilitation medicine. We should sufficiently assess the conditions such as ability, technology, and equipment; when we are not competent, we should carry out the multidisciplinary collaboration in order to reduce the sufferings of patients.

3.5.5 The Relationship of the Requirements of Patient and Family Members with the Repair and Reconstruction

The patient and family members with different social backgrounds, economic bases, ages, and genders have their different requirements. Before the surgical plan is designed, the

opinions of the patients and their families are solicited to reach an understanding.

The main objectives of the repair and reconstruction include: (1) the limb salvage is guaranteed; (2) the basic functions are restored; (3) there is no tumor; and (4) the application is basically satisfactory.

The excessive requirements should be concretely analyzed according to the specific circumstance; some functional reconstructions which can't be realized or have a small possibility should not be allowed blindly.

3.6 The Repair Method after Resection of Soft Tissue Sarcoma

The repair and reconstructive surgery plays an important role in the treatment process of soft tissue sarcoma. Approximately 15% of soft tissue sarcomas in the lower limbs need to undergo repair and reconstructive surgery to help cover the soft tissue defects. Since supporting body weight, maintaining standing balance, and walking are important functions of the lower limbs, the repair core after limb salvage therapy of soft tissue sarcoma of the lower limb is to preserve function, namely, to ensure that the bone is covered, the important neurovascular injury is avoided, and the dynamic reconstruction is a kind of repair and reconstruction. For wounds after resection of huge malignant tumor, the plastic surgery can help achieve the reasonable coverage of the wound through its acquainted means of tissue transplantation. Therefore, when a surgical plan is developed, if the tissue transplantation is involved, the preoperative planning participated by plastic surgeons will make the surgical design more rational.

3.6.1 Soft Tissue Sarcoma Resection and Dynamic Function Damage

The malignant tumors in nerve and muscle themselves will naturally affect or damage the dynamics of related muscles, also involving other nerves and muscles. Therefore, in the surgical treatment of soft tissue sarcomas, it is a common occurrence that the resection of nerves and muscles causes function damages. In the clinic, the number of patients requiring dynamical reconstruction may rank only second to the number of patients requiring special means to cover the wounds.

In the surgical treatment of soft tissue sarcoma, regardless of the selection of radical resection, chamber resection, or marginal resection, it is rare to simply resect a segment of nerve trunk, which is mostly accompanied by muscle resection; even the nerve defects may also be attributed to the muscle disuse. Therefore, it is more practical to make statistics for the types of damages taking the muscle as the unit.

1. Single muscle type: Generally speaking, one of the characteristics of muscle groups of limbs is that a group of muscles assume a group of actions which are approximately the same (the overall direction of motions is consistent); there are small differences among specific muscles. Since the terminations of muscles, their traveling direction and the sizes of muscle bellies are different, each performs its own main functions, which is taken as its specificity, when a muscle is damaged and resected, and the functions controlled by this muscle are lost. The single muscle damage refers to such type.

   After resection of a single muscle group, most sites need not undergo reconstruction, such as gastrocnemius muscle and soleus muscle. But it is required to specifically analyze the status of single muscle function in the overall function to decide whether the reconstruction is carried out. For example, the resection of quadriceps femoris muscle will seriously affect the stability of the knee joint; it is required to carry out functional reconstruction.
2. Muscle group type: Clinically several muscles with similar functional and anatomical layers are called as the muscle group, such as triceps surae muscle. The reconstruction can be simplified because of functional overlap.
3. Compartment type: The functions of muscles in the same compartment are mostly approximate; the functions are affected obviously after total resection; the total loss of functions in one direction may occur; it is required to carry out reconstruction; because there are more muscle bundles, and the functional division of labor is more exquisite, when the reconstruction is carried out, it is impossible to reach every aspect of a matter; only its main parts are selectively reconstructed, namely, the muscle functions to complete the basic action are reconstructed.
4. Dual compartment type: After resection of dual compartments, usually the motions in two directions are totally lost, and this has a huge influence on the functions. Due to the limited dynamical sources, only the functions which are physiologically necessary and can combine both aspects are reconstructed. If necessary, some joints are fixed to make up for a lack of dynamics.

3.6.2 The Method of Dynamic Reconstruction

For the content to be reconstructed, in principle, the tissues that have been destroyed should be repaired.

1. Nerve repair: When the tumor is located in the nerve trunk itself, a segment of nerve trunk is resected, the damages to the surrounding muscles are not serious, and the nerve repair can be selected. The commonly used methods for nerve repair include: (1) end-to-end nerve anastomosis, (2) end-to-side nerve anastomosis, and (3) nerve transplantation. But when there is a large segment of nerve trunk defect, the efficacy is poor. It is generally believed that after nerve repair, if about 50% of neurological functions can be recovered, the repairing efficacy

is already better. Further, since the nerve grows slowly, the nerve repair is not applicable for the sarcoma with higher degree of malignancy.

The side-to-side nerve anastomosis is a newly acquired method for peripheral nerve repair, the nerve axon can grow into the distal end through side-to-side anastomosis, and the functional effect is satisfactory. This method may have significance for saving the function of the residual nerve when the sarcoma involves the nerve, and it is required to carry out nerve segment resection.

2. The reconstruction of the muscle function: When the nerve and muscle are simultaneously resected, the nerve repair should be abandoned, and it is required to focus on the reconstruction of the muscle function; the simple resection of the muscle should further be performed with such a method. In terms of the development of the current technology, it is still impossible to talk about muscle repair, and the replacement method is mainly used to reconstruct the resected muscle or the function of the denervated muscle. The alternative reconstruction of muscle function mainly includes two types of local muscle (tendon) transposition and vascularized muscle transplantation.
   (1) Local muscle (tendon) transposition: All movement functions of the skeletal muscles are to convey the force to the ending point of a certain bone through muscle contraction and pull the bone and joint to produce the movement. Therefore, the change in the attachment points of the muscle can cause changes in the action direction of the force and the magnitude of the force. The clustered muscles mostly have functional similarities, and a part of them is cut off for other use, which has no significant impact on the main functions.
      1) Single attachment point transposition: The vicinity of the starting or ending point of the muscle is cut off, and then the muscle is transferred to another ending point or another acting surface and is fixed again; when the muscle contracts, the direction of acting force is partially changed; thus, a new action is created. For example, the anterior tibial muscle is moved outward to replace the evertor muscle; the introversive and dorsally stretched original muscle is moved outward to exceed the midline and is fixed; the resulting action changes the introversion into extroversion. The posterior tibial muscle is moved forward to replace the back extensor muscle for the same reason; when the direction of traction force exceeds the midline of the coronal plane of the ankle joint, the plantar flexion force is turned into the dorsiflexion force.
      2) Dual attachment point transposition: It refers to when both the starting point and ending point of the muscles are cut off, the direction and position are redeployed, and then the fixation is made. This method completely changes the direction of the original acting force of the muscle, the transposition amplitude is great, and the function which cannot be completed during the single attachment point transposition can be completed. This method is equivalent to the island muscle transplantation because it is only connected to the neurovascular pedicle; it is required that the precision of surgical operations is high, and the improper treatment may easily cause muscle necrosis.
      3) The first stage completion of dynamical reconstruction and wound coverage: When local defect is combined with dynamic dysfunction, the method of myocutaneous flap transposition is selected, the muscle is used to reconstruct the dynamics, and the carried skin is used to cover the wound. For example, after total resection of the deltoid muscle (including skin resection), the latissimus dorsi myocutaneous flap pedicled with thoracodorsal artery, vein, and nerve can be applied to make dual attachment point transposition, in order to achieve the purpose of not only reconstructing the abduction function of the upper limb but also covering the wound.
   (2) Vascularized muscle transplantation: Namely, the method of vascularized muscle transplantation is used to reconstruct the tumorous dynamic muscle defect, for example, the free transplantation of gracilis muscle, rectus abdominis muscle, and latissimus dorsi muscle is used for the reconstruction of foot dorsiflexion function after resection of the front compartment of the calf. Since the muscle transplantation itself has some problems and the use of muscle replacement for a few muscles with fine functions has limitations, then there is less clinical application of muscle transplantation.

3.6.3 The Principles for Local Muscle (Tendon) Translocation

1. Donor site selection: Since the retraining of the functions of the synergistic muscles is easier, the synergistic muscles should be selected at first, and then the antagonistic muscles are selected. The donor sites which are not significantly affected and are easy to operate and translocate are preferably selected. The commonly used transposition muscles and alternative muscles are seen in Table 18.2.
2. Donor site preparation: The tumor bed is negative or theoretically negative. The muscle tendon to be transposed should have a soft tissue bed with rich blood supply and should avoid direct close contact or overlap with bone,

Table 18.2 Commonly used transposition muscles and alternative muscles

Defected muscles	Alternative muscles
Gluteus maximus muscle	Tensor fasciae latae muscle
Gluteus medius muscle	External oblique muscle, tensor fasciae latae muscle
Quadriceps femoris muscle	Biceps femoris muscle, semitendinosus muscle, adductor magnus muscle, sartorius muscle
Anterior tibial muscle	Long fibular muscle, short fibular muscle, posterior tibial muscle
Long fibular muscle, short fibular muscle	Anterior tibial muscle, posterior tibial muscle
Triceps surae muscle	Anterior tibial muscle, long fibular muscle, posterior tibial muscle

nerves, or blood vessels. The muscle tendon after transposition should be covered by the normal skin soft tissue, namely, the skin flap.

3. Accurate operation: When the muscle to be transposed is separated, it is avoided to damage the neurovascular pedicle. The whole length of transposed muscle should be kept flat and straight and should be not angulated to facilitate the linear force transmission. When the antagonistic muscles are transposed, the main body should cross the interface between two antagonistic directions. Because the tendon of stump is mostly longer, the selection range of new attachment points is greater; the woven suture should be mainly based on which one can reduce the stretch. The anastomosis sites should avoid joints and the areas prone to friction. The bony attachment is not used as far as possible. The fixation in an overcorrect position is performed.
4. Functional training: The early passive training is gradually changed to active training.

3.7 Repair Methods after Resection of Soft Tissue Sarcomas of the Lower Limbs

3.7.1 Buttocks

1. The tumors on the superficial face of deep fascia
   (1) Tumors in the iliac area: Tumors on the superficial surface of the deep fascia in the iliac area, the superficial fascia compartment including the tensor fasciae latae muscle, and the superficial surface of deep fascia in the exposed portion of the gluteus medius muscle can be removed; the resulted wounds can be directly sutured or covered with the skin flap, and the affected side is relatively immobilized after surgery, especially the wound coverage and immobilization around the joints are very important.
   (2) The tumor in the buttocks: For tumors which are located on the superficial face of deep fascia in the buttocks, the resection plane should be determined according to the situation of involvement of the gluteal fascia. Because the fibers in the superficial layer of the deep fascia extend into the muscle fibers, the simple deep fascia resection should carry a few muscle fibers. If the gluteal fascia is involved obviously, a layer of or even the whole gluteus maximus muscle should be removed. The methods for wound repair are selected according to the scalar principle of wound repair. When being located in weight-bearing areas, such as near the ischial tuberosity, the myocutaneous flap or skin flap surgery must be performed, and it is best to carry sensory nerves simultaneously.
2. The tumors on the deep surface of the deep fascia
   (1) Tumors in the iliac area: When the sarcoma in the iliac area is located within the tensor fascia lata muscle, and the surrounding fascia structure is intact, the tensor fascia lata muscle together with its deep fascia can be removed as a compartment; the iliotibial band is fixed in situ onto the vastus lateralis muscle, which requires no special repair, and mostly has no effect on functions.
   (2) Tumors in the gluteal area: When the sarcoma is located between gluteus maximus muscles and near the gluteus maximus muscles or the superficial tumor invades into the muscular layer, the gluteus maximus compartment should be resected while including all skins which coat the fascia and the cover surface. When the gluteus maximus muscles are removed, in the bone attachment area and its vicinity, the subperiosteal layer should be resected, while the inferior gluteal nerve and blood vessels are ligated and cut off, the gluteus maximus compartment is relatively complete, and the muscular layer is thick; when the selection is appropriate, the recurrence rate is very low. After simple total resection of gluteus maximus muscle, the claudication in adults is often not so obvious, and this may be related to the compensations of tensor fasciae latae muscle, musculus sacrospinalis, and the gluteus medius and minimus muscles. Therefore, the replacement surgery is mostly not required after simple resection of gluteus maximus muscle.
   (3) The tumors in the area of gluteus medius and minimus muscles: The tumors in the area above the piriformis muscle mainly invade the gluteus medius and minimus muscles; this area combined with the piriformis muscle and the gluteal nerves and blood vessels can be resected. Because this area is covered by the upper part of the gluteus maximus muscle, if necessary, the deep fascia and its upper muscle can be

resected. In terms of the resection range, the deep layers should include the periosteum and outer plate of the iliac wing and the whole ilium. Because the muscle amplitude of the muscle in this area is smaller, and the function of fascia is not perfect, in addition, the recurrence rate of tumor is higher compared with the simple resection of gluteus maximus muscle; the postoperative radiotherapy should be additionally carried out according to the specific circumstance in the incisal margin. If the gluteus medius muscle and the upper part of the gluteus maximus muscle are resected during surgery, the majority of patients will walk with a swaying gait; at this time, the starting point of tensor fasciae latae muscle is transferred posteriorly, which can get the desired effect.

(4) Tumors in the area under the piriformis muscle: When the sarcoma is located under the piriformis muscle and in front of the sciatic nerve, the area under the piriformis muscle and the small external rotator group can be resected, and the nerve is retained, but only the epineurium of the sciatic nerve is resected, and the lower part of the gluteus maximus muscle can be treated according to the circumstances. When the inferior gluteal nerve and blood vessel are involved, the lower part of the gluteus maximus muscle cannot be retained in most cases; it should also be resected simultaneously.

For the tumors in the area under the piriformis muscle, anatomically the front part is looser and the posterior part is tenser; the tumor is easy to protrude forward, often invading the pelvic cavity or the area near the obturator; it is difficult to achieve the ideal incisal margin. At the same time, because the pelvic organs can't be viewed directly, they are prone to subsidiary injury, and particular attentions should be paid to them during surgery. The postoperative radiotherapy should be combined mostly to compensate for insufficient incisal margin. It is not required to carry out reconstruction after resection of the small external rotator group.

(5) Huge tumors in the buttocks: When the tumor located in the buttock is huge, and the zoning resection cannot be performed, en bloc resection in the gluteal region can be selected; the resected tissues can include gluteus maximus muscle, gluteus medius muscle, gluteus minimus muscle, tensor fasciae latae muscle, and ilium; the sciatic nerve should still be retained as far as possible; the additional radiotherapy is carried out after surgery. If the sciatic nerve is resected at a high level, the functional damage is very difficult to repair; if it must be resected, it may also be difficult to achieve negative incisal margins in local area; therefore, the wound repair is carried out mainly with skin flap, myocutaneous flap, or free skin flap.

(6) The tumors near the apophysis: The apophyses in the buttocks or the adjacent area including the iliac crest, greater trochanter, and ischial tuberosity. The tumors in iliac crest can be resected in most cases; the wound is closed directly. If the greater trochanter of the femur and the ischial tuberosity present with obvious involvement, the bone should be treated simultaneously; the exposed area can be repaired with myocutaneous flap or skin flap; the commonly used flaps include the gracilis myocutaneous flap, sartorius myocutaneous flap, and tensor fascia lata myocutaneous flap.

3. Commonly used repair methods for skin and soft tissue defects in the iliac and gluteal areas

(1) The posterior femoral cutaneous neurovascular flap: In 1992, Masquelet firstly put forward that the cutaneous neurovascular flap is a new type of skin flap which is based on the cutaneous nerve and nutrient vessel for its survival. Hereafter, because this type of skin flap has advantages that it doesn't damage the major blood vessels in the limbs, the blood supply is reliable, the pedicled transposition is performed to repair the receptor site, the surgical risk is small, there is a condition for reconstruction of sensory function, the surgical method for antegrade or retrograde transfer of skin flap can be designed, and it has been widely used clinically.

1) Applied anatomy: The posterior femoral cutaneous nerve (PFCN) penetrates out from the midpoint of the inferior margin of gluteus maximus muscle to enter into the posterior femoral region; the main trunk runs downward along the posterior femoral median line (from the midpoint of inferior margin of gluteus maximus muscle to the midpoint of the connecting line between the internal and external femoral condyles) and penetrates superficially out of the deep fascia at 9.1 ± 3.2 cm above the adductor tubercle in the lower segment of the thigh. The transverse diameter of the posterior femoral cutaneous nerve at the lower margin of the gluteus maximus muscle is 3.0 ± 0.6 mm; it gradually becomes thin in the process of running downward. It firstly runs along the medial side of the biceps femoris muscle and then runs downward between the biceps femoris muscle and semitendinosus muscle to the posterior region of the knee. The blood supply of the posterior femoral cutaneous nerve and the posterior femoral skin mainly has three main sources, namely, the inferior gluteal artery in the proximal posterior thigh, the myocutaneous perforating arteries of the deep femoral artery in the middle segment of posterior thigh, and the fascial and cutaneous branch of the popliteal artery in the distal posterior thigh.

2) Case V: For the patients with fibrous tissue sarcoma in the gluteal area, before surgery, Doppler is mostly used to find and mark the accompanying vessels of the posterior femoral cutaneous nerve at area near the midpoint of inferior margin of gluteus maximus muscle in the posterior thigh. The marked site is taken as the rotation point of the skin flap, the cutaneous nerve is taken as the central axis, the posterior femoral cutaneous neurovascular flap is designed, the lower boundary is located at 8–10 cm above the transverse striation of popliteal fossa, the width of skin flap can be up to 10 cm, and the skin flap with a maximum area of 15 × 10 cm can be harvested (it is designed according to defect size). The bilateral sides of skin flap, distal skin and subcutaneous tissues, and the deep fascia are incised along the designed incision line; the skin flap is separated upward between the deep fascia flap and myolemma; it is required to carefully ligate 3 to 5 perforator nutrient vessels from the femoral artery during separation; attentions should be paid to protecting the sciatic nerve which runs deeply between biceps femoris muscle and semimembranosus muscle. The skin and subcutaneous tissue between the proximal end of the skin flap and the rotation point are incised and turned over toward bilateral sides; the cutaneous nerve, nutrient vessels, superficial veins, and deep fascia are retained; and 2–3 cm fascia pedicle is retained respectively on both sides of the traveling path of the cutaneous nerve. The skin flap is anterogradely rotated and transplanted into the defect area in the receptor site and is fixed and sutured, and the donor site is closed and sutured directly. The negative pressure drainage tube is placed in donor site and under the skin flap in the receptor site, and the drainage tube is removed 24–48 h later (Fig. 18.14).

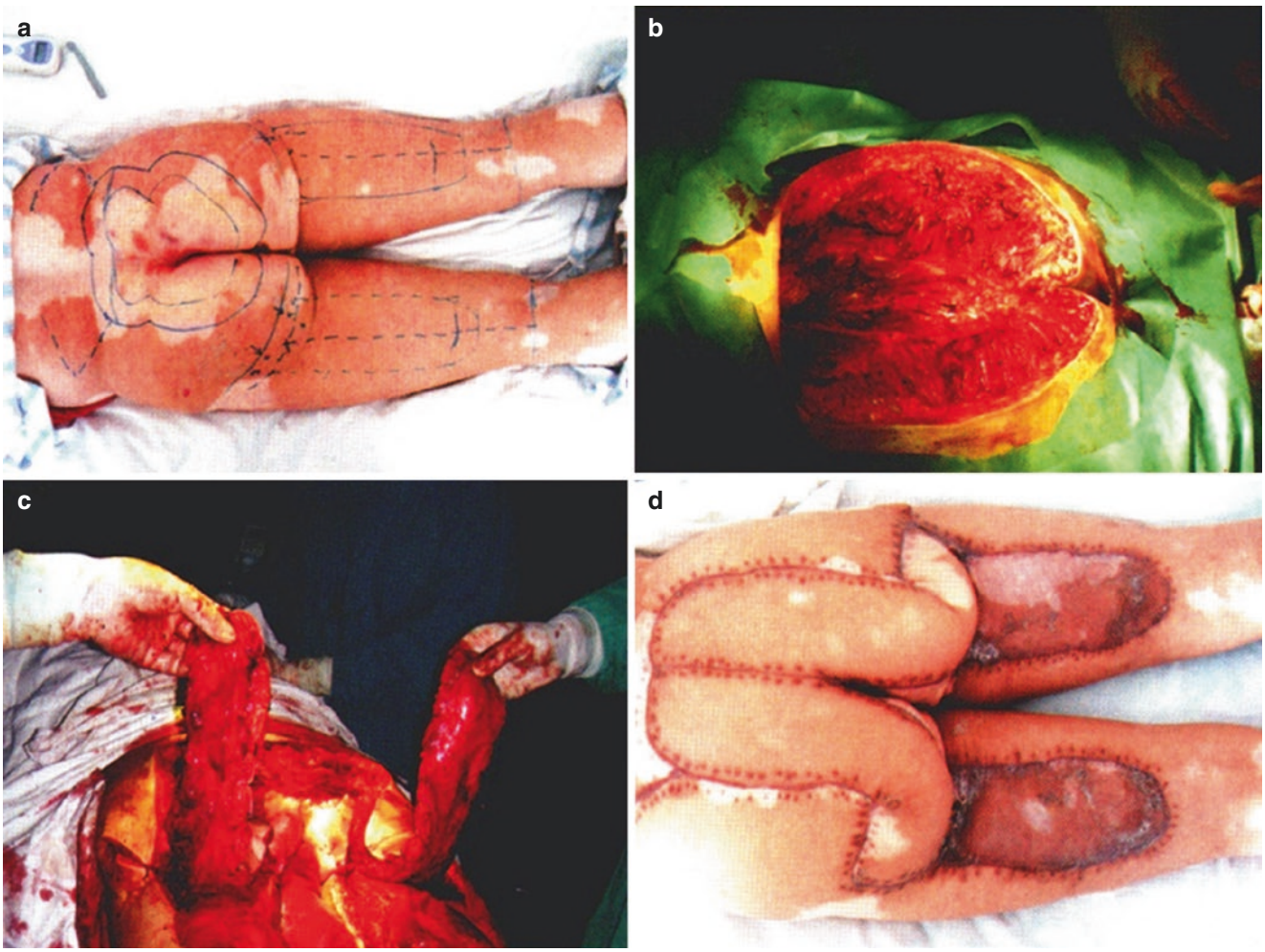

Fig. 18.14 Case V. (**a**) The resection range of the tumor was marked and the posterior femoral cutaneous neurovascular flap was designed before surgery. (**b**) The residual wound after tumor tissue resection. (**c**) The harvested bilateral posterior femoral cutaneous neurovascular flap. (**d**) At two weeks after surgery

(2) Tensor fascia lata myocutaneous flap: The tensor fasciae latae muscle originates from the lateral margin of the iliac crest, behind the starting point of the sartorius muscle at the anterior superior iliac spine. The muscle belly is longitudinal, and it is totally wrapped in the deep fascia and is transited into the iliotibial band in the vicinity of the greater trochanter of the femur. The ascending branch of the lateral femoral circumflex artery enters into the anterior margin of the tensor fasciae latae muscle through the posterior side of rectus femoris muscle at about 8 cm below the anterior superior iliac spine.

1) Applied anatomy: The blood vessels of the tensor fascia lata myocutaneous flap are constant, the blood supply is rich, it is easy to harvest, the transposition is convenient, and this area is an ideal donor site; its distal end often carries the iliotibial band, increasing the local anti-pressure and antifriction abilities. When it is harvested, the conjoint tendon of it and the gluteus maximus muscle are discerned, and herein the incision is made, which is an important step, and the myocutaneous flap can be quickly harvested.
2) Design, harvesting, and transposition: The length of myocutaneous flap can start from the iliac crest to the site at 5 cm above the knee, and the width is about 10 cm taking the muscle as the center. The posterior margin line of myocutaneous flap is incised according to design, the underneath separation is carried out on the deep surfaces of the tensor fasciae latae muscle and iliotibial band, the distal end is transected, and the skin and the margin of deep fascia are fixed (Fig. 18.15a). The upward side of the posterior margin is incised downward, the proximal posterior side is separated, and the starting point of the muscle is cut off at the outer margin of the iliac crest (Fig. 18.14b). The myocutaneous flap is turned over forward, and the ascending branch of the lateral femoral circumflex artery can be observed and touched on the deep surface of the muscle at about 7 cm under the lower margin of the anterior superior iliac spine. The whole anterior margin of myocutaneous flap is cut off under direct vision, and attention is paid to protecting the neurovascular pedicle. After the myocutaneous flap is completely lifted up, the distal end is rotated backward by 90°; it is noted that the vascular pedicle should be not distorted. All flap margins are sutured without tension; the donor site is sutured directly (Fig. 18.14c). The patient should take a supine position with hip extension or a lateral position for 2 weeks after surgery.

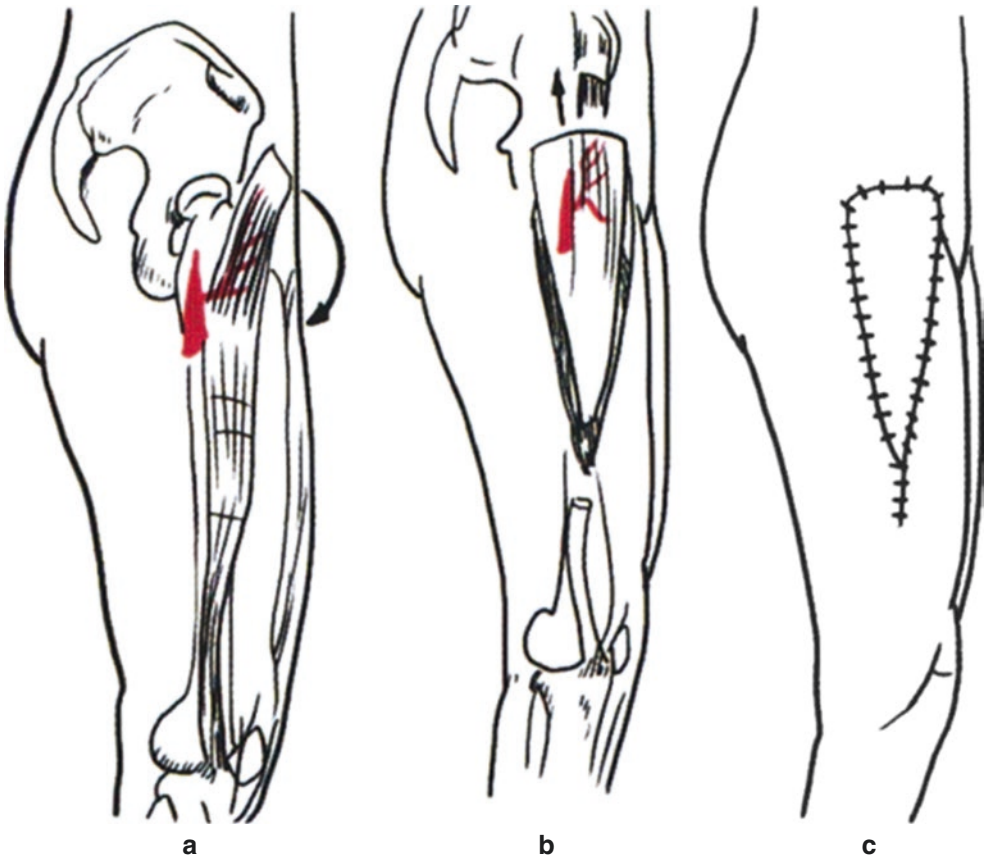

Fig. 18.15 The status of blood supply of tensor fascia latae muscle and its application in the repair of wound in the region of the greater trochanter. (**a**) Tensor fascia latae muscle. (**b**) Harvesting of tensor fascia lata myocutaneous flap. (**c**) After the tensor fascia lata myocutaneous flap was used to repair and suture the wound in the region of the greater trochanter

(3) Gluteal myocutaneous flap

1) Applied anatomy: The gluteus maximus muscle can be divided into upper and lower portions with piriformis muscle as the boundary; the blood supply of the upper portion is provided by the superficial branch of the superior gluteal artery which originates above the piriformis muscle; the blood supply of the lower portion comes from the inferior gluteal artery given off under the piriformis muscle and at the medial side of the sciatic nerve. All muscles are innervated by the inferior gluteal nerve.
2) Design, harvesting, and transposition: The axis point is located on the upper middle one third part of the connecting line between the posterior superior iliac spine and the greater trochanter of the femur, namely, the site where the superior gluteal artery penetrates out from the piriformis muscle. According to the design of the skin flap, the skin, subcutaneous tissue, deep fascia, and the gluteus maximus muscle are incised by layers from far and near, and the margins of the abovementioned tissues are sutured to prevent separation of the skin and soft tissue from the muscle flap. The blunt dissection is carried out in the clearance between the gluteus maximus and medius muscles; attentions are paid to avoiding damage to the superficial branch of the superior gluteal artery. Whether the gluteus maximus is split off along the running path of the blood vessel is determined according to the type of the skin flap, the myocutaneous flap is dissociated and rotated to repair the wound, and a negative pressure drainage tube is placed in the wound.
3) Case VI: The patient had a malignant fibrous histiocytoma in sacrococcygeal region; the gluteal myocutaneous flap was used to repair the defect after sacrococcygeal tumor resection (Fig. 18.16).

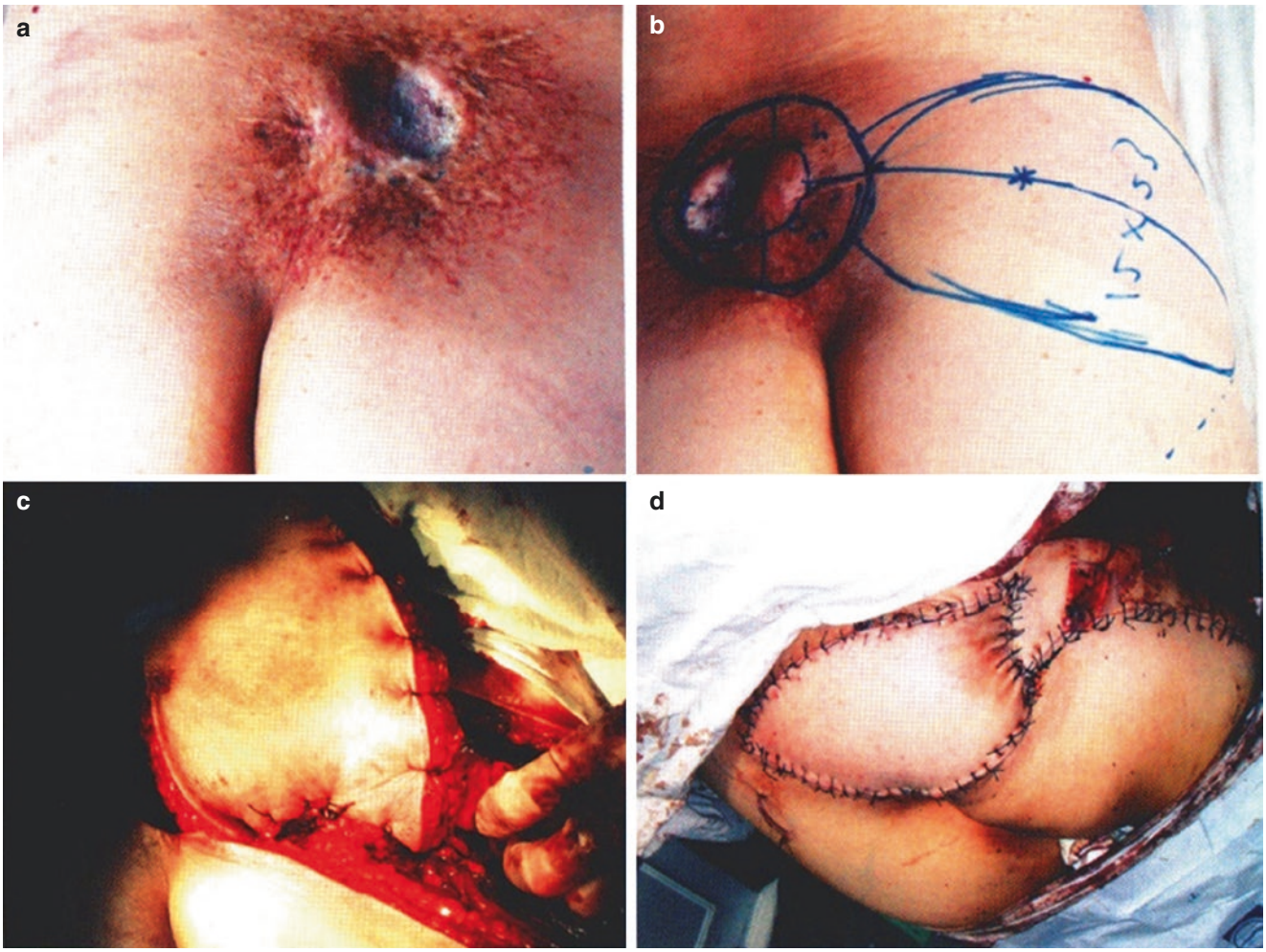

Fig. 18.16 Case VI. (**a**) Preoperative lesion. (**b**) The resection range of the tumor was marked and the right gluteal myocutaneous flap was designed before surgery. (**c**) The pedicled gluteal myocutaneous flap was transferred to repair the wound after tumor resection. (**d**) The donor site is closed and sutured after dissociation and rotation of the myocutaneous flap

(4) Gracilis myocutaneous flap:

1) Applied anatomy: The aponeurosis of the gracilis muscle starts from the inferior pubic ramus, travels downward and is transited into the strip-shaped muscle tendon at the level of the medial epicondyle of pubic bone, and ends at the medial tibial tuberosity. The blood supply of the gracilis muscle is rich and comes from multisources, including the gracilis muscle branch of the deep femoral artery, the medial femoral circumflex artery, the obturator artery, and the descending genicular artery. Among the arteries providing blood supply to the middle and upper part of the gracilis muscle, the arteries originating from the gracilis muscle branch of the deep femoral artery account for the vast majority (96%); the branch is given off mostly from the medial and anterior walls of the deep femoral artery. It runs obliquely and constantly downward at the deep surface of the long adductor muscle after being given off; its trunk gives off 3–4 branches at about 2–3 cm outside the junction point of the middle and upper one third of the gracilis muscle, which are distributed in the gracilis muscle. Their concomitant veins are double branches in most cases and single branch in a few cases. The blood vessels providing blood supply to the lower part of the gracilis muscle come mostly from the descending genicular artery; there are rich arterial anastomoses among the arteries from the upper, middle, and lower segments of the gracilis muscle; the arteries from the middle and lower segments of the gracilis muscle are ligated and cut off; the blood supply of the muscle flap can be provided via vascular anastomosis. The nerve controlling the gracilis muscle comes from the branch of the anterior branch of the obturator nerve, after the nerve enters into the thigh, runs obliquely between the long and short adductor muscles toward the lower medial side, and gradually runs accompanying with the major blood vessels of the gracilis muscle to form the neurovascular bundle, which enters into the muscle at the anterior margin of the junction of middle and upper one third of the gracilis muscle (Fig. 18.17).

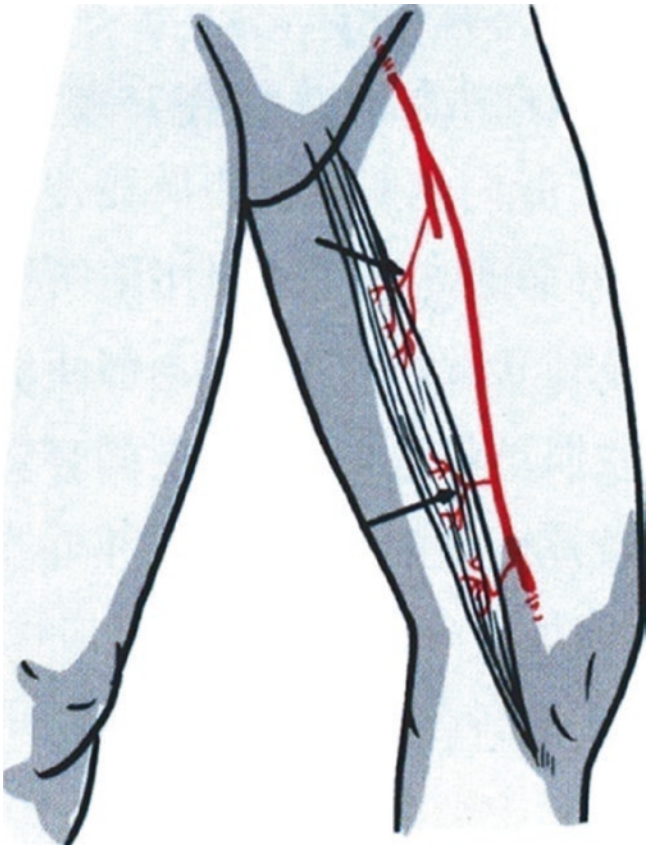

Fig. 18.17 Relationship between the gracilis muscle and its nutrient vessels

2) Design, harvesting, and transposition: The medial points of the pubic tubercle and knee joint are marked, and the skin flap is designed within 10 cm range in the upper and middle thirds of the posterior area (Fig. 18.18). The site at about 8 cm under the pubic tubercle is taken as the rotation axis of the myocutaneous flap; the distance from the axis point to the farthest point of the skin flap is the length of the skin flap. In consideration of the skin flap shrinkage, generally the side length of the myocutaneous flap is greater than that of the defect by 10%.

Firstly incise the skin, subcutaneous tissue, and the deep fascia at the anterior side of the myocutaneous flap, bluntly dissect between the long adductor muscle and the gracilis muscle, then separate out the nourishing blood vessels and nerves of the gracilis muscle, and dissociate toward the proximal end along the blood vessels and nerves to the beginning part of the blood vessel, and then incise the skin, subcutaneous tissue, and deep fascia surrounding the myocutaneous flap. In the process of transecting the gracilis muscle at the upper and lower ends of the myocutaneous flap, the subcutaneous tissue of the myocutaneous flap is sutured with the myolemma at any moment to avoid separation of both parts. The vascular pedicle is further dissociated on the deep surface of the gracilis muscle, and generally the vascular pedicle with a length of 5–6 cm can be dissociated, it is completely dissociated for being easily transferred into the defect area, and the wound in the donor site is closed. The skin flap is transferred into the defect area through the subcutaneous tunnel between the donor site and the defect area.

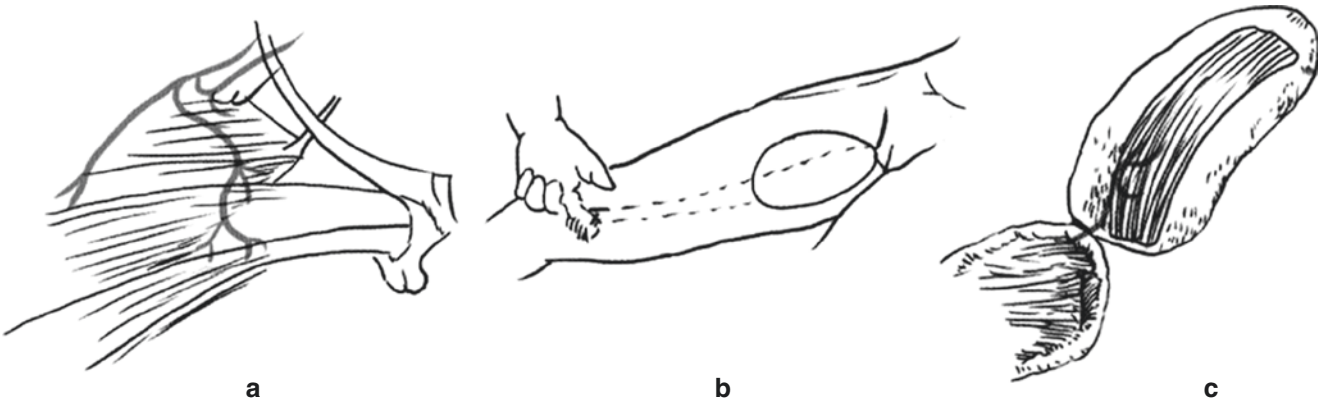

Fig. 18.18 Design of gracilis myocutaneous flap and island skin flap. (**a**) The gracilis muscle and its nutrient vessels. (**b**) Skin flap design. (**c**) The harvested island gracilis myocutaneous flap

3.7.2 Femoral Area (Thigh Area)

1. The tumors on the superficial surface of the deep fascia: In addition to the greater femoral trochanter and knee joint, the thigh area is almost entirely covered with abundant and thick muscles; the tumors on the superficial surface of the deep fascia located on the whole perimeter of the thigh can be resected with the superficial fascia compartment including the deep fascia; the wound is directly sutured or treated with free skin transplantation according to size. And after the superficial tumors located near the greater femoral trochanter and the knee joint are resected, it should be considered to carry out repair surgery with skin flap or myocutaneous flap.
2. The tumors on the deep surface of the deep fascia
   (1) The tumors in the anterior femoral region: Although the anterior femoral region is a more complete compartment, but its range is very wide, and different parts have different characteristics, its resection cannot be generally referred to as the anterior compartment resection.
      1) The tumors in front of the anterior femoral region: The sarcomas which simply invade the rectus femoris muscles or grow between the rectus femoris muscles, with intact peripheral interface, can be treated with rectus femoris muscle resection alone. If the sarcoma is located between rectus femoris muscle and vastus intermedius muscle, it is separated mostly with the myolemma or aponeurosis structure; the fused area is also the tendinous tissue; therefore, the postoperative effect is good, and it should be considered as a typical location for muscle compartment resection. The resection of the rectus femoris muscle has little impact on the extension of knee joint, it is not necessary to carry out reconstruction, and the medial and lateral vastus muscles are drawn toward the midline and are sutured when necessary.
      2) The tumors at the medial side of the anterior femoral region: When the tumor is located in the medial vastus muscle or the superficial tumor invades the medial vastus muscle, the resection range is determined according to the surface where the tumor is located, its anatomical features, and the relationship of the tumor with the rectus femoris muscle and the vastus intermedius muscle; if necessary, the en bloc resection of rectus femoris muscle, vastus intermedius muscle, and medial vastus muscle can be carried out. If the tumor is located completely between the medial vastus muscles, there is a barrier between the tumor and the rectus femoris muscle; when there is a safe distance between the tumor and the vastus intermedius muscle, the medial vastus muscle can be resected only. For the tumor with a closer distance from the adductor muscles, a part of adductor muscles should be resected simultaneously, because the segment of medial intermuscular septum in the medial vastus muscle is relatively weak, the barrier function is poorer, and the safe distance should be increased. When the tumor may affect the adjacent adductor canals or blood vessels, the adductor canals and blood vessels should be resected, or the blood vessels are retained, and the additional radiotherapy is carried out after surgery. After vascular resection, the blood vessel transplantation should be carried out to reconstruct the blood circulation.
      3) The tumors in lateral side of anterior femoral region: When the sarcoma is located between the vastus lateralis muscles and involves the vastus lateralis

muscles, since the horizontal development of the sarcoma between muscles is slower than the vertical development, in fact, the tumor still has a considerable distance from the midline, and the distance is often more than 3–5 cm. Even if the tumor is larger, it can still have this characteristic. All vastus lateralis muscle and part of vastus intermedius muscle outside the midline are resected in this case, and a safe distance can be achieved. In addition, the lateral intermuscular septum at the lateral side is resected, and the effect of the barrier resection can be compared with that of the radical resection of the entire compartment. When the tumor invades laterally or toward the deep area to perforate through the vastus lateralis muscle and invade the vastus intermedius muscle, although the tumor is still in situ, the incisal margin should be transferred inward correspondingly, until the entire compartment is resected.

(2) The tumors in the medial femoral region:
   1) The tumors in the medial femoral region with a more limited range: When the sarcoma is located on the deep surface of pectineal muscle, which is equivalent to the junctional zone between the medial and posterior compartment and the inferior gluteal area, the incisal margins can be designed taking the iliopsoas muscle and the femoral quadratus muscle as the rear interface; the en bloc resection of femoral quadratus muscle, part of iliopsoas muscle, and pectineal muscle are carried out; and the incisal margins are relatively ideal. The locations of the tumors in these areas are deep, the diagnoses are difficult, the tumor is mostly larger when it is detected, and it should not rely solely on surgery and mostly requires undergoing postoperative radiotherapy.
   2) The tumors with involvement of the entire compartment: The sarcoma in the medial femoral region involves the entire medial compartment and has not yet broken through the compartment wall; the medial compartment resection can be carried out.
   3) Dynamic repair and reconstruction: The obturator nerves and blood vessels run through the upper barrier resection of the medial femoral region while controlling the adductor muscles. When the compartment resection or the barrier resection in the upper part is carried out, the obturator nerves and blood vessels can be resected along with the tumor. Since the function of the adductor muscle is relatively subordinate, whether the nerve resection or the muscle resection has a small influence on function, it is not required to carry out repair, and the normal gait can almost be achieved relying on gravity adduction.

(3) The tumors in the posterior femoral region:
   1) The tumors tilting to one side of the posterior femoral region: The muscles in the posterior femoral region are divided into medial and lateral groups taking the midline as the boundary. In addition to that, the proximal end of the long head of the biceps femoris muscle crosses the sciatic nerve, and the rest of the muscles almost take the sciatic nerve as the boundary. The semimembranosus muscle is located in the medial half, and the biceps femoris muscle is located in the lateral half; the intermediate contact is relatively loose. When the tumor is located on one side and has a certain distance from the midline, the total resection of the medial half or the lateral half can be selected, while the fascia and adipose tissue adjacent to the boundary are included, and the additional radiotherapy is carried out after surgery if necessary.
   2) The tumors at the center of the posterior femoral region: When the tumor is located at the center of the posterior femoral region and the volume is large, in theory, the posterior compartment resection should be carried out, and the contents to be resected include three hamstring muscles, the sciatic nerve, and the associated fascias. The local control should be ideal after surgery. Because the posterior compartment resection includes the resection of the sciatic nerve, therefore, the lower limb function is severely impaired after surgery. After the sciatic nerve is completely resected, all muscles in the calf and foot will be paralyzed, and all plantar sensations will be lost. Due to the loss of numerous motor functions, in addition to the repair of the nerve itself, there are almost no other reconstruction methods.

For the sciatic nerve repair, both the source of materials and the recovery after nerve repair are not ideal. Therefore, the sciatic nerve should be retained as far as possible. The following methods for retaining the sciatic nerve can be tried: (1) The resection of the epineurium of the sciatic nerve plus radiotherapy. It is used mostly when the sciatic nerve is violated slightly. (2) The tibial nerve or the common peroneal nerve – one of the two is retained, especially the tibial nerve. When the tumor is located under the middle segment, mostly the sciatic nerve has been split into two parts; even if the outside appearance has not been separated, the intrathecal nerves have been divided into two nerve trunks; the nerve trunk with light involvement is selectively retained. One of the two nerves is retained; after the motor function is corrected with the dynamic balance, the foot function is still satisfactory. Another advantage of retaining the tibial nerve

is that the plantar sensation is retained simultaneously, and its significance is greater than that of retaining the peroneal nerve. When the tibial nerve cannot be retained, the plantar sensation cannot be recovered, and the feet should be given with physical protection, for example, the patient wears loose shoes, the shoes are padded with thicker soft insoles, and attention should be paid to heat preservation during winter, and at the same time, the amount of exercise should be reduced. It would be better to repair the pressure ulcers which have occurred with the neurosensory skin flap, and the dorsal pedis flap may be an ideal donor site.

3.7.3 Calves

1. Tumors in the superficial surface of the deep fascia: The deep fascia on the deep surface of subcutaneous tissue of the calf is intact, thick, hard, and tough; it is the excellent natural barrier to stop the invasion of the sarcoma in superficial layer toward the deep layer. The tumors located in these areas belong to the typical intracavity type; the effect of the tumor resection including deep fascia is good. When the deep fascia of the calf migrates to the front side of the fibula, it is fused together with periosteum at the front side of the tibia, and therefore, the malignant tumor in this place should be treated with subperiosteal resection. Whether the tumors are located directly in these areas or are located in the vicinities of these areas, the bone problems are often involved, the bone involvement or bone exposure is commonly seen, and both involve the problem of coverage.

   Clinically, the skin defects with a width of about 2 cm in tibialis anterior region cannot be sutured directly in most cases and are repaired with the use of various methods for tissue flap transplantation or transposition. The commonly used skin flaps include fasciocutaneous flap, gastroecnemius myocutaneous flap, soleus myocutaneous flap, the fasciocutaneous island flap with sural nerve, gastrocnemius muscle flap combined with skin transplantation, the skin flap in the medial calf, and the skin flap in the lateral calf.
2. The tumors at the deep surface of the deep fascia
   (1) The tumors in the pretibial compartment: When the sarcoma in the anterior tibial compartment or superficial sarcoma perforates through the deep fascia and invades the compartment, the resection of anterior tibial compartment can be carried out, and the contents to be resected include anterior tibial muscle, flexor hallucis longus, extensor digitorum longus, anterior tibial artery and vein, deep peroneal nerve, the periosteum at the lateral surface of the tibia, and the lateral intermuscular septum. The interosseous membrane between the tibia and fibula can be retained depending on specific circumstance as a barrier to prevent the invasion of posterior tibial compartment by the recurrent tumor.

   After resection of the pretibial muscle group, mainly the dorsiflexion functions of ankle joint and toes are lost. Because the plantar flexion force of the flexor group loses the antagonism, the equinus deformity will appear, the walking will be severely affected, the dorsiflexion function reconstruction should be carried out, and the methods wherein the posterior tibial muscle is transferred forward and the long peroneal muscle or short peroneal muscle is transferred inward can be used.

   (2) The tumors in the lateral compartment: After resection of the lateral compartment, the eversion function of the foot is lost; the strong varus force loses the antagonism, which will cause varus foot deformity. The varus foot cannot walk properly, and the eversion function should be reconstructed. The anterior tibial muscle is transferred outward, and the effect is good. The loss of superficial peroneal nerve accompanying the resection of the lateral compartment will also cause the lack of sensation in a large area of skin in foot dorsum; some time later after surgery, there may be partial compensation.

   (3) The tumors across the anterior and lateral compartments: The huge sarcomas in the anterolateral calf often involve the anterior and lateral compartments: such patients seen in clinic often have multiple recurrences until the tumors are huge, and even the tumors are ulcerated. The cross-sectional imaging of the tumor segment is carefully observed, in which the effective barrier can still be found; the dual compartments can be resected. The tumor ulceration can be seen as a compartment opening to the space, the safe skin incisal margins across the two compartments are designed, and the local control is ideal after surgery. The resected tissues include all soft tissues in two compartments, the upper and middle segments of the fibula and posterior intermuscular septum; because a considerable number of tissues are resected, the resulting dysfunctions are equivalent to the complete loss of functions of two compartments, that is, defunctionalization in bilateral directions, which brings difficulties to functional reconstruction.

   (4) The tumors in superficial posterior compartment: The tumors of triceps surae muscle or superficial tumors which invade the superficial posterior compartment can be treated with total resection of the superficial posterior compartment in the calf. After resection of the tumor and its superficial compartment, the plantar flexion force is significantly affected, although the muscle group and the long and short peroneal muscles in the deep posterior compartment also have the plantar flexion function, but cannot replace the strong tensile force of the

Achilles tendon; it is required to carry out the functional reconstruction. When the skin and soft tissue are resected together, it is mostly required to carry out free skin flap transplantation to repair the wound.

(5) The tumors in the deep posterior compartment: The tumors simply located in the deep posterior compartment are rarely seen; it is mostly observed that the sarcoma in the superficial posterior compartment invades into the deep posterior compartment or the tumor in bone and periosteum invades into the deep posterior compartment. The resection range of the deep posterior compartment includes three muscles including flexor hallucis longus muscle, flexor digitorum longus muscle, and posterior tibial muscle, a group of important nerves and blood vessels, the periosteums of two adjacent bones, and the transverse intermuscular septum. After muscle removal, as long as the Achilles tendon is intact, the impact on the function is acceptable. The more serious problem is the removal of the tibial nerve; after the segment of the tibial nerve in the calf is removed, this will result in the paralysis of most intrinsic foot muscles and the complete loss of plantar sensation; and these dysfunctions are almost impossible to be repaired.

(6) The tumors in dual posterior compartments: When the sarcoma in the posterior calf invades the dual compartments, it may be considered that the dual compartments are resected; as long as the sarcoma does not exceed this range, the barrier structures of superficial and deep compartments are used in combination; the local control is ideal. When the muscle surgery cannot repair the function, it can be considered that the ankle arthrodesis or pantalar arthrodesis can be carried out.

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Defect Repair After Genital Malignant Tumor Surgery

19

Kaixiang Cheng, Daochou Long, Yu Xie, Jing Wang, Zan Li, Xiao Zhou, and Yile Chen

1 Overview of Penile Cancer

Kaixiang Cheng

1.1 Incidence Rate and Diagnosis

1.1.1 Incidence Rate

The penile cancer is the most common malignant penile tumor, accounting for 90–97.4% of malignant penile tumors. According to the statistics in Shanghai, the incidence rate of penile cancer is 1.09/100,000. With the improvement of living conditions and people's increased awareness of health literacy, the incidence rate of penile cancer decreases year by year, and the penile cancer has become a kind of rare tumor. The average onset age of penile cancer is about 60 years old in China.

The exact cause of penile cancer is not known, and currently the theories on redundant prepuce, phimosis, and smegma preputii are more recognized. In addition, viral infection, the scar ulcer after penile trauma, smoking, penis rash, and increased number of sexual partners are risk factors associated with penile cancer incidence.

1.1.2 Pathological Diagnosis

Among the penile cancers, the squamous cell carcinoma accounts for 95%, and other tumors are relatively rare. The penile cancer is used to appear mostly in the glans penis, coronary sulcus, and inner plate of prepuce and rarely in the penis body. Penile cancers can be roughly divided into papillary carcinoma and invasive carcinoma according to morphology. The papillary carcinoma starts mostly from pimple-like nodules or warts, shows exogenous growth, and looks like a cauliflower. The invasive cancer starts mostly from lesions such as eczema or vitiligo, shows infiltrative growth, and can form ulcers.

The most commonly used diagnosis and staging of penile cancer is the TNM staging of the Union for International Cancer Control (UICC) 2009.

1.2 Clinical Symptoms and Signs

During early canceration, the glans penis or foreskin epithelium is hypertrophic, may be concealed or ignored, and is difficult to find. In most cases, there are pimples, ulcers, warts, or cauliflower patch on the glans penis, and then erosion occurs, the margins are hard and untidy, and the patient is aware of tingling or burning pain and has purulent and malodorous secretions. When there is phimosis or the foreskin cannot be upturned, the surgeon can carefully touch across the foreskin to feel for lumps or nodules, and there is local tenderness. At the front end of the penis, the purulent or hemorrhagic secretions often flow out by themselves. In primary focuses and inguinal lymph node metastases of the advanced patients, ulcers, suppuration, and bleeding can occur; when there are distant metastases, there will appear symptoms in corresponding regions and systemic manifestations such as weight loss, anemia, and cachexia.

1.3 Applied Anatomy

The penile cancer is mainly metastasized through lymphatic channels, is firstly metastasized into the superficial inguinal lymph nodes, and then is metastasized into the deep inguinal lymph nodes; if it is further metastasized, it can reach to the

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external iliac lymph nodes, internal iliac lymph nodes, and obturator lymph nodes. The blood metastasis is rare. In advanced cases, there are often metastases in the lung, liver, kidney, brain, and other organs.

1.4 Treatment Plan

The treatment of the penile cancer is mainly surgical treatment [1–3], and the laser treatment, radiotherapy, and chemotherapy can also be carried out. The surgical treatment includes treatments of primary focus and lymph node.

1.4.1 Surgical Treatment

1. The treatment with preservation of the penis: The small tumors with primary focuses confined to the foreskin and the tumors without deep infiltration and lymph node metastasis before stage T_1 can be treated selectively by surgical treatment with preservation of the penis. The treatment methods include circumcision and partial resection of the lesion.
2. Partial resection of the penis: It is recommended that the patients with poorly differentiated T_1 tumors and T_2 tumors are treated by partial resection of the penis. When the lesions are confined to the glans penis, part or all of the glans penis can be removed, and the tumor-free margins are determined according to physical examination and the degree of tumor differentiation (1.5 cm for highly and moderately differentiated cancers, 2 cm for poorly differentiated cancers).
3. Total penectomy + perineal urethrostomy: It is recommended that the patients with worse than stage T_2 penile cancers undergo total penectomy + perineal urethrostomy. The patients with T_2 penile cancers who can't keep functional stumps after partial resection should also undergo total penectomy + perineal urethrostomy. When the scrotum is involved, the total penectomy and the resection of the scrotum and testis are performed simultaneously.
4. Whether there is metastasis in the ilioinguinal lymph node, the dissection area is the determining factor affecting the survival rate. For patients with preoperative inguinal lymphadenectasis, after resection of the primary focus, the antibiotic treatment is carried out for 3–4 weeks, and then the swollen lymph nodes are palpable in inguinal region; it is required to carry out regional lymph node dissection. And for some patients with one of the following risk factors, it is required to carry out prophylactic inguinal lymph node dissection: (1) poorly differentiated penile cancer, (2) T_2 and above tumors, (3) the tumors with vascular and lymphatic invasion, and (4) the patients who cannot be followed up. According to the characteristics of crossing drainage of the penis lymphatic drainage, it is required to carry out bilateral inguinal lymph node dissection. Patients with equal or more than two metastatic inguinal lymph nodes or single lymph node which is equal or more than 3 cm are required to undergo iliac lymph node dissection.

The range for groin lymph node dissection:

(1) Inguinal lymphadenectomy: The anterior margin is located at the level of the navel and the anterior superior iliac spine, the lower margin reaches the femoral triangle top, the outer boundary starts from the inside of the anterior superior iliac spine downward to the medial side of the sartorius muscle, and the inner boundary locates at 3 cm beside the anterior median line of the inguinal ligament.

(2) Iliac lymph node dissection: The upper boundary reaches to the bifurcation of the femoral canal, the lower boundary reaches to the femoral canal, the lateral boundary reaches to the medial side of the femoral branch of the genitofemoral nerve, and the inner boundary reaches to the tendinous arch of the levator ani.

1.4.2 Chemical Treatment

The penile cancers are mostly well-differentiated squamous cell carcinomas and are mostly insensitive to chemotherapy. The efficacy of single chemotherapy alone on the penile cancer is not satisfactory and is mostly used for the adjuvant treatment and combination therapy. The commonly used drugs include cisplatin, fluorouracil, vincristine, methotrexate, and bleomycin, and generally the combination drug therapy is carried out. Studies have shown that the patients with regional lymph node metastasis receive adjuvant chemotherapy after radical surgery, and a 5-year survival rate is improved. The patients with inguinal lymph node metastasis are treated with neoadjuvant chemotherapy, which gives the patients with the opportunity of radical surgery. The chemotherapy also has certain effects on the advanced patients.

1.4.3 Radiotherapy

Radiotherapy is the auxiliary method for treatment of penile cancer, including X-ray external irradiation, iridium contact therapy, cobalt-60 gamma irradiation, and accelerator X-ray. The patients with local lesion diameter less than 2 cm, superficial and exophytic type, no infiltration, and no lymph node metastasis can be treated selectively using the radical radiotherapy. The preoperative radiotherapy can make some penile cancer patients with fixed lumps undergo surgery. For patients with lymph node metastasis, the postoperative radiotherapy can reduce the preoperative local recurrence rate. If the primary lesion diameter is greater than 5 cm, the tumor has reached the penile base, there is deep infiltration and adjacent tissue involvement, bilateral inguinal lymph

nodes have been metastasized and fixed, the skin is red and swollen but not yet ulcerated, and the palliative radiotherapy can be carried out.

1.4.4 Repair of Penis Defects

Penile cancer surgery may cause patients defect in most part of or the whole penis, so they are considered to undergo penis reconstruction surgery. Most scholars choose the timing for penis reconstruction surgery after the patients have 2-year tumor-free survival, and some scholars choose the timing for penis reconstruction surgery after the patients have 1-year tumor-free survival. Whether the radical penile surgery and penile reconstruction can be simultaneously performed still needs further study. The purpose of penile reconstruction is to maintain male reproductive function, upright urination, and normal sexual psychological needs [1].

The penile reconstruction has a history of 70 years and has experienced four stages such as penile reconstruction with skin tube, free skin flap (microsurgical technique), penile reconstruction with pedicled skin flap, and Cheng Kaixiang reconstruction of the penis (composite skin flap). In 1992, scholars such as Young V.L. et al. proposed the method for penile reconstruction with prefabricated flap, but it has not been reported in the literatures. Domestic scholar Long Daochou carried out penile reconstruction by extending the penis and also achieved success.

Currently there are more than ten kinds of methods for penile reconstruction using tissue sources from different parts and different vascular pedicle skin flap, such as penile reconstruction with forearm free skin flap dominated mainly by Gao Xueshu and Zhang Disheng, penile reconstruction with abdominal pedicle flap and pudendal thigh pedicled flap dominated mainly by He Qinglian and Lin Zihao, and penile reconstruction with scapular free flap dominated mainly by Li Senkai and Jon Hage, while Sadov and Hagg JJ advocate that the fibula skin flap in the calf is used to reconstruct the penis. Cheng Kaixiang advocates that Cheng Kaixiang reconstruction of the penis or the penile reconstruction with composite free skin flap is carried out if having suitable condition. Cheng Kaixiang suggests that no matter what method is used, the surgical results must meet the following requirements: The reconstructed penis has certain length, diameter, and realistic appearance, a good sensation, and postoperative patency of the urethra. While the donor site has no serious defect, functional disorder, or ugly appearance.

When the defects occur after penile cancer surgery, the surgeons who have rich knowledge accumulation can only make scientific choices for the methods for penile reconstruction, and the correct choice of surgical method is essential for successful operation. A patient cannot fit all methods, but each patient always has one of the most suitable methods.

2 Penile Reconstruction

Kaixiang Cheng, Daochou Long, and Yu Xie

2.1 Penile Reconstruction with Forearm Free Skin Flap

The radial artery is taken as the center, and the forearm free skin flap with a length of 10–12 cm and a width of 12–14 cm is designed and can be combined with the surgical method using the radius body as the prosthesis for penile reconstruction. The method is the main surgical method for current surgical penile reconstruction.

2.1.1 Indications

Penile defects are caused by various reasons, and the penile stump is less than 2 cm. The forearm skin has no lesions or scars, the subcutaneous fat thickness in the forearm is no more than 1 cm, and the Aller test shows good collateral circulation in the hand.

2.1.2 Applied Anatomy

The distal forearm skin flap for penile reconstruction mainly depends on blood supply of the cutaneous branches of one-third of the radial artery in the distal forearm. Herein the radial artery has 2–3 cutaneous branches passing through the flexor carpi radialis muscle or directly entering into the skin flap. The venous return relies mainly on the radial vein and cephalic vein. The sensory nerve is dominated by the forearm lateral nerve. The distal myocutaneous perforator of radial artery can provide blood supply for the skin in three-fourth circumference of the whole distal forearm. But after the skin flap is harvested and rolled into the penis, bilateral margins of the skin flap may have blood supply disorder or necrosis, which may be due to the fact that the rolled penis has partial blood supply disorder due to edema; therefore, this point may be considered when the skin flap is designed.

2.1.3 Surgical Methods

1. Design and harvesting of skin flap: The skin flap with a length of 11 cm and a width of 14–15 cm is designed and harvested in the distal forearm. The design of the skin flap is divided into three parts:
   (1) The urethral flap is 13 cm × 3.5 cm, including the skin flap forming the glans penis.
   (2) The suture zone skin flap is 11 cm × 1 cm; the epithelium is removed.

(3) The penile skin flap is 11 cm × 10.5 cm.
The range of the skin flap starts from radial side of facies volaris of the flexor carpi ulnaris muscle to the margin of the extensor carpi ulnaris muscle in the dorsal forearm, bypassing the radius.

2. Phalloplasty: The skin surface of the urethral flap is turned over inwardly and rolled into the urethra with 7-0 nylon thread; 2.0 cm skin flap in the distal end is retained to form the glans penis. The costal cartilage is harvested to constitute the T-shaped support body and is placed at the back side of the urethra, and the T-shaped head is at the distal end and is fixed with three stitches using 5-0 nylon thread. Finally, the penile skin flap is used to wrap the whole urethra and the support body, and they are sutured respectively. The distal end of the reconstructed penis and the skin flap at the distal urethra commonly constitute the glans penis and urethral orifice and are sutured.
3. Penile implantation: The residual urethra is taken as the center to make radial incisions to form a wound with a diameter of 4 cm, while the residual cavernous body and penis dorsal nerve are dissected. An 8 cm long longitudinal incision is made below the contralateral groin of the skin flap donor site to expose the branch of the great saphenous vein and the inferior epigastric artery for anastomosis. A subcutaneous tunnel of about two fingers wide is made between two incisions, and then the prefabricated whole penis with vascular pedicle is cut off and transplanted into the receptor site. Firstly, the proximal cartilage is placed at the back side of the cavernous body and fixed and sutured with nylon thread, and the cavernous body and cartilage are overlapped for 2 cm. Then urethral anastomosis is performed; the interrupted suture is performed with 7-0 interrupted suture. A Z-plasty is made at the ventral side of the urethral anastomotic stoma to prevent urethral stricture. A stent is placed behind the urethral anastomotic stoma to wash clean the urethra. Finally, the vascular pedicle is passed through the tunnel to reach the groin incision to carry out the neurovascular anastomosis. The lateral cutaneous nerve of the forearm is sutured with the dorsal penile nerve bundle. The end-to-end anastomosis between the radial artery in skin flap and the inferior epigastric artery is performed; the end-to-end anastomosis between veins can be performed, such as the anastomosis between the radial vein and the superficial epigastric vein and the anastomosis between the cephalic vein and superficial pudendal vein. After vascular anastomoses are completed, the observation is carried out for 5 min; when the blood supply to the reconstructed penis is normal, all wounds are sutured, and, at the same time, the drainage strips are placed in the groin incision and the incision at the penile base. So far, the penile reconstruction with forearm free skin flap is completed. The forearm donor site can be repaired with transplantation of intermediate-thickness skin graft, and suprapubic cystostomy is still an essential step.
4. Postoperative treatment: The patients need to stay in bed and are routinely treated with broad-spectrum antibiotics. It is necessary to apply a small amount of anticoagulant drugs, such as low molecular weight dextran and dipyridamole. The changes in blood supply of the reconstructed penis should be closely observed after surgery, the drainage strips are removed 2 days later, the patients start to urinate on their own 2 weeks later, and the cystostomy tube is pulled out 16 days later without abnormal situation. The stitches are taken out 2 weeks later.
5. Precautions: The reconstruction with forearm free skin flap can be completed at a time. All different types of penile defects are indications. The skin flap thickness is moderate, the size of the reconstructed penis is appropriate, and the skin flap has longer vascular pedicle (8–10 cm) and sensory nerves and is a good material for penile reconstruction, but after the wound left in the donor site is repaired, the appearance is impeded. Analyzing according to the long-term follow-up data, at 2 years after penile reconstruction, the penis body and glans penis have more subcutaneous soft tissue atrophy, which accounts for about 10% of the circumference of the penis body. Although the sensory nerve anastomosis is performed during penile reconstruction, there are still some defects in the sensory function of the distal penis; its cause is related to the fact that the lateral antebrachial cutaneous nerve only controls one-fourth to one-third of the area of the whole skin flap.

2.2 Cheng Kaixiang Reconstruction of the Penis

Cheng Kaixiang reconstruction of the penis is a penile reconstruction named by the American Orthopedic Association in 1997. The forearm free skin flap is used to reconstruct the penis; part of the stump of the penis or part of the distal small penis is cut off and transplanted onto the distal end of the penis body for glans penis reconstruction; after the entire penis is formed, the vascular pedicle of forearm free skin flap is cut off and is transplanted onto to the perineum, and the normal blood supply of the reconstructed penis will be reestablished through vascular anastomosis, and the related nerves are anastomosed to complete the penile construction. The reconstructed penis completed by this kind of method not only has a lifelike appearance and sensory function but also has good sexual function [2].

2.2.1 Indications

The indications of Cheng Kaixiang reconstruction of the penis are patients with congenital penile dysplasia or

congenital micropenis and traumatic penile defect, but the small penis or residual penis must have a length of 2 cm for transplantation.

2.2.2 Applied Anatomy

The penile stump or the distal end of the small penis has 6–8 bundles of penis dorsal nerve fibers; the penis body reconstructed with forearm free skin flap has lateral antebrachial cutaneous nerve (both anterior and posterior branches), and the nerves carried by the reconstructed penis are anastomosed with the pudendal nerves. The penis after such reconstruction has a complete sensory function, and the reconstructed glans penis has normal erectile function.

2.2.3 Surgical Methods

The surgery is usually performed under general anesthesia and can be divided into the following steps:

1. Phalloplasty: The penis body is reconstructed with forearm free skin flap and a 10 cm long costal cartilage. According to the conventional method, the radial artery is taken as the axis to design a 10–11 cm × 15 cm skin flap on the unilateral distal forearm, a 3.5–4 cm palm ulnar section of the skin flap is the skin flap forming the urethra, a 1 cm × 10 cm skin flap at the radial side of the urethral flap is designed as the suture zone, and the skin flap in the radial side is used to wrap the urethra and cartilage support. The cephalic vein is dissected out simultaneously when the skin flap is dissected, and two main branches of the forearm lateral cutaneous nerve are simultaneously dissected out and included in the skin flap. In addition to that, the nerve controls the cutaneous sensation of one-third of the area of the skin flap, and its bilateral ends will also be anastomosed with the dorsal penile nerves in the penile stump and formed glans penis. Beyond that, when the radial artery and vein at the most distal end of the skin flap are cut off, their tiny branches must be retained respectively to be anastomosed with penile dorsal artery and vein within the formed glans penis.
2. Preparation of the perineum and formed glans penis: The suprapubic cystostomy is performed at first. A longitudinal S-shaped incision is made under the contralateral groin of the limb where the forearm skin flap is harvested; the great saphenous vein and its branches, the femoral artery, and the inferior epigastric artery and vein are exposed; and 3–4 cm long inferior epigastric artery and vein are dissected out and cut off and then are rotated toward the direction of the penile base. Part of the inguinal ligament and internal oblique muscle which are incised when the blood vessels are dissected must be repaired before the incision is closed; otherwise, it is easy to lead to herniation of abdominal contents. At the same time, a branch of the great saphenous vein which is matched with the diameter of the cephalic vein is selected for anastomosis. After the receptor blood vessels are prepared, a 2 cm wide subcutaneous tunnel is made within the incision toward the penile base to introduce donor site vascular pedicle. The preparation of the formed glans penis is determined according to the length of the penile stump or the congenital small penis. Under static condition, when the length of the penile stump or the congenital small penis is greater than 2 cm, part of them can be cut down as tissue sources for glans penis reconstruction. Firstly, a circular skin incision is performed at the penile base with a distance of 2 cm from the most distal end, and the dorsal penile artery and vein are carefully dissected at the dorsal side of the penis. Typically the dorsal penile vein is located in the dorsal center, and the dorsal penile arteries are located on both sides. The blood vessels are dissected out and dissociated up to a length of 0.5 cm for anastomosis. After the blood vessel preparation is completed, the dorsal penile nerve is dissected. The nerve is located at the lateral side of the dorsal penile artery and shows a longitudinal network-like distribution; the longitudinal nerve branches are connected between each other by transverse nerve fibers. During dissection, it is only needed to separate out the longitudinal nerve trunks. At bilateral sides of dorsal penis, there are usually 6–7 longitudinal dorsal penile nerve bundles. The sensation recovery of the formed glans penis depends on the quality and quantity of the nerve anastomoses, and therefore the nerve anastomoses should be carried out as many as possible, so that the glans penis has a good sensory function after surgery. After the neurovascular bundle dissection is completed, the corpus cavernosum and corpus spongiosum are cut off, and the cavernous wounds at both proximal and distal ends need to be repaired and closed, so as to prevent postoperative bleeding, but also conducive to strong glans penis erection after surgery. After the penile stump or the congenital small penis are partially or completely dissociated, the blood vessels and nerves are completely cut off, are transferred to the forearm donor site, and are anastomosed with the blood vessels in distal end of the reconstructed penis body in a series fashion.
3. Tandem transplantation of the penis body and the glans penis: The penile stump or the glans penis of congenital small penis with neurovascular pedicle is cut off and transferred to the donor site of penis body where the forearm skin flap is formed, the end-to-end anastomosis between the dorsal penile artery of this transplant and the small artery branch of the distal radial artery is performed, and the end-to-end anastomosis between the dorsal penile vein and the small branch of radial vein is performed. Since the dorsal penile artery in stationary state is very small, the anastomosis according to the conventional method is prone to failure; therefore, the use of three-

point or four-point supporting method is used to anastomose the blood vessel with only a diameter of 0.4–0.6 mm. The four-point support method is to use 11-0 nylon thread suture needle to pass through both ends of the blood vessels to be anastomosed and hook both ends, but not withdraw the needle, and use it as a stent to prop up the blood vessel opening, and then additional three suture needles are successively sewn into the blood vessel wall according to equal segments. When four suture needles have completely hooked both ends of the blood vessels to be anastomosed, the status of the blood vessel alignment can be clearly observed, and the needles can only be withdrawn and knotted one by one until it is satisfactory. When the first knot is being tied, the other three supporting suture needles prop up the lumen opening to assist in correct alignment of blood vessel walls. The use of this method can improve the patency rate of microvascular anastomosis. It is enough to anastomose the dorsal penile artery and vein with a diameter of 0.4–0.6 mm by 4–6 stitches; if there is obvious anastomotic bleeding, it can be sutured with an additional stitch, and the excessive stitches are not conducive to vascular patency. After completion of vascular anastomosis, the reconstruction of dorsal penile nerve within the glans penis is started, namely, the 6–7 bundles of longitudinal nerves are gathered together and anastomosed end to end with the distal end of thick lateral antebrachial cutaneous nerves within the skin flap for penile reconstruction. After the completion of vascular and neural anastomosis, the closed stump of the cavernous body of the reconstructed glans penis is jointly connected and sutured to the transverse end of supporting T-shaped costal cartilage, so that the stump of the cavernous body of the glans penis can sit rightly on the transverse costal cartilage, and the reconstructed glans penis has a solid and reliable base after surgery during erection. Finally, the urethra within the reconstructed penis body is anastomosed end to end with the urethra within the reconstructed glans penis with a 7-0 nylon thread, while the distal skin on the reconstructed penis body is sutured with the proximal skin on the reconstructed glans penis. In this way, the penis body reconstructed by the forearm skin flap and the glans penis transplanted and reconstructed by the penile stump or the glans penis of congenital small penis constitute a complete reconstructed penis, only after the proximal ends of the radial artery and vein and nerve are cut off, and the complete reconstructed penis can be transferred to the receptor site in perineum.

4. Penile implantation: After tandem connection of the reconstructed penis body and reconstructed glans penis, if there is no blood supply disorder, the radial artery and vein and the cephalic vein at the proximal end of the reconstructed penis and two branches of the lateral antebrachial cutaneous nerve can be cut off, the whole formed penis is transferred to the receptor site in perineum, and the fixation of the supporting body and the anastomoses of urethra, blood vessels, and nerves are carried out in the end.

   Firstly, the proximal end of the supporting cartilage in the reconstruction penis body is sutured and fixed with the stump of the cavernous body in the perineum, and then the proximal urethra within the reconstructed penis body is anastomosed end to end with the urethra within the penile stump in the perineum; a Z-plasty is performed at the ventral side of the urethral anastomotic stoma to prevent postoperative urethral stricture. 7-0 nylon thread can be used as the suture line. The proximal end of the lateral antebrachial cutaneous nerve within the reconstructed penis body is anastomosed with the dorsal penile nerve within the stump at penile base (6–7 bundles of longitudinal neural trunks) which is consistent with the beam axis. The quantity and method of the neural anastomosis should be consistent with those of the neural anastomosis between the reconstructed penis body and the reconstructed glans penis, so that better sensory functions can be finally achieved. After neural anastomosis, 8–10 cm long vascular pedicle of radial artery and vein and cephalic vein is introduced into the tunnel to reach the groin incision for anastomosis with blood vessels in the receptor site. The sequence and method of vascular anastomosis should be the end-to-end anastomosis between the cephalic vein and the superficial pudendal vein, the end-to-end anastomosis between the radial artery and inferior epigastric artery, and the end-to-end anastomosis between the radial vein and inferior epigastric vein. At last, the skin wound in penile base and the wound in receptor site of blood vessels in the groin are sutured, and the negative pressure drainage tubes are simultaneously placed in both places. The stent with side holes is inserted into the urethra of the reconstructed penis, and it can be used not only for urethra flushing but also for drainage of urethral secretions.

5. Postoperative treatment: The patient needs to stay in bed for 10 days, takes liquid diet within 3 days, takes semifluid diet 3 days later, and takes normal diet 1 week later. At 3 days after surgery, the urethra flushing and bladder washing start to be carried out. The reconstructed penis must make an angle of 135 ° with the abdominal wall to be fixed and bandaged. The broad-spectrum antibiotics are administered for 3–4 days. The bladder colostomy tube starts to be gripped 2 weeks later; the patient urinates voluntarily from the reconstructed penis, if there are no abnormalities; and the bladder colostomy tube is removed 3 days later. The stitches are taken out at 12–14 days after surgery. The anticoagulant drugs are properly administered, for example, 500 ml low molecular weight dextran

is administered intravenously twice daily, and an appropriate dose of dipyridamole is taken orally.

6. A few problems on postoperative functional recovery: The sensation recovery of the glans penis reconstructed with this method starts earliest at 5 months after surgery; 80% of sensations are recovered 8–12 months later. The two-point discrimination of the normal glans (frenum area) is 8–12 mm and can also reach 12 mm at 2 years after the patients undergo surgery. Such good sensation recovery of the reconstructed penis depends on the design of surgical method and the perfect repair of dorsal penile nerve, which is the basis of the recovery of the sensory function of the reconstructed glans penis at 8 months after surgery. In addition to relying on its own sensory nerve repair, the sensation recovery of the penis body also relies on the growth of the sensory nerve terminals in penile stump and the stump of cavernous body of the glans penis into the penis body, to make the sensation recovery of the reconstructed penis body close to the level of a normal person. At 2 years after surgery, 90–100% of the area of the entire penis returns to normal sensory function. The atrophy rate of the reconstructed penis during the denervation period is 5–8%, while the glans penis doesn't have any atrophic phenomenon.

After penile reconstruction using this method, driven by sexual desire, the glans penis of the patient can erect like that in a normal person, the entire penis can be erected under interaction with the cavernous body at penile base, the patient has sexual pleasure during sexual intercourse, and the coming time of the sexual orgasm is appropriate. The woman who has a sexual feeling within the scope of normal requirement can also achieve orgasm. All patients with penile reconstruction have serious psychological disorders before surgery; they do not dare to contact with the opposite sex and often show indifference and retreat to the opposite sex but have very strong desires to understand the sexual knowledge. The more they understand the sexual knowledge, the more pessimistic and disappointed they are toward the life. The patients tend to have high hopes for the function of the reconstructed penis after surgery but know little about the actual situation, and therefore they need correct guidance and analysis from the psychiatrists to gradually eliminate their psychological barriers, so that they can realize that they are normal men. After recovery of the sensory function of the penis, they are encouraged to play an active role in sexual intercourse with the opposite sex, which ultimately helps patients develop healthy psychological qualities. This is also the fundamental purpose of Cheng Kaixiang reconstruction of the penis.

The surgical method has not been applied by the authors in patients undergoing penile cancer surgery. The feasibility of the use of Cheng Kaixiang reconstruction of the penis in penile reconstruction for penile cancer patients after undergoing partial penial amputation needs further discussion.

2.3 Penile Construction with Abdominal Fascial Pedicle Skin Flap

This is the surgical method of taking the femoral pulse site under the abdominal inguinal ligament as the starting point to design a skin flap with superficial epigastric artery and superficial circumflex iliac vessels, which is rotated to the penile base to reconstruct the penis.

2.3.1 Indications and Contraindications

The surgical method is suitable for patients with penile defects due to various kinds of reasons and without abdominal damage and scar; it is not applicable in patients with penile cancer who have undergone inguinal lymph node dissection.

2.3.2 Applied Anatomy

The blood supply of the skin and subcutaneous tissue in lower abdominal wall mainly comes from four sources: (1) superficial epigastric artery (superficial inguinal artery), (2) the superficial iliac circumflex artery, (3) the small artery branches penetrating out from the rectus abdominis muscle after the inferior epigastric artery enters into the rectus abdominis muscle, and (4) the muscle perforator of the deep circumflex iliac artery. The penile reconstruction with abdominal fascia pedicled flap is to take the superficial epigastric artery and vein and the superficial iliac circumflex artery and vein as the main nutritional blood vessels.

2.3.3 Surgical Methods

1. Design of skin flap: It is better to design the skin flap in the left side, and the abdominal wall cannot have obvious scar tissues. The femoral pulse site under the abdominal inguinal ligament is taken as the starting point and axis to design the skin flap vertically upward. The length of pedicle of the skin flap is 8–10 cm; the size of the skin flap is 11 cm × 15~16 cm, wherein 3.5 cm × 14 cm inner skin flap is prepared as the urethra and glans penis; a 1 cm × 11 cm skin flap is prepared as suture zone; it is required to remove the epithelium; an 11.5 cm × 11 cm skin flap is prepared as the penis body to wrap the urethra and cartilage support. If the fat under the abdominal wall is thick, it is needed to increase the width of the skin flap by 1–2 cm to prevent that the prepared penis flap cannot completely wrap the urethra and cartilage support. When the pedicle is designed, the femoral pulse site is taken as the starting point, and it gradually expands upward and presents a fan shape, mainly including superficial epigas-

tric artery. The area connecting the subcutaneous pedicle and the skin flap should have a width of 6–8 cm, in order to ensure the normal blood supply to the skin flap.

2. Harvesting of skin flap: At first, the subcutaneous pedicle is dissected and separated, and the skin is longitudinally incised at the designed axial line of skin flap to reach deeply up to the superficial subcutaneous layer. The skin and a small amount of subcutaneous tissue are separated with the subcutaneous pedicle. The skin transverse incision is made at the junction of the suture zone and skin flap, the layers are the same as those of the original incision, and then the entire subcutaneous pedicle is exposed. After the blood vessels within the pedicle are carefully identified, the subcutaneous pedicle is separated from the surface of the external oblique muscle. After the completion of the preparation of the pedicle of the skin flap, the whole designed skin flap is incised and separated from the abdominal wall; the dissecting layers are the same as the deep surface layers of the subcutaneous pedicle. After completion of the dissection of the skin flap, the epithelia in a 1 cm × 11 cm suture zone are removed to facilitate the formation of the penis.
3. Harvesting of rib strip and phalloplasty: An oblique incision is made in the right hypochondrium to expose the costal cartilage. A 10 cm × 1 cm rib strip is harvested (if the rib is relatively curved, two relatively short and straight ribs can be harvested, which are jointedly connected into a 10 cm long rib); at the same time, a 2 cm long small strip is harvested again, and the support is made as T shape. In this way, the appearances of the reconstructed penis and glans penis are relatively plump.

   After harvesting of the skin flap, the blood supply of the skin flap is carefully observed for 5 –10 min; if the blood supply is normal, the phalloplasty can be performed. At first, the skin surface in the urethra area of the skin flap urethra area is sewn inwardly into a tubular shape to prepare the urethra, while a stent tube is placed in the reconstructed urethra. A 2 cm distal skin flap in this area is not sutured, and the glans penis is finally formed. Then the rib strip is placed in the dorsal side of the formed urethra, the transverse head is placed in the area of the glans penis, and the costal cartilage is sutured and fixed with three stitches. Finally, the rest of the skin flap is used to wrap the costal cartilage and the formed urethra and is sutured with the wound margins in the suture zone, respectively. After the penis body is formed, the skin surface of the extruded skin flap in the distal end of the urethra which has been not sutured is sutured outwardly with the wound margin in the distal end of the penis body. In this way, the preparation of a complete penis is completed.
4. Penile implantation: At the receptor site in the perineum, the penile stump is taken as the center, the residual foreskin is incised radially, and the wound is expanded to be matched with the wound at the proximal end of reconstructed penis. The urethral stump is separated from the cavernous body by 0.5 cm × 1 cm to facilitate the anastomosis. If there is a urethral stricture, part of the urethra can be resected; if there is a urethral defect, the urethra of the reconstructed penis can be designed to be longer, so as to be conducive to the first stage repair of the urethra. After the preparation of the receptor site, a subcutaneous tunnel is made between the wound in the penile base and the proximal wound in the pedicle of the abdominal skin flap; the formed penis is transferred to the receptor site. Firstly, the costal cartilage is sutured and fixed with the stump of the cavernous body of the penis, the costal cartilage is placed at the dorsal side of the cavernous body, and they are overlapped with each other by 2 cm and are sutured with 3-0 nylon thread. Hereafter, the urethra is anastomosed with 7-0 nylon thread; Z-plasty is performed at the ventral side of the anastomotic stoma to prevent urethral stricture. After suture, the stent tube within the formed penis is reinserted into the urethra itself by 3 cm. The skin at the outer side of the penis is sutured at last, and the penile reconstruction is completed. The abdominal wound surface is repaired with transplantation of intermediate-thickness skin graft, while the suprapubic cystostomy is performed.
5. Postoperative treatment: It is necessary to suck on the stent tube within the urethra of the reconstructed penis at 3 days after surgery to prevent urethral infection caused by the accumulation of secretions. The suction is performed twice a day, which is continuously performed until the patient can urinate voluntarily. The cystostomy should be maintained for 2–3 weeks. If the wound healing is normal at 2 weeks after surgery, the stent tube within the penis can be removed, and the patient is allowed to urinate voluntarily. After 2 days of voluntary urination, if there is no abnormal situation, the cystostomy tube can be removed. At 2 weeks after surgery, the stitches in the receptor site and the abdominal donor site are taken out.
6. Advantages and disadvantages: When the penile reconstruction is completed at one time with the lower abdominal fascial pedicle flap, the donor site is relatively hidden, the vascular anastomosis is not required, and the surgical operation is convenient. However, the patients with abdominal fat hypertrophy and patients undergoing bilateral inguinal lymph node dissection after penile cancer resection cannot use this method. According to the authors' experiences, after penile reconstruction using this method, the sensory function of the reconstructed penis body is poor; although the patients can urinate in standing position and have a reproductive function, they are very dissatisfied with their sex lives and have great psychological disorders.

2.4 Penile Reconstruction with Femoral Anterolateral Island Flap

Penis reconstruction surgery uses the femoral anterolateral island flap pedicled with the descending branch of the lateral femoral circumflex artery.

2.4.1 Indications and Contraindications

For the penile defects due to various reasons, the femoral anterolateral island flap can be used to complete the penile reconstruction at one time. Due to the fact that the skin flap contains part of femoral fascia lata, the toughness of the reconstructed penis is enhanced, so that the glans penis and the penis body are relatively plump and the appearance of the glans penis is more satisfactory after a long term. The blood vessels for femoral anterolateral island flap are relatively constant, and the donor site is concealed. The patients with fat thighs or hypertrichosis cannot use this method.

2.4.2 Applied Anatomy

The blood supply of the anterolateral thigh flap comes from the myocutaneous perforator of the descending branch of the lateral femoral circumflex artery. The descending branch of the lateral femoral circumflex artery mainly originates from the lateral femoral circumflex artery and can also be given off by the deep femoral artery or femoral artery. The descending branch is accompanied by the nerve in the lateral femoral muscle, runs obliquely downward between the rectus femoris muscle and vastus lateralis muscle, and gives off 1–4 branches near the midpoint of the connecting line between the anterior superior iliac spine and the outer upper margin of the patella; most branches are myocutaneous artery perforators in the vastus lateralis muscle, and the remote branches are thinner. The initial outer diameter of the descending branch of the lateral femoral circumflex artery is 2 mm in average, the average outer diameter of two accompanying veins is 3.5 mm, and the descending branch as the vascular pedicle of the skin flap has a length of 8–12 cm.

2.4.3 Surgical Methods

1. Surgical design: A skin flap with a length of 11 cm and a width of 15–16 cm is designed at the midpoint of the connecting line between the anterior superior iliac spine in anterolateral femoral area and the outer upper margin of the patella. The skin flap is divided into three parts:
   (1) Urethral flap: The size is 15 cm × 3.5~4 cm, the skin is inwardly rolled and sutured to form the urethra, and the distal end is extended by 2–3 cm to form the glans penis. The diameter of the formed urethra is about 1.3 cm.
   (2) Penile flap: The length is 11 cm, and the width is 11–13 cm; it is determined depending on the muscle quantity carried by the pedicle and the thickness of the rib cartilage support. This part is used to wrap the urethra and the support to form the penis body.
   (3) The area between the urethra and the penis body: It is the suture zone; the skin flap has a length of 11 cm and a width of 1 cm; its epidermis needs to be removed. It is the joint part of the formed urethra and penis. The descending branch of the lateral femoral circumflex artery should have a length of 10–11 cm from the upper margin of the skin flap; too much tension will not occur when the skin flap is transferred to the penile base; therefore, the upper margin of the entire skin flap should be placed on the horizontal line at 1–1.5 cm above the midpoint of the connecting line between the anterior superior iliac spine and the outer upper margin of the patella.
2. Skin flap harvesting: An incision is made from the point of intersection between the connecting line from the anterior superior iliac spine to the outer upper margin of the patella and the upper margin of the skin flap toward the direction of the inguinal femoral artery pulse site, the upper portion of the incision exposes the lateral femoral circumflex artery and vein given off from the deep femoral artery, and the lower portion of the incision is connected with the upper margin incision of the skin flap. The intermuscular space between the rectus femoris muscle and the vastus lateralis muscle is exposed, and the travel direction of the intermuscular space is similar to that of the connecting line from the anterior superior iliac spine to the outer upper margin of the patella. The medial side of the anterolateral thigh flap is lifted up at the superficial surface of the myolemma; the descending branch of lateral circumflex femoral artery to the muscular-skin branches and direct cutaneous branches of skin flap are carefully identified. Sometimes the muscular-skin branches are very thin; it is likely to cause damage or spasm during their separation; at the moment a small amount of muscle can be separated together with the muscular-skin branches. The descending branches of the lateral femoral circumflex vessels and the nerve bundle can be found in the intermuscular space, the blood vessels are separated proximally to the roots, and attentions should be paid to protecting the motor branch of the femoral nerve. The lateral thigh is incised along the design line of the skin flap, the distal end of the skin flap is also incised according to the design line, and the entire skin flap is lifted up with a small amount of the fascia lata. The formed island skin flap is passed through under the rectus femoris muscle and sartorius muscle to the thigh incision and is passed through the subcutaneous tunnel at the medial side of the thigh root to the penile base. Finally, the urethroplasty and phalloplasty are performed.
3. Penile implantation: The operation method of implanting the formed penis in the residual penile base is the same as

that in penile reconstruction with abdominal skin flap. The anterolateral femoral cutaneous nerve carried by the anterolateral thigh flap can be anastomosed with the dorsal penile nerve to improve the sensory function of the reconstructed penis after surgery. After the completion of penile reconstruction, the suprapubic cystostomy is performed conventionally. The thigh donor site wound is repaired with transplantation of the intermediate-thickness skin graft.

4. Postoperative treatment: The broad-spectrum antibiotics are used routinely, while the low molecular weight dextran can be applied to improve the microcirculation of the formed penis. At 3 days after surgery, the suction on the stent tube within the urethra is carried out to prevent urinary tract infections. The patient urinates voluntarily 2 weeks later, and after 2 days of voluntary urination, if there is no abnormal situation, the cystostomy tube can be removed.

2.5 Penile Reconstruction with Penile Elongation

This method is to separate the remaining cavernous body of the penis; the scrotal skin flap is lifted to wrap the elongated cavernous body of the penis and then is sutured, and it becomes a surgical method for penile reconstruction.

2.5.1 Indications

1. The surgical method is applicable for patients with injuries due to animal bites, flame, electric burns, or incised injury, or the defect in most part of the penis after penile cancer surgery. And for repair of some penile defect wounds, while no inflammatory lesions occur in the perineum.

2.5.2 Applied Anatomy

1. The blood supply of the scrotal skin flap comes from a total of three groups:
   (1) Anterior scrotal artery: It comes from the upstream terminal branch of the superficial external pudendal artery and provides blood supply to the front part of the scrotum.
   (2) Lateral scrotal artery: It comes from the anterior cutaneous branch of the obturator artery and provides blood supply to the middle one-third of the skin at lateral side of the scrotum.
   (3) Posterior scrotal artery: It comes from the internal pudendal artery, is divided into the medial and lateral branches, and constitutes the septal scrotal artery.

   The branches of the above three groups of arteries are anastomosed with each other to form a multiple-source blood supply system; when the trunk blood vessel is cut off, the skin flap can still survive through receiving the blood supply from the vascular network.
2. Scrotal vein: Draining into the great saphenous vein via the external pudendal vein, the veins of the scrotal wall are accompanied by the arteries of the same name. And the remaining venous plexus drains into the internal iliac vein via the internal pudendal vein.
3. Scrotal nerves and lymph: The scrotal nerves include the ilioinguinal nerve and the genital branch of the genitofemoral nerve; they are distributed in the anterior one-third of the scrotum; the posterior scrotal nerve of perineal nerve and the perineal branch of the posterior femoral cutaneous nerve are distributed in the posterior two-thirds of the scrotum. The scrotal lymph refluxes mainly into the superficial inguinal lymph nodes and deep lymph nodes.

2.5.3 Surgical Methods

1. Surgical design: A circular incision line is designed at the penile base through simulating the shape of the glans penis. The incision line of the skin flap for reconstructing the anterior wall of the scrotum is drawn out with enough width and length to wrap three cavernous bodies.
2. Surgical steps: Incise the skin according to the circular incision line at the penile base, enter deeply into the shallow and deep suspensory ligaments of the penis and cut off to the pubic arch, reach the ischiocavernosus muscle on both sides, cut off part of the aponeurosis, and fully strip off the cavernous body. Separate the vascularized fascia fat flap on both sides; when the suture is performed, the fascia fat flap is filled into the depression in front of the pubic arch and is sutured and fixed. Generally 6–10 cm cavernous body of the penis is separated out.

   Incise the scrotal skin and sarcolemma according to the drawing line, and retain bilateral anterior scrotal arteries and the mediastinal blood vessels of the scrotum. Lift up skin flap and wear a hole on the ventral side of the penis; the cavernous body of the penis is taken out from the hole and is transferred to the bottom of the scrotal skin flap, which facilitates the skin flap to wrap and suture the cavernous body of the penis. The scrotal skin flap has the multisource blood supplies, and the blood supply is rich (the authors have not observed the cases with scrotal skin flap necrosis); the incision is hidden after surgery, no scar is observed in the back of the penis, and the skin flap is thin and flexible, with good elasticity and strong scalability. After using this elongation method, the penis can achieve or reach close to the normal length and can also maintain a normal erection function and approximately normal sensory function.
3. Postoperative treatment: The patient has bed rest for 2–3 days, and the drainage strip and urethral catheter are removed at 48 h after surgery. The dressing is changed every day; an angle of 45 ° between the penis and the abdominal wall is kept during bandaging to facilitate the venous and lymphatic return. The antibiotics are

intravenously administered for 3–5 days. The frenum area can be dressed with elastic bandage to reduce edema, and the drugs reducing edema such as *Salvia miltiorrhiza* and aescuven forte are used if necessary.

From 1984 to 2012, Long Daochou et al. had completed a total of 98 cases of penile reconstruction with penile elongation, of which three cases of patients with penile cancers underwent resection of about two-thirds of the penis at a local hospital. No inguinal lymph node metastasis occurs, nor the inguinal lymph node dissection was performed. After 3–4 years observation after surgery, the lesion did not reoccur, thus the penile reconstruction using this method was performed. The length of the cavernous body of the penis is elongated by 6–8 cm, and up to 10 cm in individual cases. In addition, the blood vessels and nerves of the scrotum and the cavernous body of the penis were retained. After surgery, the penis had approximately normal sensory function, normal erection function, reaching 8–12 cm during erection.

2.5.4 Typical Case

Case I The patient, aged 48, had undergone partial penial amputation due to penile cancer; the stump wound was repaired with skin transplantation. The patient underwent penile reconstruction at 3 years after surgery (Fig. 19.1).

Case II The patients, aged 50, underwent partial penis resection due to penis cancer, the length of the residual penis was 2 cm, the stump was sutured to repair the wound, and the penile reconstruction was performed 6 years after surgery (Fig. 19.2). This section describes several kinds of commonly used surgical methods for penile reconstruction [1–3]. Owing to various reasons, there are a limited number of patients undergoing penile reconstruction after penile cancer surgery in clinics. It is believed that along with the advance of society, people's increasing requirement of sexual life, as well as the continuous improvement of penile reconstruction technology, the penile reconstruction will get more applications in patients with penile defect after penile cancer surgery.

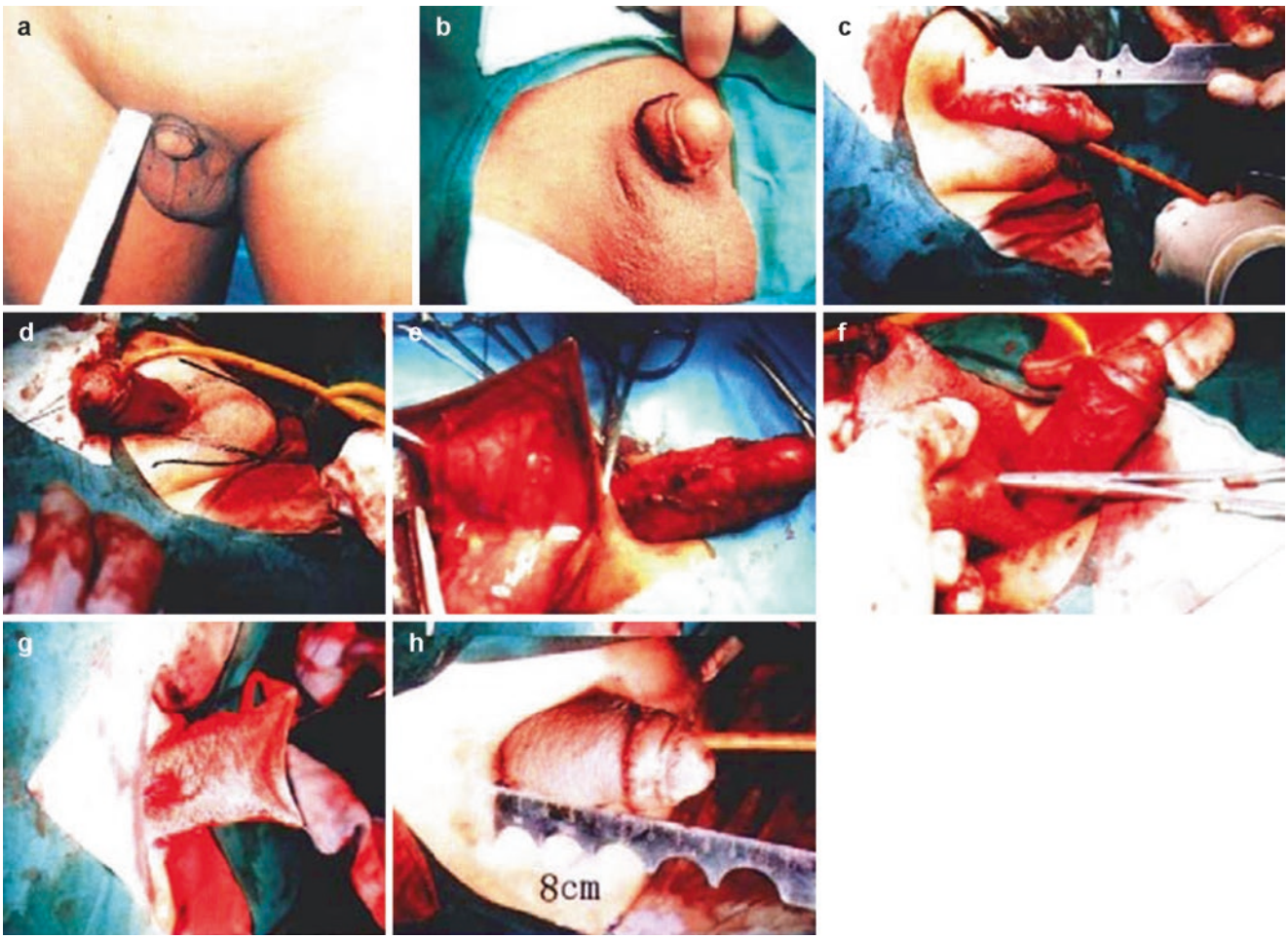

Fig. 19.1 Case I. (**a**) The length of the residual penis was 1.5 cm before surgery. (**b**) The circular incision at the penile base. (**c**) The cavernous body was extended to 8 cm. (**d**) Design of scrotal skin flap. (**e**) The scrotal septal blood vessels were visible. (**f**) A hole was made at the root of the scrotum, which facilitated to take out the cavernous body. (**g**) The scrotal skin flap was translocated to the upper side of the cavernous body and was easy to wrap and suture the cavernous body. (h) The length of the reconstructed penis was 8 cm

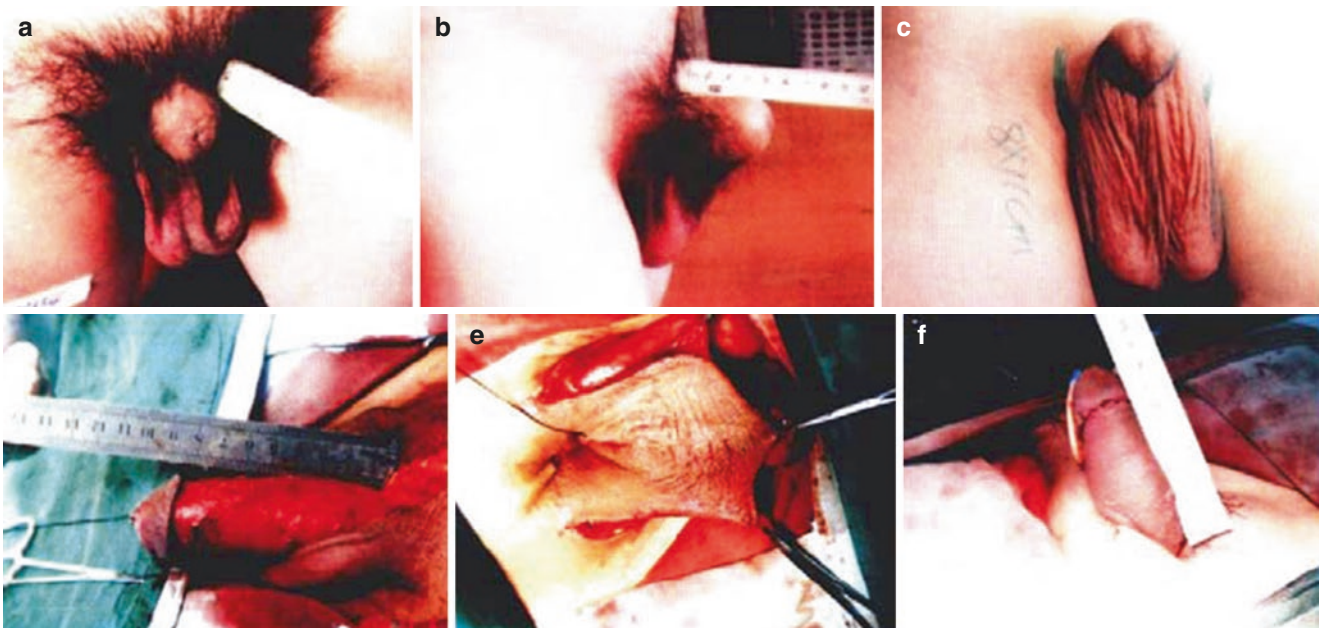

Fig. 19.2 Case II. (**a**) The length of the residual penis was 2 cm before surgery. (**b**) The length of the erected penis was 5 cm. (**c**) The design of scrotal skin flap. (**d**) A 10 cm cavernous body was separated. (**e**) The cavernous body was transferred from the hole to the area under the skin flap. (**f**) The scrotal skin flap was used to wrap the extended cavernous body to suture and reconstruct the penis

3 Overview of Vulvar Cancer

Jing Wang

3.1 Incidence Rate and Diagnosis

3.1.1 Incidence Rate

The vulvar cancer is a malignant tumor from the vulvar skin, mucous membrane, and its appendant organs and greater vestibular gland; the incidence rate accounts for 2–5% of the female genital tumors; the International Federation of Gynecology and Obstetrics (FIGO) reported that the incidence rate of vulvar cancer in Western women is 2–5/100,000.

Its etiology is not yet clear; it may be related to viral infection (human papillomavirus 16, 18, and 31 are more common), sexually transmitted diseases, low immunity, and chronic skin diseases (such as vulvar dystrophy). The vulvar cancer mostly occurs in postmenopausal women, and the average onset age is 52 years. The vulvar cancer is located in the body surface and can be diagnosed definitely based on medical history, symptoms, signs, and biopsy examination. The lesions can involve the vulva, perineum, or areas around the anus and can be divided into midline type and lateral type. The cancers in labia majora are most common, followed by the cancers in labia minora, clitoris, posterior commissure of the perineum, perineum, and urethra.

3.1.2 Pathological Diagnosis

The main pathological type is the squamous cell carcinoma, accounting for more than 80%, which is followed by the malignant melanoma (4.5%), basal cell carcinoma (2.5%), Paget's disease (2.5%), adenocarcinoma (2.5%), and sarcoma (2%).

Currently, the clinical and pathological staging system for the vulvar cancer is the standard established by the International Federation of Gynecology and Obstetrics (FIGO) in 2009 (FIGO 2009).

3.2 Clinical Symptoms and Signs

The most common symptom of the vulvar cancer is localized itching, followed by vulvar mass, bleeding, pain, and increased secretions. In the vulvar skin or mucous membrane of the patients with early vulvar cancers, localized or diffused multifocal black-brown or brown maculopapules can be observed, or the mucous membrane in focus is rough and erosive, or there is thickening lichen sclerosus of the vulva with clefts. The primary tumor of the invasive vulvar cancer is mostly single limited mass or ulcerative mass. Seventy percent of tumors occur in the vulvar lips; the labia majora is most commonly seen, followed by the labia minora, clitoris, and perineum. Advanced tumors may invade the urethra and (or) bladder, anus and (or) the rectum, vagina, and pubic bone or ischium.

3.3 Applied Anatomy

In addition to local invasion, the vulvar cancer is metastasized mainly through the lymphatic tract, and the lymphatic metastasis pathway is consistent with the anatomical characteristics of lymphatic drainage in the vulvar area.

3.3.1 Regional Lymphatic Drainage

The lymphatic drainages from the labia majora and labia minora, clitoris, posterior commissure of the perineum, and perineum firstly enter into the superficial inguinal lymph nodes and then enter into the deep inguinal lymph nodes. All lymphatic drainages are aggregated into Cloquet's lymph nodes and pass through this place to enter into the pelvic lymph nodes. In addition, the lymphatic vessels still have channels to enter into external iliac lymph nodes via the pubic symphysis or enter into obturator lymph nodes via the dorsal vein of the clitoris. When the lesions involve the urethra, bladder, vagina, or rectum, other lymphatic drainages can directly enter into the pelvic lymph nodes.

3.3.2 The Relevant Factors of Lymph Node Metastasis

The lymph node metastases are related to the size and location of the cancer focus, the relationship with neighboring organs, tissue differential degree, tumor infiltration depth, the presence or absence of lymphatic and vascular invasion, and the clinical stage.

3.3.3 Preoperative Evaluation of the Lymph Node Metastasis

1. Clinically attentions should be paid to palpable and fixed lymph nodes which are gathered into groups; these lymph nodes are generally positive.
2. The imageological examinations such as CT, MRI, or PET-CT can only be used as reference.
3. The sentinel lymph nodes (SLN) are the level I lymph nodes of the primary tumor lymphatic drainage; the pathological state of this group of lymph nodes can guide the need for extensive lymphadenectomy. The concept was firstly proposed in the study of penile cancer by Cabanas in 1976; in 1979, Disaia put forward SLN in vulvar cancer and considered that the inguinal lymph nodes firstly receive the lymphatic drainage from the vulva.
4. Detection method:
   (1) Bioactive dyes such as methylene blue and isosulfan blue.
   (2) Radioactive tracers such as ^{99m} Tc sulfur colloid (^{99m}Tc-SC) and ^{99m} Tc-human serum albumin (^{99m}Tc-HSA).
   (3) Radionuclide colloid injection: The bioactive dye and radionuclide colloid injection are combinedly used as the most commonly used method; the detection rate is high.
5. The clinical significance of SLN rationally determines the surgical ranges of the secondary vulvar lesions (groin and pelvic lymph nodes) and reduces the surgical traumas and complications. But because the lymph node metastasis has a jumping phenomenon, negative SLN cannot exclude the possibility of lymph node metastasis; at present, the priority is given to clinical studies.

3.4 Treatment Plan

3.4.1 Surgical Treatment

The vulvar cancer is mainly treated with surgery:

1. The classic radical resection of vulvar cancer, namely, the Way surgical method (1940), is the extensive vulvar resection (including the mons pubis, the labia majora and labia minora, the perineum, part of the vagina or part of the lower urethra, and the subcutaneous adipose tissue in corresponding parts; the depth reaches to the layers of fascia and myolemma) plus bilateral inguinal lymphadenectomy or pelvic lymphadenectomy. This surgical method is applicable to the following high-risk patients:
   (1) The focus is midline type.
   (2) The lymph nodes are suspected positive and N1 and N2.
   (3) The focus is highly differentiated (G1), with a depth of > 5 mm; moderately differentiated (G2), with a depth of 2 mm; poorly differentiated (G3), with an unlimited depth.
   (4) There is cancer cell infiltration in lymphatic vessel clearance.
2. Changes in surgical method's individualization of vulvar cancer surgery:
   (1) The limited tumor can be treated with modified partial vulvectomy.
   (2) T_1 stage, the invasive depth ≤ 1 mm, and the groin lymph node (GN) dissection are not performed.
   (3) Unilateral lesion (T_0): The unilateral GN dissection is performed; if the pathological result is negative, the contralateral GN dissection is not performed.
   (4) Modified groin surgery (the fascia lata and great saphenous vein are retained).
   (5) The routine pelvic lymph node dissection is not performed, even if there are multiple positive GNs; the pelvic lymph node dissection can also be canceled; instead, the radiotherapy is carried out in areas of GNs and pelvic lymph nodes.
   (6) The advanced patients receive preoperative radiotherapy and chemotherapy and don't undergo pelvic organ resection.

3.4.2 Radiotherapy

Because of poor tolerance to radiotherapy, the vulvar tissue cannot be treated preferably by radiotherapy even though it is sensitive to radiotherapy pathologically to a certain extent. At present, the radiotherapy is generally used as the palliative treatment or the supplement of the surgical treatment, for example, the postoperative radiotherapies on the inguinal area and the area outside the pelvic cavity in patients with inguinal lymph node metastases are carried out to reduce the possibility of recurrence and metastasis, and the patients with huge masses invading the adjacent organs undergo preoperative radiotherapy or adjuvant chemotherapy to shrink the tumor to increase the resection rate and preserve the corresponding viscera function to improve the quality of life. In European countries with mature radiotherapy technologies, the radiotherapy interpolated among tissues is performed; it is reported that the effect is good, but it is limitedly carried out in China.

3.4.3 Chemotherapy

The chemotherapy is in the secondary position. The neoadjuvant chemotherapy and chemoradiotherapy are used in conjunction with surgical treatment and in palliative treatment for advanced and recurrent patients.

4 Repair and Reconstruction of the Defect After Vulvar Cancer Surgery

Jing Wang, Zan Li, Xiao Zhou, and Yile Chen

The radical resection of vulvar cancer requires that the incisal margin has a distance of more than 3 cm from the cancer; if the cancer involves the urethra and vagina, partial resection of the urethra and vagina and even total vaginal resection can be carried out. Since the resection depth reaches all layers of the vulva and reaches directly to the urogenital diaphragm, resulting in large area defect in local tissue and difficulty in suture, the poor blood supply caused by the forced suture leads to long healing time, scar contracture, the severe deformation of the vulva, and the stenosis of the vaginal orifice, which can cause difficulties in urination and sexual life. Therefore, while the radical vulvar surgery is performed, one-stage vulvar reconstruction and plastic surgery emerges at the right moment and is constantly improved. This section describes several more commonly used methods for vulvar reconstruction.

4.1 Repair and Reconstruction with V-Y Advancement Skin Flap and Rhomboid Fascia Skin Flap

At present, the clinically used V-Y advancement skin flap and rhomboid fascia skin flap mostly take advantage of the vulvar-inguinal skin flap and the gluteal myocutaneous flap.

4.1.1 Indications

This method is suitable for the wound with a relatively small defect.

4.1.2 Applied Anatomy

1. Vulvar-inguinal skin flap: The blood supply of the vulvar-inguinal skin flap mainly comes from the lateral branches of the posterior labial artery of the vulva. The posterior labial artery is one of the terminal branches of the internal pudendal artery; the trunk runs within the groove between bulbocavernosus and ischiocavernosus muscles toward the medial upper side to the labia majora, passes through from the superficial transverse perineal muscle to the posterior margin of the vaginal orifice, and gives off 2–3 branches, namely, the lateral branches of the posterior labial artery of the vulva; they run toward the anterolateral side, are distributed in the lower end of the vulvar-inguinal skin flap, and are anastomosed with the descending branch of the anterior cutaneous branch of the obturator artery and the branch of the medial femoral circumflex artery at the upper medial side of the thigh. The vulvar-inguinal skin flap is innervated by the lateral branch of the posterior labial nerve of the vulva; the posterior labial nerve is accompanied by the blood vessels of the same name; after crossing the superficial transverse perineal muscle, it is mainly distributed in the labia majora and gives off 2–3 lateral branches of the posterior labial nerve at the level of posterior margin of the vaginal orifice, which are distributed in the vulvar-inguinal skin flap [4, 5].
2. Gluteal myocutaneous flap: The gluteus maximus muscle is the largest rhomboid muscle in the hip, with a superficial location. The blood supply of the gluteus maximus muscle is very rich; the main blood vessels include:
   (1) Superior gluteal arteries: Two arteries such as deep and superficial arteries are separated from the internal iliac artery, and the superficial branch provides blood supply to the gluteus maximus muscle and the skin on the upper hip and subcutaneous adipose tissue. The deep branch provides blood supply to the gluteus medius muscle.

(2) Inferior gluteal artery: It is also the branch of the internal iliac artery and is mainly distributed in the lower part of the gluteus maximus muscle and the posterior side of the thigh.
(3) Other blood vessels: The distal part of the gluteus maximus muscle is fed by the first perforator artery from the lateral femoral circumflex artery, the transverse branch of the medial femoral circumflex artery, and the anastomotic branch of the transverse branch of the lateral femoral circumflex artery. Both the superior and inferior gluteal arteries have corresponding accompanying veins [5–7].

4.1.3 Surgical Methods

1. V-Y advancement skin flap: After vulvectomy, according to the size of wound defect, taking this as a triangular base, the skin flap including the skin, subcutaneous tissue, and fascia is designed. The ratio of the triangular base to both sides is 1:2 to 1:1.5, and sometimes in order to increase the mobility of the skin flap, the lower margin of the skin flap can be dissociated downward; the range is one-third of the length of the skin flap, so that the skin flap can be sutured with the wound; the wound after the advancement of triangle skin flap is directly sutured [8, 9].
2. Rhomboid fascia skin flap: After vulvectomy, according to the size of wound defect, it is appropriate that the ratio between the length and width of the skin flap is less than 1:3, the skin flap is lifted up from the deep fascia of the distal skin flap, the blood supply of the distal skin flap is examined, the skin flap is transferred to repair the vulvar defect under no tension, and both sides of the donor site are sutured directly.

4.1.4 Typical Case

Case III The patient, aged 46 years, had a vulvar mass for 2 years. Pathological examination: highly differentiated squamous cell carcinoma. The patient underwent extensive resection of vulvar cancer + bilateral inguinal lymph node dissection + the repair of vulvar defect with the vulvar-inguinal skin flap (Fig. 19.3).

Case IV The patient, aged 57 years old, had a vulvar mass for 6 months. Pathological examination: highly and moderately differentiated squamous cell carcinoma. The patient underwent the vulvar cancer resection, and the ortho-position skin flap was transferred to repair the vulvar defect (Fig. 19.4).

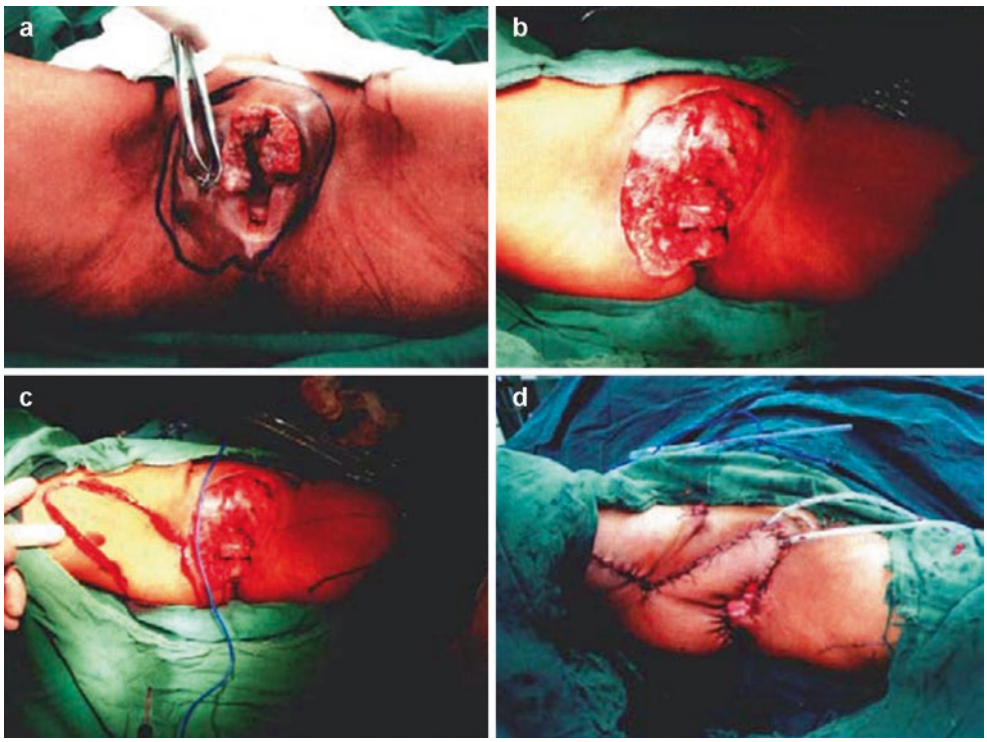

Fig. 19.3 Case III. (**a**) Huge vulvar mass. (**b**) The patient underwent extended resection of vulvar cancer + bilateral inguinal lymphadenectomy, which caused the huge vulvar defect after surgery. (**c**) The *right* pudendal thigh skin flap was designed. (**d**) The pudendal thigh skin flap with pedicle in the posterior part was harvested, which was directly transferred to repair the vulvar defect, the *left side* was sutured, and at the same time, the urethral orifice and vagina were repaired

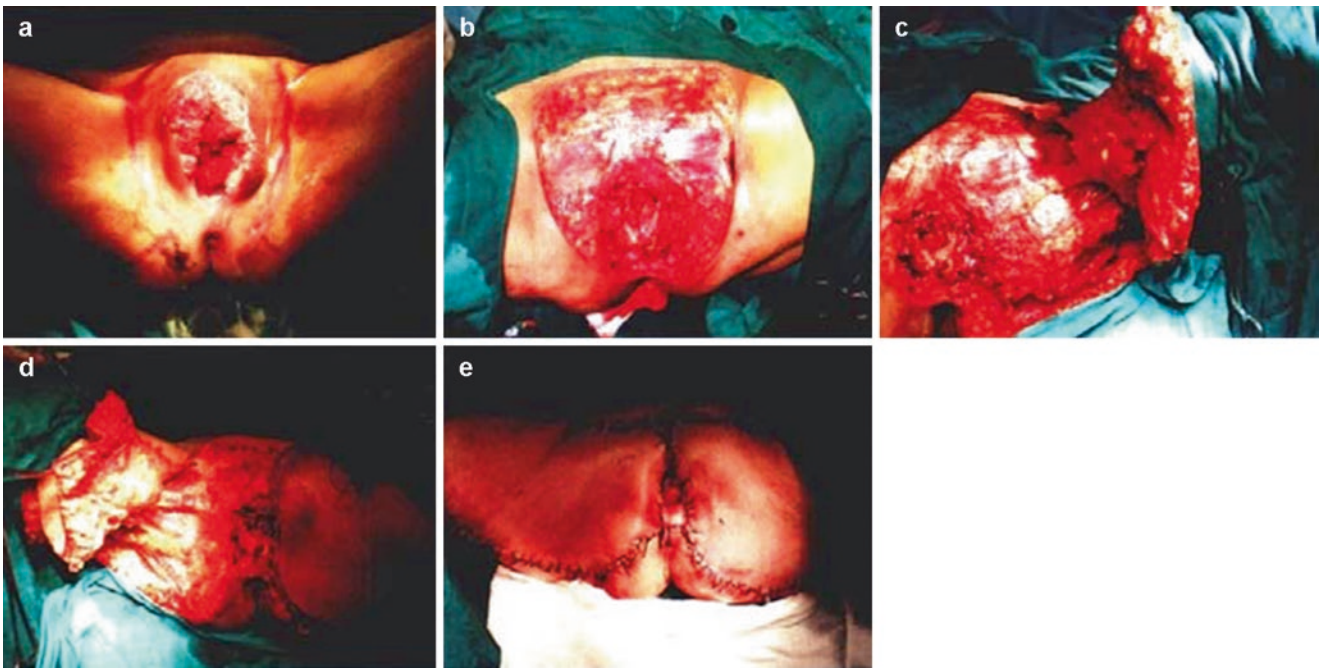

Fig. 19.4 Case IV. (**a**) Before vulvar cancer surgery. (**b**) The huge defect after resection of the primary focus. (**c**) The *left* lateral orthoposition skin flap was harvested, and the external pudendal arteries were retained. (**d**) The *right* skin flap was harvested. (**e**) The bilateral skin flaps were dissociated, rotated, and translocated to repair the vulvar defect and repair the urethra and the external vaginal orifice at the same time

4.2 Repair and Reconstruction with Gracilis Myocutaneous Flap

The gracilis myocutaneous flap is the myocutaneous flap commonly used for vulvar reconstruction and repair.

4.2.1 Indications

This method is applicable to the repair of defects after all types of vulvar cancer surgeries.

4.2.2 Applied Anatomy

The gracilis muscle is located in the subcutaneous area of the inner thigh, with a superficial location, starts with the flat broad muscle tendon from the pubic bone and the lower branch of the ischium, and ends at the inner side surface of the tibial tuberosity. The main nutrient vessels include the gracilis branch of the deep femoral artery, followed by the branches of the medial femoral circumflex artery, femoral artery, and obturator artery. The sartorius muscle passes obliquely through the superficial layer of the distal gracilis muscle, where there are no myocutaneous branches of the gracilis muscle blood vessels to the skin. The gracilis muscle is controlled by the anterior branch of the obturator nerve.

4.2.3 Surgical Method

1. Transfer of gracilis myocutaneous flap with vascular pedicle:
   (1) Skin flap design: The site at about 8 cm below the pubic tubercle at the affected side is taken as the axis point of the rotation of the vascular pedicle, and the design scope of the skin flap should exceed the defect area by about 3 cm.
   (2) Key points of operation: The incision reaches the deep fascia; the nutrient vessels and nerves of the gracilis muscle are dissociated between the long adductor muscle and the gracilis muscle and are dissociated to the starting part, the skin, subcutaneous tissue, and deep fascia surrounding the myocutaneous flap are incised; and the gracilis muscle is intersected at the upper and lower ends of the myocutaneous flap.

It should be noted that the subcutaneous tissues are sutured with the fascia at any time to maintain good blood supply. After 5–6 cm vascular pedicle is dissociated at the deep surface of the gracilis muscle, the donor site wound is closed, and the rubber tube is placed for drainage. A 4–5 cm wide subcutaneous tunnel is made between the donor site and receptor site, the myocutaneous flap is transferred from the tunnel to the receptor site, its proximal end is located at the site of the pubic symphysis, and its distal end is located at the site of the distal end of the perineum. The myocutaneous flap is sutured by full thickness with the medial and lateral margins of the vulvar incision, and the rubber tube is placed for drainage.

(3) Precautions: When the myocutaneous flap is harvested, the aseptic technique and tumor-free technique should be strictly applied, the donor site should be sutured in order and without tension, and the drainage is unobstructed. The antibiotics and general support treatment are routinely carried out.

(4) Advantages: The gracilis muscle belongs to the adductor muscle group of the thigh and is not the main participating muscle, and therefore, there is little effect on limb function after its resection. The gracilis muscle is a flat and thin ribbon-shaped muscle with a most superficial location, it is adjacent to the vulva, its harvesting is convenient, the dissociating range and the radian of rotation are large, the myocutaneous flap itself has constant blood supply, the blood vessels and nerves are retained during surgery, the anti-infection ability is strong, it is easy to survive, surgical operations are simple and safe, and it is easy for patients to accept.

2. Dissociation of skin flap: The dissociation of skin flap requires the use of microsurgical operation skills and operating apparatuses to carry out vascular anastomosis; the myocutaneous flap can be transplanted to any defect. But the range of skin flap available for harvesting is only limited to two-thirds of the skin on the gracilis muscle.
3. Pedicled transfer of long gracilis myocutaneous flap with a crossing boundary blood supply from the obturator artery: Because the skin flap for pedicled transfer must take the site where the branch of the deep femoral artery enters into the gracilis muscle as the pivot point for the rotation, namely, the site of the upper middle one-third of the gracilis muscle, in this way, the distance of transfer of the gracilis myocutaneous flap to the perineal area is limited. In order to carry out pedicled transfer of the gracilis myocutaneous flap to the perineal area with a short distance, some scholars design the short gracilis myocutaneous flap taking the starting part of the gracilis muscle as the rotation pedicle; this type of skin flap takes the terminal branches of the obturator artery as the source of blood supply, but there are disadvantages that the harvesting range of the skin flap is limited to the blood supply area; its tissue volume is limited and it is difficult to repair the larger defect. According to the principle of reversed-flow axial flap with a crossing boundary blood supply from the artery, after ligation of the branches of the deep femoral artery of the skin flap, relying on the anastomotic branches between the terminal branches of the obturator artery and the deep femoral artery and its branches, using the principle of arterial pressure difference to enter into the lumen of the branch of the deep femoral artery to produce blood supply, Chen Zongji designed the long gracilis myocutaneous flap with a crossing boundary blood supply from the obturator artery, and the skin flap has reliable blood supply, large tissue volume, and wide rotating surface and can be used to repair the total vulvar defect and reconstruct the vagina at the same time.

4.3 Repair and Reconstruction with the Anterolateral Thigh Flap

The anterolateral thigh flap is the skin flap taking the perforating branch of the descending branch of the lateral femoral circumflex artery as the pedicle, and there are generally 2–4 perforating branches, which penetrate out from the surface of the vastus lateralis muscles or between the vastus lateralis muscles. The skin flap has advantages such as hidden position, large tissue volume for harvesting, long vascular pedicle, and rich blood supply [10].

4.3.1 Indications

It can be used to repair a wide range of vulvar defects.

4.3.2 Applied Anatomy

After given off from the deep femoral artery or the femoral artery, the lateral femoral circumflex artery is quickly divided into the ascending branch, transverse branch, and descending branch. The descending branch of the lateral femoral

circumflex artery gives off the anterolateral cutaneous artery to feed the femoral anterolateral skin, and the forms mainly include the myocutaneous artery perforator and the intermuscular septum cutaneous branch. The myocutaneous artery perforator vessel is the small branch vessel of the descending artery and passes through the vastus lateralis muscle to the skin, while the intermuscular septum cutaneous branch penetrates superficially out of the intermuscular space between the rectus femoris muscle and the vastus lateralis muscle and directly passes through the fascia to the skin. The descending branches of the lateral femoral circumflex artery mostly have two accompanying veins. The lateral femoral cutaneous nerve is the sensory nerve of this skin flap; it is given off from the lumbar plexus, and then passes through the deep surface of the inguinal ligament to the thigh at 1 cm at the medial side of the anterior superior iliac spine, and is divided into the thick and long anterior branch and the short and thin posterior branch.

4.3.3 Surgical Method

1. Skin flap design: The patient is placed in the supine position, a connecting line between the anterior superior iliac spine and the outer upper margin of the patella (the line from ilium to patella) is made, the site where the first myocutaneous artery given off by the descending branch of the lateral femoral circumflex artery penetrates out of the skin is found near the midpoint of the connecting line, and this point is placed near the center of the upper one-third of skin flap when the skin flap is designed. Then the line from ilium to patella is taken as the axis to mark boundaries of the skin flap according to the shape and size of the defect area, the upper boundary can reach up to the distal end of the tensor fasciae latae muscle, the lower boundary reaches to the site at 7 cm above the patella, the medial boundary reaches to the medial margin of the rectus femoris muscle, and the lateral boundary reaches to the lateral femoral intermuscular septum or is slightly larger.
2. Skin flap dissociation: According to preoperative design, incise the skin, subcutaneous tissue, and deep fascia along the lateral side of the skin flap and extend the incision downward. Lift up the skin flap at the deep surface of the fascia lata, find the perforating branch entering into the fascia, retrogradely trace along the perforating branch, and gradually cut off the vastus lateralis muscle that it passes through. At the deep surface of the fascia lata, find the perforating branch of the lateral femoral circumflex artery, then apply retrograde separation and find vascular pedicle. Separate along lateral femoral circumflex artery, then find and retain the perforating branch needed for flaps. The upper, medial, and lower surfaces of the skin flap are completely incised, and the skin flap is completely dissociated.
3. Skin flap transfer: It is not necessary to cut off pedicle after harvesting of the skin flap; the skin flap is transferred to the vulvar area through the subcutaneous tunnel to repair the defect. If the vulvar defect is too large, the wound after harvesting of the anterolateral thigh flap cannot be directly sutured; it is required to carry out skin transplantation, resulting in the secondary trauma after skin harvesting; under the case that the muscle hernia surgery may be formed after surgery, the color Doppler or CT can be used preoperatively to accurately position the perforating branches of the lateral femoral circumflex artery, depending on the locations and sizes of different perforating branches; the form of single-pedicle double flaps or multiple flaps is prepared, and then double flaps are jointedly connected to repair the primary focus defect; in this way the donor site wound can be directly sutured, which reduces the secondary damage.

4.3.4 Typical Case

Case V The patient, aged 25 years old, had vulvar mass for 1 year. Pathological examination: highly differentiated squamous cell carcinoma. The patient underwent expanded resection of vulvar cancer and repair of vulvar defect with lateral femoral flap (Fig. 19.5).

There are a variety of methods for repairing the wound after vulvar cancer surgery, but it is not the case that each method is suitable for every patient; therefore, we need to choose the most appropriate method depending on the circumstances of the patient.

The ideal vulvar reconstruction should meet the following requirements: ① The skin flap carries the skin and subcutaneous tissue with a good blood supply, and its thickness is proximate to that of the defect. ② The superficial area of designed skin flap is equivalent to that of the receptor site. ③ The sensation and function of the vulva are reconstructed. ④ The reconstructed vulva has a nearly natural appearance. ⑤ The skin flap can be used for one-stage repair of vulvar defects. ⑥ The damage to the donor site is minimized as far as possible.

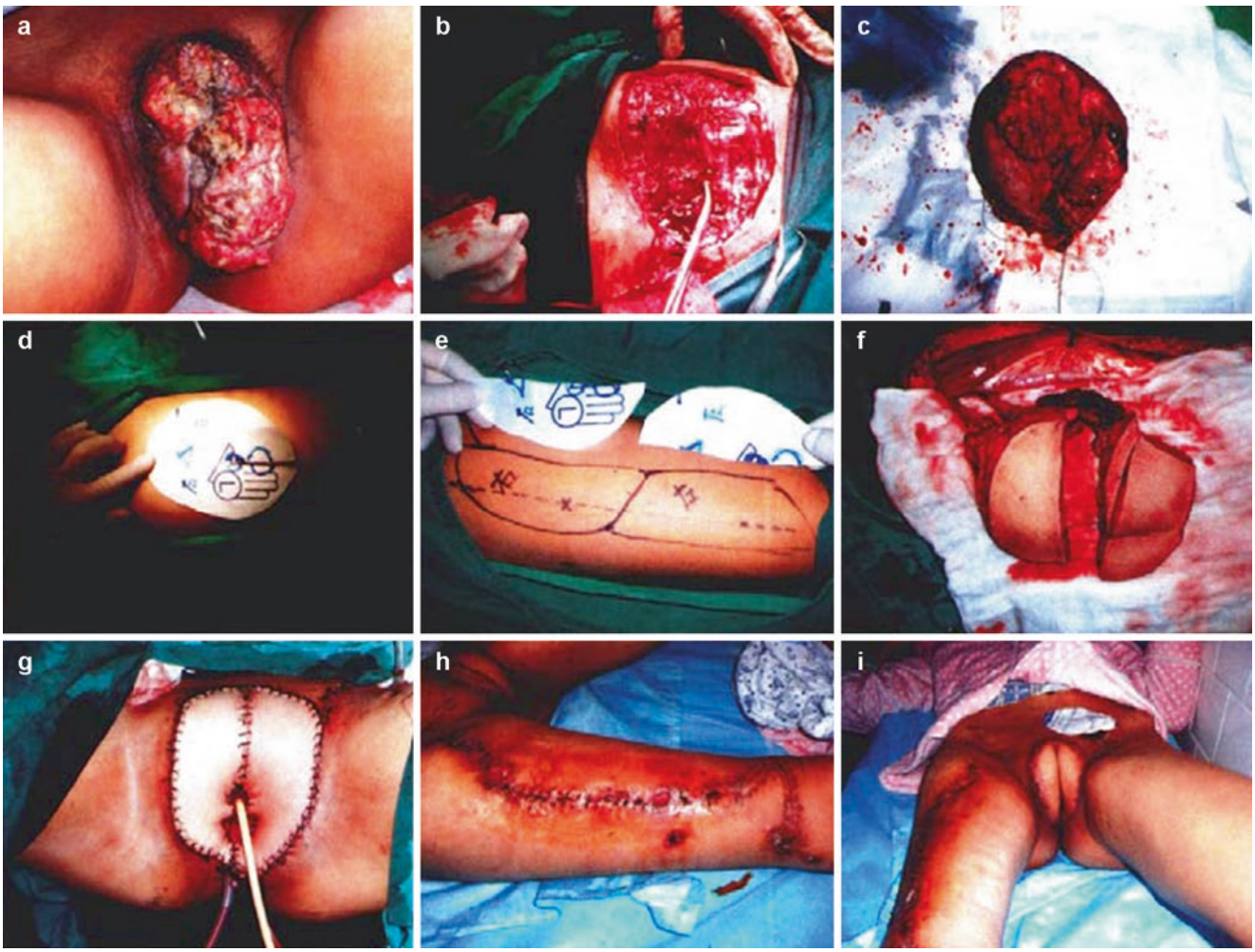

Fig. 19.5 Case V. (**a**) The huge vulvar mass was fixed, and the external urethral orifice and external vaginal orifice were covered and invaded by the mass. (**b**) The patient underwent expanded resection of vulvar mass + bilateral inguinal lymphadenectomy. (**c**) The specimen of vulvar cancer resection. (**d**) The anterolateral thigh flap was designed according to vulvar defect. (**e**) Two femoral anterolateral perforating branches were selected, the site to be repaired is separated, and two skin flaps are designed. (**f**) Two perforating branch skin flaps pedicled with the descending branch of the femoral circumflex artery. (**g**) The skin flap was transferred to the vulvar area through the subcutaneous tunnel; two skin flaps were jointedly connected to repair the vulvar defect and repair the urethral orifice and vaginal orifice at the same time. (**h**) The skin flap donor site in lateral thigh was directly sutured; the wound healed basically at 2 weeks after surgery. (**i**) The vulvar skin flap healed well at a month after surgery, the urination seemed to be fine, and the vaginal secretions were discharged smoothly

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Application of Skin Soft Tissue Expansion in Oncoplastic Surgery

20

Lin Xiaoxi, Zhou Bo, and Zhou Xiao

1 Overview

The skin soft tissue expansion is called the skin expansion for short; it generally refers to a method where the skin soft tissue expander is implanted under the normal skin soft tissue; the injection pot is used to inject liquid into the expander capsule to increase the volume of the expander and make it produce pressure on the skin soft tissue on its surface; through the localized effect of the expansion mechanism, the cleavage and proliferation as well as the intercellular space of the tissue and epidermal cells are increased, thus increasing the area of the skin, or the skin soft tissue is expanded and extended through the external mechanical traction on the skin, and the newly increased skin soft tissue is used for tissue repair and organ reconstruction [1]. In 1957, Neumann firstly reported the clinical application of tissue expansion [2]. The skin soft tissue expansion in the usual sense was first put forward by Radovan (one plastic surgeon in America); he and Schuhe (a biomedical engineer) developed the first real water injection-type skin soft tissue expander and firstly used it in clinic [3]. In addition to the water injection-type skin soft tissue expander, the permeable self-expanding skin expander developed by Austad et al. in 1979 also has been applied in clinic, because it contains hypertonic solution; once the leakage occurs, the serious consequences such as local skin necrosis will occur, and its expansion speed and capacity are difficult to control. Therefore, currently it is rarely used in China. In addition to the built-in expander which is implanted in the skin, Lasheen also reported an external suction device which can expand the skin; its principles are quite different from the expander which is implanted in the skin, but its clinical application has also achieved good results [4].

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So far, the skin soft tissue expansion is still the most reliable method to provide additional autologous skin, and the texture and color of the skin after expansion are similar to those of the area to be repaired, and thus an excellent aesthetic effect can be obtained after surgery. In China, Zhang Disheng et al. firstly introduced the use of skin soft tissue expansion in the treatment of post-burn deformities, and thereafter, the skin soft tissue expansion has been very widely used in the field of plastic surgery and reconstruction in China.

The local skin flap transfer and free skin graft transplantation or the transplantation of more complex distal skin flap or free skin flap can be selectively used for one-stage repair of the wound after resection of the body surface tumor, but all these methods cause damages to the donor sites, or the appearance is affected due to the postoperative contracture of the grafted skin, and ultimately the difficult situation of robbing Peter to pay Paul cannot be avoided. For some tumors in the head, face, jaw, and neck, it is not only required that the wound after tumor resection is completely repaired, but considerations should be also given to the aesthetic effects of five sense organs; the skin soft tissue expansion technology not only can use the surrounding skin with similar texture and color to repair the wound perfectly and will not cause secondary damage to the donor site and thus obtain an excellent repair effect. As academician Zhang Disheng said: "the skin soft tissue expansion technology is the most creative achievement in the history of plastic surgery; it changes the usual practice of robbing Peter to pay Paul, so that many patients achieve unprecedented satisfactory results. The skin soft tissue expansion technology is a landmark achievement of the progress of plastic surgery." In the process of clinical application, for body surface benign tumors, the expander can be implanted in the skin at one stage; after the full expansion of skin soft tissue, the selective surgery to remove the tumor can be carried out; at the same time, the expander is taken out; the redundant skin soft tissue is used for one-stage repair of the tissue defect; while for the body surface malignant tumors, a series of comprehensive treatments are carried out generally after radical

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tumor surgery; according to the needs of patients, the skin soft tissue expansion is carried out at the second stage to repair or reconstruct the area with surface deformity or defect after resection of the malignant tumor.

1.1 The Principle of Skin Soft Tissue Expansion

The principle of skin soft tissue expansion is not a unique concept in plastic surgery; some people get inspiration from the phenomenon that the skin of the abdomen of the pregnant woman is gradually expanded along with the fetus growth, and the skin of an obese person is expanded along with an increase in subcutaneous fat. Studies have shown that after a certain capacity expansion, the local skin area can be increased by 80–140%. From the histological point of view, there are three possible sources for excessive skin [5]:

1. The absolute number of cells is increased through cell proliferation and mitosis, which is generally known as "biological proliferation."
2. Due to the traction force generated by continuously increased pressure, the intercellular spaces are broadened, and the intercellular substances are increased, which is generally known as "elastic expansion."
3. Under the condition that the surface tension is increased, the adjacent tissues are pulled and thus move toward the expansion area, which is generally known as the "the creep deformation of the tissue."

Numerous studies show that the expander implanted under the skin soft tissue can make the epidermal basal cells proliferate through the stimulation effect of mechanical tension; although both the corium layer and subcutaneous layer can be thinned due to the expansion, the synthetic amount of dermal collagen and the blood circulation amount of the skin are increased, which is the net increment in the amount of the tissues after skin soft tissue expansion; and the elastic deformation of the skin and the creep deformation of the tissue lead to the skin flap after expansion which has a certain trend of retraction. Another important feature of the skin soft tissue expansion is the reconstruction of the blood supply of the skin flap after expansion, which is different from a simple delayed skin flap surgery in which only the direction of the blood circulation or pathway is changed, but there exist new blood vessels and the establishment of new blood supply pathways, so that the skin flap after expansion has a better blood supply compared with the random pattern skin flap or the delayed skin flap.

For estimation of the area of the skin after expansion, predecessors have summarized many calculation methods, but the formulas which are practically used in clinic are less [6]. Expansion efficiency of the skin expander could be different in different implanting positions, and even with the same expander, the skin expansion efficiencies in all directions are also quite different. The skin on the top of expander often has the highest expansion efficiency, the closer the margin is, the lower the efficiency is. Therefore, there is no standard scientific method for the calculation of the skin area to be expanded. The skin in the process of the water injection and expansion of the expander is increased in three-dimensional space; the flattening and transfer of the skin flap after the removal of the expander during the second-stage surgery will result in the loss of the effective expansion area; in addition to that, the skin flap itself has a trend of contracture; part of the skin flap area after expansion is used to repair the donor site; part of the skin flap area is used to repair the lesion area; part of the skin flap area is still required to be used to counteract the contracture of the expanded skin flap. Before surgery, it is required to carefully estimate the area of the region to be repaired, design the placement location of the expander, determine the capacity of expander, and predict the method for skin flap transfer in second-stage surgery; all these are key problems to be addressed during skin soft tissue expansion.

For the relationship between the expanded volume and the repairing area, according to the clinical experiences of Plastic Surgery Department of Xijing Hospital of The Fourth Military Medical University, the expanded volume for repairing 1 cm^2 scalp defect is 3.5 ml, repairing 1 cm^2 faciocervical defect requires 4.5–5 ml expanded volume, and the expanded volume for repairing 1 cm^2 defect on the trunk and limbs is between both as mentioned above. However, some scholars believe that when the above criteria are applied to faciocervical area, the expanded volume is smaller. Ai Yufeng and Lu Kaihua et al. studied and found that there are very big differences in the expanded volume per unit volume of the expander among different parts of the body. To repair 1 cm^2 defect range, the defect in head requires 3.5–4.0 ml expanded volume, the defect in face requires 6–8 ml expanded volume, and the defect in neck requires 12–14 ml expanded volume, and therefore when the repairing area and expanded volume are estimated, the principle of more rather than less should be followed [7].

The basic researches on skin soft tissue expansion technology have made a lot of encouraging results in recent years; most of researches focus on aspects of how to increase the expansion speed of the skin flap, improve the quality of the expanded skin flap, and reduce the associated complications; some achievements have certain clinical application values. For example, Li Xiangyun used 40% normal saline for injection expansion, which can effectively relieve the pain during injecting solution and reduce the retraction rate of the expanded skin flap [8]; Ju et al. carried out hyperbaric

oxygen therapy in the process of skin flap expansion and found that the hyperbaric oxygen therapy can significantly improve the blood supply of the expanded skin flap and accelerate the expansion process [9]. In addition, the local external use of recombinant human epidermal growth factor on the expanded skin flap, the injection of triamcinolone acetonide and verapamil into the expander capsule, and smearing the chitosan in expansion gap have certain effects on accelerating the skin flap expansion and reducing the contracture of the skin flap.

1.2 The Structure and Classification of the Skin Soft Tissue Expander

The early skin soft tissue expanders are divided into two categories of controllable type and self-inflatable type. Since the extension speed and the expansion time of the self-inflatable expander are difficult to control, it is rarely used in clinic, and therefore, this section focuses on the controllable expander.

The controllable soft tissue expander consists of three parts such as expander capsule, injection pot, and aqueduct (Fig. 20.1), and the advantage is that the capacity and time of the expansion can be controlled according to the needs.

1.2.1 Expander Capsule

The expander capsule is the main part of the expander, and its main function is to receive the injected water to complete the expansion of the skin tissue; thus, it is required that the expander capsule itself not only has better elastic scalability and good leakproofness but also has strong blast-resistant and tear-resistant abilities and can receive the injected water over the rated capacity for expansion. According to the shapes of the expander capsules, the expanders can be divided into several types of round, square, kidney-shaped, cylindrical, and special-shaped expanders (Fig. 20.2), and each type has different capacity specifications.

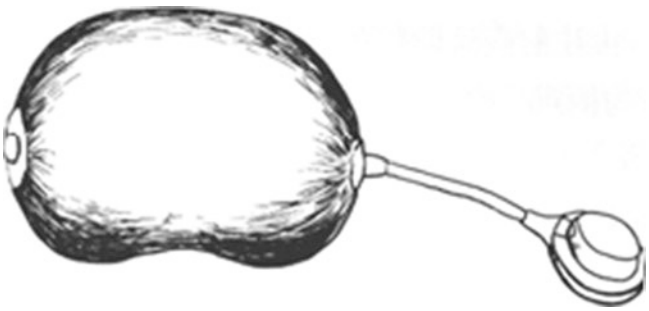

Fig. 20.1 The main structure of the expander

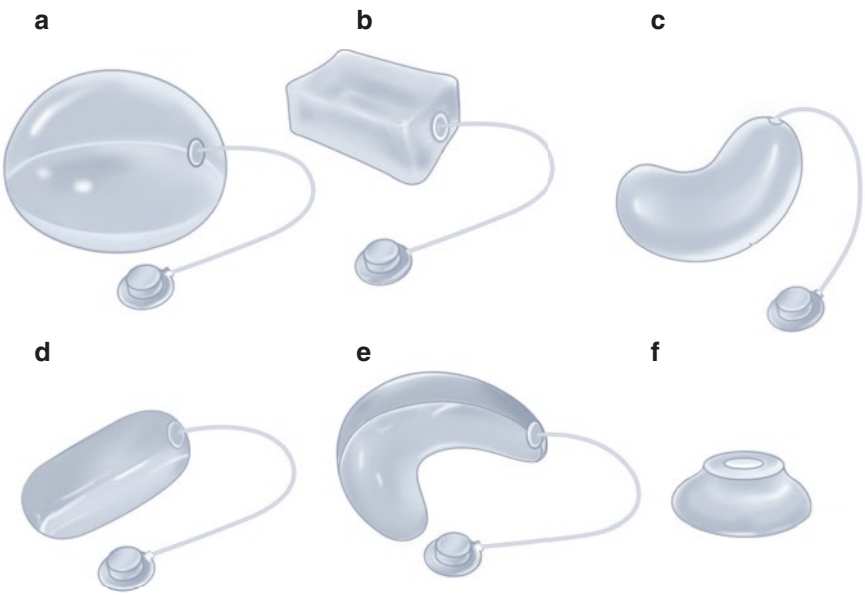

Fig. 20.2 The expander capsules with different shapes. (**a**) Round. (**b**) Square. (**c**) Kidney shaped. (**d**) Cylindrical. (**e**) Crescent shaped. (**f**) Top injectable type

1. Round expanders. They include spherical, hemispherical, elliptical, and pie-shaped expanders, which have capacity specifications of 30, 50, 100, 140, 300, and 500 ml. This type of expanders after expansion can make the skin surface hemispherical, the central expansion rate was highest, and it can be used in various parts of the body, of which, during breast reconstruction process, the saline-filled prosthesis is also a round expander.
2. Square expanders. They include rectangular, cubic, and ice bag-shaped expanders, which have capacity specifications of 100, 170, 250, 500, and 700 ml. The skin flap formed after the expansion of the square expander capsule is easy to be slided and advanced forward and backward, and thus they are mostly used in the trunk and limbs.
3. Kidney-shaped expanders. The kidney-shaped expander capsules have capacity specifications of 20, 30, 50, 100, 250, and 450 ml. The skins expanded by this type of expanders are bulged as kidney shaped, the inner radian is smaller, and the outer radian is larger, and thus the skin expansion rate is higher, and they are mostly used in parts matching the radians, such as mandibular margin, neck, infraorbital area, and retroauricular area.
4. Cylindrical expanders. They include cylindrical and semicylindrical expanders, which have capacity specifications of 10, 100, 200, and 400 ml; they are mainly used for the expansion of the limb skin.
5. Special-shaped expanders. The expander capsules are designed according to special parts or special needs, such as C-shaped expander used in periorbital area, horseshoe-shaped expander used in mandibular area, and long strip-shaped expander used in dorsal side of fingers.

1.2.2 Injection Pot

The injection pot is the major component which receives puncture and injects the expansion solution into the expander capsule, and the main structures include top cover, bottom cover, anti-puncture stainless steel sheet or nylon sheet, and anti-leakage device. The valves can be divided into unidirectional valve and bidirectional valve according to whether limiting the flow direction of the expansion solution. Because the unidirectional valve only allows the flow of the expansion solution from the injection pot to the expander capsule, although it can effectively prevent valve leakage, but once the excessive injected water leads to the blood supply disorder of the expanded skin, the treatment will be more difficult, the bidirectional valve is mostly used in domestic hospitals, and the advantage is that the intracapsular pressure can be adjusted through injecting or drawing out the expansion solution.

Another kind of external water injection valve has a similar principle with the built-in valve, but the injection pot is placed externally during surgery. Some expanders are still designed with flapper type valve, which is connected to the end of the aqueduct; after the front-end nipple of the syringe is inserted into the valve, the valve can be opened immediately for water injection.

1.2.3 Aqueduct

The aqueduct is the silicon tube connecting the injection valve and expander capsule, the length is about 5–15 cm, and the diameter is generally 2.0–3.5 mm. The tube walls generally have a certain thickness, so as to avoid being flattened, twisted, and folded.

Over the years, with the widely application of expanders in clinic, some domestic scholars have also carried out continuous improvement on the expander, so that it can be better applied in clinic or research. For example, Li Jiang et al. developed the thin-walled vertical tube expander; because the tube is perpendicular to the long axis of the expander, the injection pot is separated from the tube; it can be implanted under the skin through minimally invasive surgery, while the use of an external injection pot avoids problems of expander tube folding and injection pot leakage; its clinical application has achieved better results. Liu Wenge et al. developed the expander with structures such as double capsules and double tubes; its external capsule is used to store the drug solution promoting the expansion; the internal capsule is used for water injection and expansion, and the expansion time is reduced through combined use of the drug solution, so that the expansion efficiency is greatly improved. Jiang Huiqing et al. developed the polyester mesh unidirectional expander. The strength of the bottom is increased, and the expander produces a unidirectional expansion effect, which is more favorable for the expansion of cervical and abdominal skins. Lu Yanlin et al. modified an expander; the aqueduct is fixedly connected with the injection valve, and the aqueduct and expander capsule are produced separately; the length of the aqueduct is up to 100 cm; when being used, it can be cut short according to actual need, and then it is bonded together with the expander capsule using adhesives, so that the distance between the implanted expander capsule and the injection pot is increased, reducing the incidence rate of infection when the injection pot is placed externally [10].

1.3 Surgical Steps

1.3.1 Expander Implantation

The expander implantation is the first-stage surgery we often mention.

1. Selection of expansion area. The expanders with different shapes are selected according to characteristics of the defect areas to be repaired; the area where the expander is implanted is generally selected in the area adjacent to the

lesion area; in this way, the color and texture of the expanded skin are most similar to the area to be repaired; thereby, an excellent postoperative aesthetic effect is obtained. The situation such as scarring, trauma, or infection should be avoided in the proposed expansion area, so as not to cause infection or exposure after expander implantation. At the same time, consideration should be given to the blood supply situation of prefabricated skin flap in the implantation site of the expander; the proposed expansion area should be far away from the sites where the main supplying vessels of the skin flap penetrate out; especially when the expander is implanted in the limbs or trunk, attention should be paid to retaining the longitudinal blood vessels in line with the direction of the skin flap expansion, while the unnecessary transverse blood vessels are cut off, so as to achieve the effect of skin flap delay. Selecting the appropriate expansion area is the guarantee of the surgical efficiency, and the placement location and direction of the expander have an important impact on the skin expansion efficiency. According to the study of Fan Pengju et al., because the skin has anisotropy in the expansion process, the expansion efficiency is lowest along the direction of Langer's lines, and the expansion efficiency is highest along the direction perpendicular to Langer's lines; at the same time, the non-round expander also has different expansion potential energies in all directions; the expansion efficiency in its long axis is often not as good as that in its short axis [11]. This suggests that when the expander is implanted, the plastic surgical surgeons should not only consider the skin situation of the patient but also comprehensively consider the expansion characteristics of the surrounding normal skin and the shape of the pre-implanted expander and the expansion potential energies in all directions.

2. Incision selection. The intraoperative incision design needs to consider the factors such as the site, size, direction, and tension of the incision; the first-stage surgery also needs to consider the location of auxiliary incision in the second-stage surgery and how to transfer the skin flap, in order to take full advantage of the expanded tissues and provide favorable conditions for the second-stage surgery. The principle of skin flap design should be run through the entire surgical procedure.

The incision for expander implantation is usually selected in the place at the junction of diseased tissue and normal tissue, which is beneficial to wound healing, and can effectively prevent complications such as incision dehiscence and expander exposure. However, some scholars believe that the incision made in the normal skin side of the junction can affect the skin expansion efficiency; it is recommended to make the incision in the affected skin, but the margins of the implantation lacuna of the expander are dissociated underneath at least to the normal skin side; the isolation strip between the expander and the incision is established, which can take advantage of the normal skin without the formation of a new scar, and simultaneously ensure that the wound healing is not affected by the tensile force of the expander. For the selection of incision direction, the incision which is parallel or perpendicular to the long axis of the expander is used in most cases, so as to facilitate separating the subcutaneous lacuna. It is appropriate that the length of the incision is enough to fully separate the lacuna and doesn't exceed the lesion range. Some scholars believe that the straight incision made in the place at the junction of affected skin and normal skin is not conducive to the expansion of the skin flap; they suggested that the small V-shaped or U-shaped incision is made at the side of the affected skin, or the incision should be made perpendicular to the direction of the skin flap expansion. Some researchers have compared the advantages and disadvantages of the parallel incision and vertical incision and have found that the visual field exposure of the vertical incision is poor, and the dissection difficulty is greater and thus is not conducive to hemostasis. But as long as the operation is performed carefully during surgery, because its incision tension is perpendicular to the tension expanding the skin soft tissue, the postoperative complications such as wound dehiscence are significantly reduced, and the skin expansion efficiency is also significantly increased [12].

For some banded pigmented nevi or melanin hairy nevi, the affected skin can also be selected as the center to make the incision; the expander is implanted to expand the surrounding skin; after the expander is taken out at the second-stage surgery, the banded affected skin is removed, and the incision is directly sutured. Because when the water injection and expansion are carried out after surgery, the tension born by the incision is greater, for this type of incision, during surgery, the dermis and subcutaneous tissue should be incised at one side of the incisal margin, and then the clearance of the expansion capsule is stripped; when the incision is closed, the formed deep dermal flap should overlap into the subcutaneous area and is tiled with it to reinforce the incision.

With the popularization and application of endoscopy in plastic surgery, more and more hospitals begin using the expander implanted by minimally invasive surgery, so that the first-stage incision is smaller and smaller. Under the condition that the safe hemostasis is achieved, the appropriate implantation lacuna is separated, and the expander capsule is fully flattened; the smaller incision heals more quickly after surgery, so that the expansion cycle is shortened, and the expansion efficiency is improved. The use of endoscope for expander implantation has advantages such as shorter operative time, small

incision, faster recovery, fewer complications, and better postoperative effect and thus is highly respected by plastic surgeons [13].

3. Implantation depth. The implantation depths of the expander in different parts of the body are not the same; for example, for scalp expansion, the expander is generally implanted into the surface of the skull periosteum at the deep surface of the galea aponeurotica; for expansion of the facial buccal skin, the expander is generally implanted into the deep surface of the subcutaneous tissue and superficial surface of SMAS layer; for cervical skin expansion, the expander is generally implanted into the superficial or deep surface of the platysma muscle, but it is generally believed that the expander should be implanted into the superficial surface of the platysma muscle, because the separation operation of the deep surface of the platysma muscle may damage the cervical branch of the facial nerve; for the expansion of the skin in the trunk and limbs [14], the expander is generally implanted into the superficial surface of the deep fascia.
4. Lacuna separation. The implantation lacuna of the expander is mainly separated by means of blunt dissection; the interval in the site connected more closely can be cut off with scissors, but attentions should be paid to strict hemostasis. The separation operation should be located in the same tissue layer, to avoid that the uneven thickness of the skin flap at the surface layer causes the expander exposure in the future expansion process [15]. The size of the lacuna should exceed the margin of the flattened expander capsule by about 1 cm; if the lacuna is too small, it may lead to the fact that the expander is folded into a corner and pierces the skin. The lacuna where the injection pot is placed cannot be too close to that of the expander capsule, so as not to cause accidental injury of the expander capsule when the water injection is carried out.
5. Expander implantation and incision closure. Before expander implantation, the leakproofness of the expander should be strictly examined to ensure that no damage occurs; 10–20 ml normal saline or gas can be injected into the expander, and then the expander is placed into the water to inspect whether there is leakage. After complete hemostasis of separated lacuna, the expander is prefilled with a certain amount of normal saline (generally 10–20% of total capacity) to fully expand and flatten the expander within the lacuna. When the injection pot is placed, it should be noted that the injection surface is placed upwards to avoid its overturn and the tube folding. Before incision closure, a negative pressure drainage tube is placed at the bottom of the lacuna to facilitate postoperative drainage.

When the incision is sutured, the superficial tissue should be sutured with the deep tissues with several stitches at the 0.5–1 cm from the incisal margin, so as to prevent the translocation of the expander to the incisal margin in the process of water injection and expansion, which causes great tension on the incision and affects wound healing and even leads to expander exposure. After that, the incision is closed by means of layered intermittent suture, and the entire process must be carried out under direct vision to prevent piercing the expander. After completion of the suture, the injection pot can be punctured for water injection test to ensure that injection pot is not overturned. The negative pressure drainage tube is connected to the negative pressure suction machine for examination to ensure tight incision suture.

With the universal application of the expander and the continuous improvement of its structure, in recent years, the implantations of the expanders with external injection pot are also continuously increased. Relative to the expander with built-in injection pot, the external injection pot gets the favor of surgeons because of its easy operation, no need for percutaneous puncture, and no occurrence of situation such as surgical failure caused by overturning of injection pot, aqueduct twist, and leakage of injection pot. In addition, the external injection pot can be converted to a special valve to be connected to other automatic water injection devices; thereby, the water injection mode is further improved, and the expansion efficiency of the skin flap is increased.

1.3.2 Water Injection and Expansion

1. Conventional expansion. In general, the saline accounting for 10–15% of rated capacity is injected to the expander intraoperatively, and the water injection and expansion are carried out again at 5–7 days after surgery. The conventional expansion method is that the water injection is carried out once every 5–7 days or may be carried out twice weekly. Each injection volume is determined according to the size of the expander and the location of the expansion; generally 10–15% of the rated capacity can be injected. The isotonic saline and the isotonic solution added with antibiotics can be used as the expansion solution to prevent infection. During injection, the injection volume can be determined through the observation on the color of surface skin and the situation of capillary filling of the expanded skin flap and the simple palpation; if the surface skin becomes white after injection, and the congestion reaction disappears, the observation should be carried out for 5–10 min; if the blood flow of the skin still cannot recover to normal or the patient has an obvious pain, it is required to take some solution out until the blood flow of the surface skin is restored.

Because the conventional expansion mode of water injection has a longer interval, the entire expansion cycle is long, and there are more complications; people have always wanted to shorten the water injection cycle and increase the expansion efficiency of the skin flap. The recently developed intraoperative immediate expansion technique, the rapid expansion, and the continuous and constant pressure expansion also begin to be used in clinic and have achieved certain effects.

2. Immediate expansion. The appropriate expander is implanted in the margin of the wound to be repaired; the incision is temporarily sutured; the expander capsule is injected with water immediately and repeatedly during surgery; the skin is significantly expanded after 1–1.5 h; at the moment, the expander can be taken out, and the advancement skin flap is formed to repair the wound. This expansion method can achieve the purpose of repairing the wound at a time, but it is effective only for the wound with minor defect; it is difficult to repair a large area of skin defect. Because the expansion duration is very short, all additional skins come from the elastic expansion of the tissues and the creep deformation of the tissues; there is no cell proliferation in the biological meaning; therefore, the skin flap retracts significantly after surgery; even after suture, the incision tension will be greater; and the postoperative scar hyperplasia will be obvious.
3. Intermittent rapid expansion. Under the premise of ensuring no impact on the wound healing, the first water injection and expansion are carried out as early as possible; the interval between two adjacent water injections and expansions is significantly shortened compared with the conventional expansion. Generally the water injection is carried out once every 2–3 days or even once a day; each injection volume is determined according to the capacity of the expander and the area of the skin to be expanded and under the premise that the pressure produced by the expander capsule doesn't block the skin blood flow. After water injection, the blood supply of the expanded skin flap is closely observed for 10–20 min; if the microcirculation of the skin flap is improved, some solution will be drawn out. In most cases, it takes 10–15 days to complete the entire process of water injection and expansion [16].

   After rapid expansion, the reconstruction of skin structure is lower than the conventional expansion, also mainly through the elastic expansion and the creep deformation of the tissue; the proportion of cell proliferation is smaller, and the proportion of postoperative skin flap retraction is higher. But Zeng et al. compared the skin flaps undergoing conventional expansion and rapid expansion; with the extension of recovery time after water injection, the mechanical properties such as tension and retraction proportion of the skin flap undergoing rapid expansion constantly tend to be close to those of the skin flap undergoing conventional expansion; after completion of rapid water injection and expansion, the recovery time is 4 weeks; there is almost no difference in biomechanical properties between the prefabricated skin flaps with two expansion methods. It is visible that the convalescing period of the skin flap from the completion of water injection and expansion to second-stage surgery is one of key factors affecting the expanded skin flap.
4. Rapid expansion with continuous and constant pressure. The implanted expander which is connected to the microelectric infusion pump in vitro via a tube is continuously perfused for expansion; the perfusion pressure is generally maintained at 5.3–8.0 kPa, and the average speed of the perfusion is 1–2 ml/h. Research shows that the continuous expansion of 6 days can obtain the volume which can be obtained through conventional expansion of 27 days; a number of indicators confirm that the increased net area is a little smaller than that after conventional expansion; the continuous and constant pressure rapid expansion is a safe and reliable water injection mode with better future prospects. The disadvantage of this method is that the water injection process requires hospitalization of the patient and requires a certain equipment to complete.
5. Slow expansion. The interval between two adjacent water injections is significantly longer compared with the conventional expansion; for some sites with thinner expanded skin flap, surface scar, or radiation injury, the slow expansion can usually achieve a better efficacy, and the complication rate is usually lower.

   In addition, with regard to the total amount of water injection of the expander, most researchers believe that a certain amount of over expansion is useful and harmless. Mascio et al. studied the situations such as the overexpansion of the expander and considered that it is still safer when the total amount of water injection of the expander is 3.6 times more than its standard capacity; the carefully planned overcapacity expansion can avoid multiple surgical implantations of the expander, reduce the total hospitalization cost, and obtain a better curative effect. The study of Hafezi et al. also confirmed that the overexpansion by two–four times will not increase the complication rate throughout the surgery and can provide more skin flap area to better repair the wound [17].

1.3.3 Skin Flap Transfer After Removal of the Expander

The skin flap transfer after removal of the expander is commonly referred to as the second-stage surgery.

After the skin soft tissue undergoing full expansion achieves the desired purpose, the expander can be removed,

and the formed skin flap can be used to repair the defect area. It is important to note that after the completion of water injection process, it is required to maintain the expansion state of the skin flap for 4–6 weeks, so that the expanded skin flap can obtain sufficient biological extension and establish a stable and reliable blood supply, and reduce the incidence rate of complications such as postoperative skin flap retraction and blood supply disorders. Especially for some skin flaps undergoing overexpansion, the relaxation training of the skin flap can be carried out at 3 days before second-stage surgery, and the method is that 20–30% of the normal saline in the expander capsule is drawn out to make the skin flap softened; after the relaxed state is maintained for 24 h, an equivalent amount of normal saline is injected into the expander capsule again to maintain expansion, and this operation is repeated two–three times. The relaxation training can effectively reduce the blood supply disorders occurring due to the tortuous and spasmodic blood vessels caused by the sudden decompression after removal of the expander in the second-stage surgery [18].

The expanded skin flap can be used to repair the defect area using the transfer methods such as advancement, rotation, and stagger. Most transfer methods have been designed during the first-stage surgery, after removal of the expander, and the skin flap can be designed using the measuring methods of the corresponding points and lines; the expanded tissues are applied to the largest extent during the surgery, the auxiliary incisions are reduced as far as possible, and attentions are paid to ensure the blood supply of the skin flap. For its incision design, it is necessary to not only consider the full extension of the skin flap but also consider the hiddenness of the incision after skin flap transfer (especially the skin flap transfer in cervical-facial region), in order to obtain a good aesthetic effect.

After removal of the expander, the treatment of the fibrous capsule in the process of skin flap transfer should be determined according to circumstances. The fibrous capsule is the inner layer interface formed between the implant and the body's own tissue; it is a natural protective response of the body to the invaded foreign matters, is mainly composed of collagen and elastic fibers, and is the principal factor causing skin flap contracture and restricting the skin flap expansion. Earlier studies found that there are a large number of new small arteries, veins, and capillaries in the fibrous capsule, which has a great significance for the blood supply of skin flap, especially in the distal part of a larger skin flap, and the fibrous capsule can be absorbed automatically after removal of the expander, and therefore most scholars believe that the retaining of fibrocystic flap has a great significance for the survival of the skin flap after surgery [19]; but some researches also believe that the removal of the fibrous capsule does not significantly affect the blood supply of the skin flap.

2 Clinical Application of the Skin Soft Tissue Expansion

2.1 Application of Skin Soft Tissue Expansion in the Head, Face, and Neck

2.1.1 Application Characteristics

Tumors in the head and face account a very high proportion of body surface tumors, because they can seriously affect the looks and appearance of the people and may cause damages and deformations of the five sense organs; in the process of surgical treatment, it is not only required that the wound should be better closed after the tumor is radically resected, but it is also required that the good appearance and function of the head and face region are recovered to the maximum extent, for the larger superficial benign tumors such as giant nevus, verrucous nevus, hemangiomas, vascular malformations, and neurofibromatosis in the head and face region; the skin flap can be formed by water injection and expansion after the first-stage implantation of the expander, and then the tumor focus is resected, and the expanded skin flap is used to repair the defect area during the second-stage surgery; even some benign tumors with larger areas require fractional resection of tumor focuses and multiple repairs with expanded skin flaps. For some early stage malignant tumors, after the skin flap surrounding the lesion is pre-expanded, and then the lesion tissue is removed, and the wound is covered with the expanded skin flap, but attention must be paid to that the optimal timing of radical surgery of malignant tumor should not be delayed. For certain malignant tumors, the one-stage radical resection of the primary lesion can be performed, the skin transplantation is carried out to repair the defect; after comprehensive treatment of the malignant tumor, after sufficient follow-up and confirming that there is no dissemination or metastasis, the skin soft tissue expansion is carried out to reconstruct the deformity.

The scalp has a rich blood supply and clear layers, and the operation is relatively simple. When the expander is implanted, the clearance between the galea aponeurotica and skull periosteum should be selected as the implantation location; the clearance has a loose structure and is easier to strip off and also has less perforator vessels. After the wound of the one-stage surgery heals well, the water injection and expansion can start to be carried out immediately; the removal of the stitches is generally postponed to 10–14 days after surgery or later. During the expansion process, it should be noted that because the resistance of the hair follicle to ischemia is poor, the excessive pressure can lead to hair follicles ischemia, and thus the hair loss occurs; therefore, each injection volume cannot be too great, and the scalp is tighter; the scalp pain may occur during injection; the water injection method of small quantities in high frequency should be adopted, and the local anesthetics can also be added into the expander capsule.

Because there are important structures of five sense organs such as the eyebrows, eyes, nose, mouth, and ears, the anatomical features of tissues are that the blood supply is rich, the subcutaneous connective tissue is dense, and the layers are less clear; there are important anatomical structures such as facial nerve and parotid gland in the deep layers; when the expander is implanted, the range and invaded layers of the tumor and the aesthetic characteristics of five sense organs should be comprehensively considered, and the detailed repair plan is made before surgery. The implantation lacuna of the expander in the cheek is usually selected in deep surface of the subcutaneous tissue and the superficial surface of SMAS layer; attentions should be paid to the fine dissection and complete hemostasis in the separation process. Because most of hematomas after expansion appear in cheek, it should cause great vigilance of the plastic surgeons. In addition, the facial donor site may also have depressed deformation and auxiliary incision scars; the patients should be informed of all of these before one-stage surgery.

The cervical skin is thin, and the tissue is relatively loose with a high mobility, and the expansion efficiency is lower than those of other parts under the same conditions. Therefore, the implantation lacuna of the expander is generally selected in the superficial surface of the platysma muscle, so as to avoid the postoperative neck deformation caused by excessive expansion on the one hand and also avoid injuring the cervical branch of the facial nerve on the other hand. For the expander implanted in the neck, in the process of water injection, special attention should be paid so that a large number of important anatomical structures such as blood vessels and nerves are distributed in the neck; the water injection and expansion cannot be too forceful at a time, so as to avoid serious consequences. It has been reported abroad that when the expander in the neck was undergoing water injection and expansion, the patient had sudden bradycardia due to compression of internal carotid sinus [20].

2.1.2 Typical Case

1. Case I. The residual scars after improper treatment of port-wine stains and the patient with partial skin transplantation, the expanded forehead island flap was used to repair the skin flap (Fig. 20.3).
2. Case II. In the patient with thickened port-wine stains, the skin in forehead and left cheek was expanded to repair the lesion area (Fig. 20.4).
3. Case III. In the patient with congenital melanocytic nevi in nasal dorsum, lower eyelids, and the right cheek, the skins in forehead, face, and neck were expanded for repair (Fig. 20.5).

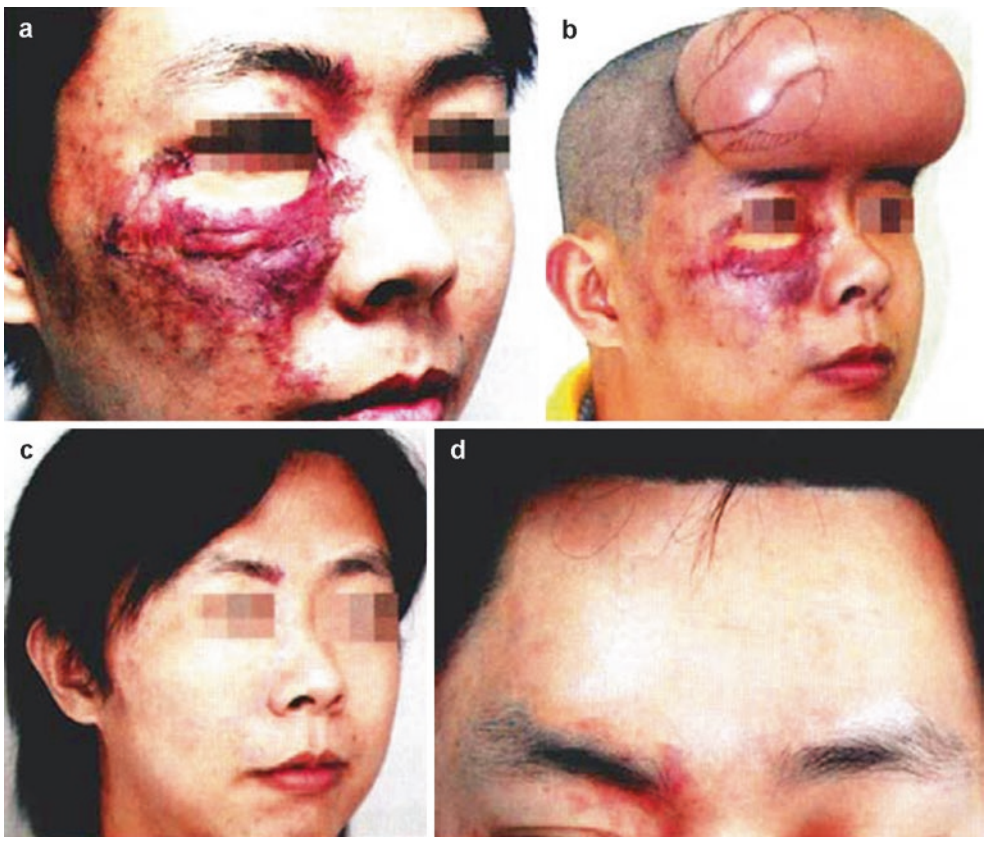

Fig. 20.3 Case I. (**a**) The residual scars after improper treatment of port-wine stains and after partial skin transplantation. (**b**) The skin expander was implanted in the forehead. (**c**) At one and a half years after the repair with the forehead island flap. (**d**) When the frontal residual donor site scars were designed, most of them were located at the hairline and the upper margin of the eyebrows, the forehead scar was not obvious

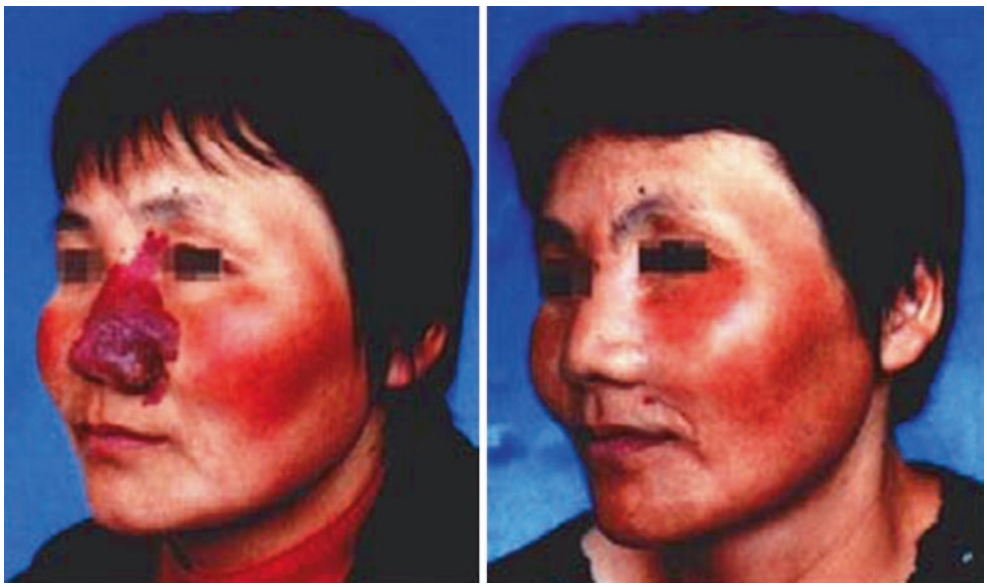

Fig. 20.4 Case II. (**a**) Before surgery. (**b**) After surgery

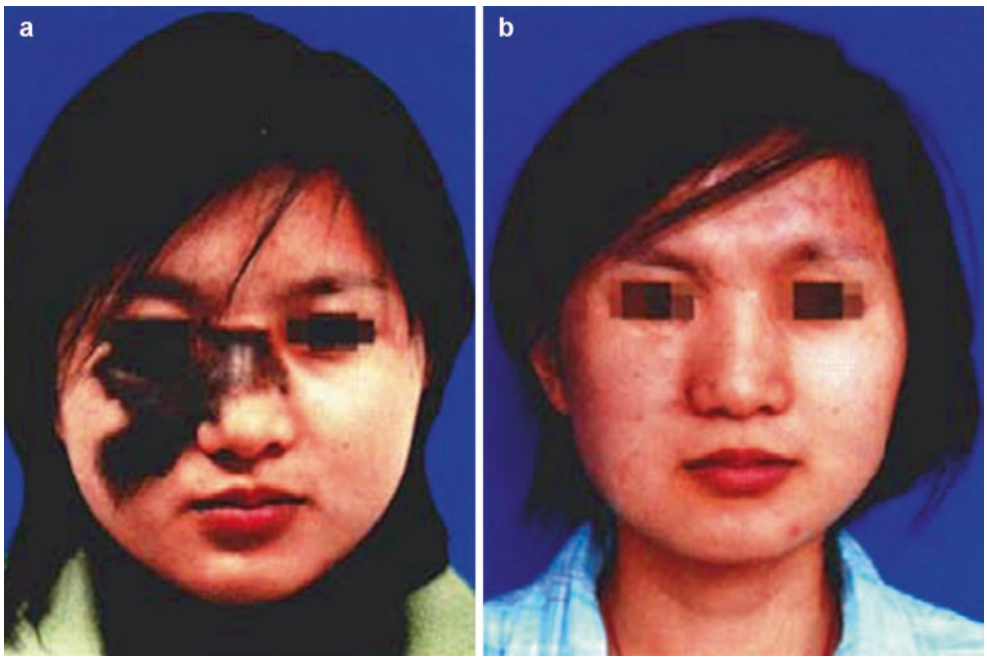

Fig. 20.5 Case III. (**a**) Before surgery. (**b**) After surgery

2.2 Application of the Skin Soft Tissue Expansion in Breast Reconstruction After Breast Cancer Surgery

With the wide development of radical mastectomy with preservation of skin and nipple-areola complex, there are also more and more breast reconstructions based on expanders and silicone gel breast prostheses. Different from the expanders in other parts of the body, the tissue expansion in the process of breast reconstruction needs to face more problems; the postoperative chemoradiotherapy, fibrous capsule contracture, and the symmetry between bilateral breasts after surgery are issues to be considered and resolved comprehensively during breast reconstruction using the expander.

The breast reconstruction after radical mastectomy can be divided into one-stage reconstruction and second-stage reconstruction according to the reconstruction period, and it

can also be divided into autologous tissue reconstruction, prosthesis reconstruction, and the combined reconstruction with autologous tissue and prosthesis according to the reconstruction mode. In addition to the simple autologous tissue reconstruction, the temporary or permanent soft tissue expander can be used to assist in various types of breast reconstructions. The implantation lacuna of the expander is mostly selected under the pectoralis major muscle; the expansion capacity can be adjusted according to the shape of the contralateral breast; after the completion of the expansion, the expander can be replaced with silicone gel prosthesis, or only the injection pot of the expander is removed, and the saline capsule is retained as a permanent prosthesis; the whole adjustment process takes 6–9 months.

The selection of the implantation timing of the expander should be determined according to the specific circumstances of the patient. The radiotherapy can cause severe capsular contracture around the expander and affect the blood supply of the expanded skin flap and the local skin appearance, so that the second-stage reconstruction has a poor aesthetic effect and the expander after implantation affects the efficacy of the radiotherapy. Therefore, the radiotherapy should be avoided in the process of the tissue expansion as far as possible. The common point of view is that the patients who needn't receive radiotherapy can undergo the reconstructive surgery with one-stage implantation of the expander; if the patients with a history of chest wall radiotherapy undergo the skin soft tissue expansion, the efficacy is poor, and the patients also have more complications compared with the patients without a history of radiotherapy, and therefore the indication of expander implantation for breast cancer patients after radiotherapy should be more strict [21]. For some breast cancer patients after modified radical mastectomy in whom the possibility of radiotherapy is not determined, Kronowitz proposed the delayed one-stage breast reconstruction based on skin soft tissue expander [22]: The first stage of surgery includes skin sparing mastectomy + expander implantation; the water injection and expansion are carried out immediately to maintain the shape of the breast at the surgical side; according to the pathological examination results of postoperative specimens, the patients who are not required to receive postoperative radiotherapy undergo second-stage reconstruction (autologous tissue filling or prosthesis implantation) after removal of expander at 2 weeks after surgery, which doesn't delay the timing of chemotherapy and can better maintain the shape of postoperative breast; for the patients who are required to receive postoperative radiotherapy, the normal saline within the expander is discharged before the start of radiotherapy, so that the chest wall is flattened to carry out radiotherapy; at 2 weeks after the end of radiotherapy, the expander is injected with normal saline again to the size before radiotherapy; 3 months later, the reconstructive surgery is carried out to remove the expander, and the autologous tissue is used to reconstruct the breast.

2.3 Application of the Skin Soft Tissue Expansion in the Body Trunk

2.3.1 Indications

The application of the skin soft tissue expansion is the best repair method for the defects after resection of larger benign body surface tumors such as melanin hairy nevi, neurofibromatosis, and vascular malformations. In general, the expander in the body trunk is selectively implanted in the superficial surface of the deep fascia, and some can also be implanted in the deep surface of the deep fascia and the surface of the myolemma. Some benign body surface tumors with larger areas often can be treated and repaired by means of repeated expansion and fractional resection. The repeated expansion is also known as the relay expansion, which refers to the fact that the expanded skin flap after transfer is expanded again until its area is sufficient to cover the wound to be repaired, but the intermission between the two adjacent expansions should be 3–6 months to allow the biological properties of the expanded skin flap recover to the state before the expansion. When the repeated expansion in the body trunk is carried out, special attention should be paid to the fact that the axial blood supply of the skin flap is not damaged.

2.3.2 Typical Case

Case IV The patient, male, suffered from Kaposi hemangioendothelioma; the ulcers occurred in the lesions after the patient was excessively treated with the radionuclide applicator 11 years ago, which was diagnosed as radiodermatitis. The ulcer still could not heal 11 years later and was expanded and aggravated further. The front left chest lesions were repaired with the expanded latissimus dorsi myocutaneous flap, the remaining lesions in front chest were repaired with the expanded right supraclavicular artery flap, and the back and armpit area flap was repaired with expanded local skin flap in the back. The patient was followed up at 6 months after surgery, and the ulcers healed well (Fig. 20.6).

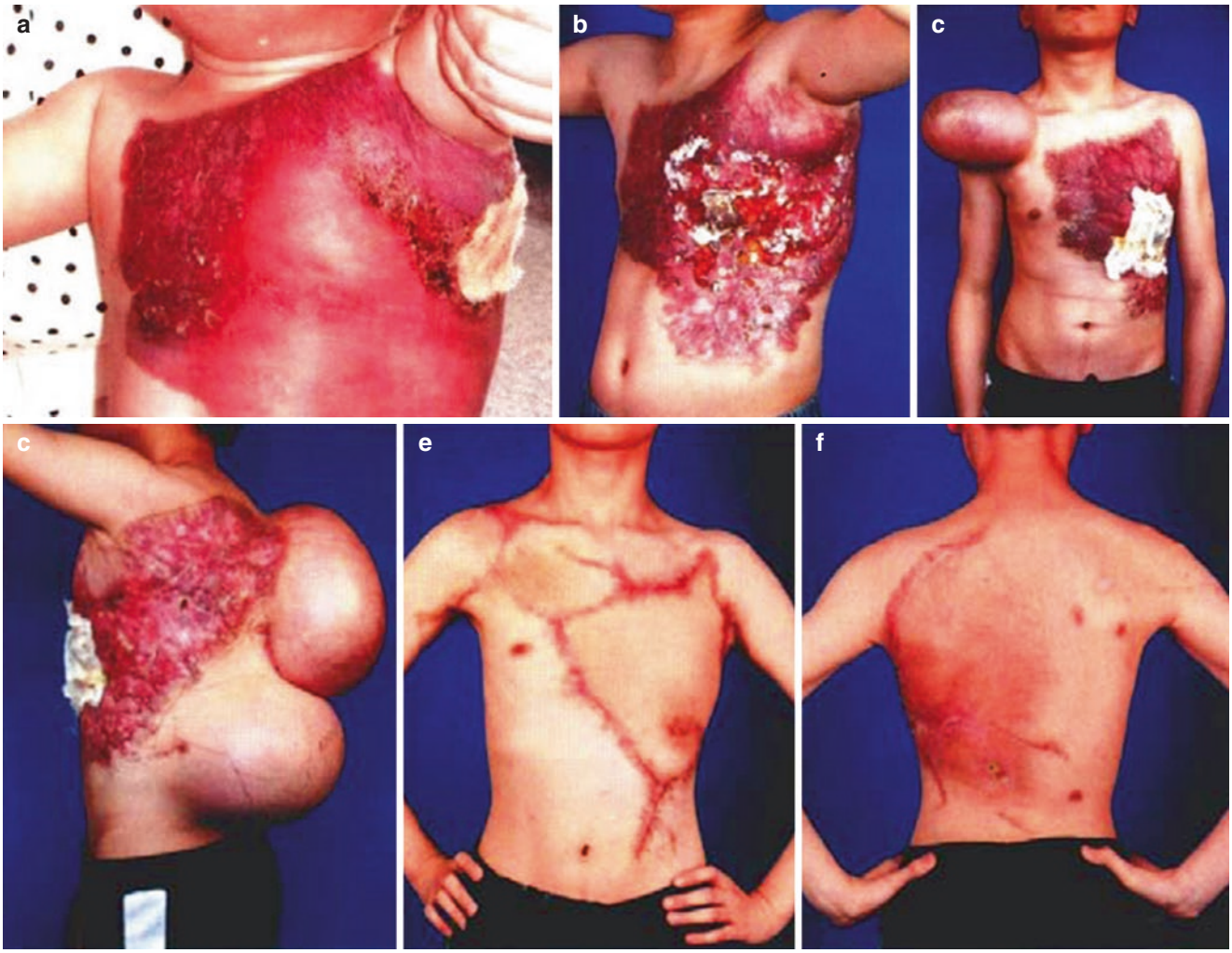

Fig. 20.6 Case IV. (**a**) The ulcers appeared in the lesion area after the patient was excessively treated with the radionuclide applicator 11 years ago. (**b**) The ulcer still could not heal 11 years later and showed a trend of expansion and aggravation. (**c**, **d**) Respectively, the front left chest lesions were repaired with the expanded latissimus dorsi myocutaneous flap, the remaining lesions in front chest were repaired with the expanded right supraclavicular artery flap, the back and armpit area flap were repaired with expanded local skin flap in the back. (**e**, **f**) The patient was followed up at 6 months after surgery, and the ulcers healed well

2.4 Application of the Skin Soft Tissue Expansions in Four Limbs

Currently, the skin soft tissue expansion in the limbs is applied rarely after resection of the tumors in four limbs. Foreign research data show that the incidence rate of complications of the expander implantation in four limbs is higher than those in other parts; especially the expander implanted in the lower limbs are more prone to infection and expander exposure; the reason may be related to factors that the body position affects the venous return and is more likely to cause tissue edema and low tissue oxygen tension and metabolic waste accumulation. Therefore, the application of the skin soft tissue expansion in the repair of the limbs defects after resection of the tumors in four limbs needs further research.

2.5 Complications of the Skin Soft Tissue Expansion and Their Prevention

The application of the skin soft tissue expansion is considered to be a significant progress in the field of plastic surgery in the twentieth century, and especially the development and application of the controllable skin soft tissue expanders are called as a milestone in the history of the development of the repair method of soft tissue defects. It provides skins available for transplantation which have a good match with the skins in receptor site in aspects of color, texture, and structure, and the defects and secondary deformities in donor site are avoided; this method has incomparable advantages over traditional repair methods. However, this method is not perfect; its longer treatment course and a series of complications that may occur in the treatment process should attract great

attention of the oncology plastic surgeons. Early reports showed that the complication rates related to the expander implantation were up to 20–40% [23].With advances in technology in recent years, the complication rate is slightly reduced, but it is also 10–20% [24]. A retrospective study in China suggests that the overall complication rate is about 11.4%. The occurrence of complications has relations with many factors such as the implantation location of the expander, the water injection volume of the expander, the general condition of the patient, and the operation technique of the performer and postoperative management; how to avoid the occurrence of all kinds of complications as far as possible are important issues to be studied and solved in the process of skin soft tissue expansion.

The complications of skin soft tissue expansion can be classified according to the operation process, including the complications of one-stage surgery, water injection process, and second-stage surgery. The complications that may occur during one-stage surgery include active bleeding, postoperative hematoma, infection, skin necrosis and wound dehiscence, etc.; the complications that may occur during water injection process include water injection difficulty, expander leakage and wound dehiscence, etc.; the complications that may occur during second-stage surgery include skin flap necrosis, hemorrhage and infection, etc. The expander exposure, hematoma formation, and infection are most commonly seen among the abovementioned complications.

2.5.1 Hematoma Formation

The hematoma formation mostly occurs within 24 h after surgery, and the incidence rate in the head, face, and neck is highest.

1. Major causes
   (a) The layers are unclear and the operations are rough in stripping process.
   (b) The hemostasis is incomplete after vascular injury during surgery.
   (c) The negative pressure drainage tube is not placed, or the drainage is inadequate after surgery.
   (d) The patients have a tendency for systemic bleeding.
   (e) The bleeding recurs after the application of adrenaline.
   (f) The ligation of broken ends of blood vessels is unreliable, or the coagulation is not complete; the postoperative activity and friction cause rebleeding.
2. Prevention and control measures
   (a) Before surgery, bleeding medical history is inquired, physical examination is practiced, and the coagulation functions are fully examined. Then patients with a bleeding tendency are excluded, as well as women with menstrual period.
   (b) The intraoperative operations are carefully performed; the separation is carefully carried out at the same level, which mainly includes the blunt dissection, and attentions should be paid to strict and thorough hemostasis in the whole process.
   (c) The amount of adrenaline in drugs for local infiltration or swelling anesthesia is strictly controlled to prevent postoperative recurrence of bleeding.
   (d) The negative pressure drainage tube is placed after surgery.
   (e) The normal saline accounting for 10–15% of rated capacity is injected to the expander after surgery, in order to reduce dead space, and plays a role in compression hemostasis, and the appropriate compression bandage is carried out.
   (f) The volume of negative pressure drainage and the blood supply to the surface of the skin flap are carefully observed after surgery; if the drainage volume is increased sharply or the surgical area was obviously swollen and purple, the active bleeding or hematoma formation should be suspected.
   (g) Once the hematoma formation is suspected, the exploration should be carried out decisively; the surgical removal is performed timely for complete hemostasis.

2.5.2 Expander Exposure

The expander exposure is more commonly seen in the incision site and after the rupture of the top end of the expanded skin flap, which is divided into two situations such as expander capsule exposure and injection pot exposure.

1. Major causes
   (a) The water injection and expansion are carried out prematurely, and the wound healing is poor.
   (b) The stripping layer is too superficial, or the major blood vessels of the skin flap are damaged, or the too large tension after the expansion leads to blood supply disorders and skin necrosis.
   (c) The expander capsule is not flattened and is angled to penetrate through the skin.
   (d) The postoperative bandage is too tight, and the injection pot compresses the skin to lead to skin necrosis.
   (e) Expander exposure usually occurs secondary to infection.
2. Prevention and control measures
   (a) The separation layers of the implantation lacuna of the expander should be correct to avoid the formation of a too thin skin flap, and there should be at least an isolation strip of 0.5–1 cm between the incision and the margin of the expander to avoid that the expansion pressure acts directly on the incision.
   (b) When the incision is sutured, the fixation is performed with several stitches at the margins of the expander; it should be avoided that the expander is translocated.

(c) During separation and coagulation process, it should be avoided that the major blood vessels are damaged, and the blood supply of the skin flap is affected.
(d) The separated lacuna should be larger than the expander, and the expander should be fully flattened to avoid distortion, folding, and angulation in the implantation process.
(e) The water injection volume is appropriate in the expansion process; the blood supply of expanded skin flap is closely observed; when the phenomena that the skin flap is pale and the congestion response is slowed or stopped appear in the expansion period, the water injection should be stopped; the observation is carried out for about 10–20 min; if the situation is not improved, it is required to draw out a moderate amount of normal saline.
(f) After the expander is exposed, if there is no infection in early stage, the water injection and expansion are carried out continuously after the debridement and suturing are performed; if it is accompanied by infection, it is required to perform immediate surgery to remove the expander.

2.5.3 Infection

It mostly refers to the concurring infection in the tissue expansion process after one-stage surgery and is one of the main complications of the tissue expansion; it can be primary, but it can also be secondary to hematoma or expander exposure; the clinical manifestations include pain, the redness of skin flap, elevated skin temperature, fever, and increased white blood cells.

1. Major causes
   (a) There are infection foci around the incision, such as folliculitis and acne.
   (b) The intraoperative sterile operation is not strict.
   (c) There are secondary infections such as hematoma and expander exposure.
   (d) The sterile operation is not strict in the process of the water injection and expansion.
   (e) There are blood-borne infections.
2. Prevention and control measures
   (a) Whether there are potential infection foci around the skin to be expanded is carefully examined before surgery. If any focus of infection is found, the surgery should be delayed.
   (b) The aseptic operation should be strictly performed during surgery to prevent iatrogenic infection.
   (c) The aseptic technique is strictly applied in the process of water injection and expansion to prevent the invasion of pathogenic bacteria from the injection pot.
   (d) It should be noted whether there are blood-borne infections; when a systemic infection is confirmed, the patient should be treated timely with antibiotics.
   (e) The complications such as hematoma and expander exposure should be timely treated.
   (f) Once the patient has symptoms of infection, anti-infection measures should be promptly taken, including the systemic use of high doses of sensitive antibiotics. The solution in the expansion capsule can be replaced with the antibiotics containing solution, and the clearance under expanded skin flap can be instilled and lavaged with antibiotic solution. If the infection is controlled invalidly, the surgical drainage should be performed to remove the expander, and the next step treatment should be carried out after the infection is cured.

2.5.4 Non-expansion of the Expander

The expander after implantation cannot be injected with water, or the expander capsule is not engorged even after being injected with water.

1. Major causes
   (a) The expander capsule is accidentally damaged during surgery.
   (b) The expander itself has a quality problem.
   (c) The tube is folded.
   (d) The injection pot is overturned.
   (e) The expander capsule is accidentally damaged in the process of puncture and water injection.
2. Prevention and control measures
   (a) The quality of the expander should be carefully examined before implantation, and the expander can be injected with water or gas to test its tightness.
   (b) In the process of operation, it should be avoided that the sharp instruments contact with the expander.
   (c) It should be noted that the expander capsule is fully flattened during implantation, and the folding and angulation of the tube are avoided.
   (d) The implantation location of the injection pot should have a certain distance from the expander capsule; the water injection and expansion should also be carefully performed to prevent accidental damage to the expander capsule.
   (e) Once the expander capsule is damaged, and the expansion process cannot be completed, the surgery must be performed to replace it with a new one. If the expander cannot be injected with water due to the folding of the tube or the overturning and dislocation of the injection pot, the regional incision can be made to adjust the positions of the injection pot and the tube.

2.5.5 Skin Flap Necrosis

The skin flap necrosis is caused mostly due to blood supply disorders or infections.

1. Major causes
   (a) The separated skin flap is too thin; especially the tension in the area of injection pot is too large, and the surface of the skin is easy to be compressed.
   (b) The separated lacuna is too small, and the tension is too large during water injection, which causes the interruption of the blood supply of skin flap.
   (c) The main feeding blood vessels of the skin flap are damaged or compressed.
   (d) In the process of second-stage skin flap transfer, the sudden relaxation of the skin flap leads to vascular tortuosity, poor perfusion and blood return, and hematoma under the skin flap.
   (e) In the process of skin flap transfer, the pedicle is twisted and compressed, and the fibrous capsule of skin flap is stripped off excessively during surgery.
2. Prevention and control measures
   (a) The preoperative design should follow the principles of skin flap design and protect the nutritional blood vessels in the direction of skin flap expansion.
   (b) The separation layers are uniform, and the damages to major blood vessels are avoided.
   (c) The bandaging fixation is appropriate, and the area of the injection pot should not be compressed.
   (d) Close attention should be paid to the blood supply of skin flap during the expansion process; the microcirculation of the skin flap is observed for at least 20 min after water injection; if it is found that the blood supply is poor, the water is timely drawn out to reduce the pressure.
   (e) The excessively expanded skin flap should undergo stress relief exercises before surgery.
   (f) The fibrous capsule wall of the skin flap should be carefully treated.
   (g) Once the symptoms of the blood supply disorder of the skin flap are observed, the disorder should be timely treated. The hyperbaric oxygen therapy can be carried out in the early stage, but what is more important is to design and arrange the effective and appropriate delayed surgery once or multiple times before surgery.

In addition to the abovementioned serious complications which may lead to the failure of skin expansion, there are still some common complications, such as pain, limb edema, and hair loss, and the complications such as neural paralysis, bone absorption, neck compression, and various degrees of donor site deformities are relatively uncommon. Such complications can be treated through slow water injection using the method of small quantities in high frequency or drawing out an appropriate amount of normal saline; some symptoms will disappear after removal of the expander during second-stage surgery. In addition to the complications, the skin soft tissue expansion itself has some inherent disadvantages, for example, the expander with repeated water injection requires that the patient visit the outpatient clinic frequently, the patient feels uncomfortable during water injection and expansion, the appearance of the patient is significantly affected before the completion of the second-stage surgery, the child patients have related psychological problems after expander implantation, as well as there is the fibrous capsule contracture after expansion and the postoperative retraction of the expanded skin flap; all these need to cause the attention of the plastic surgeons.

In addition, the oncology plastic surgeons need to pay special attention to the intended population and the surgical time selection of the skin soft tissue expansion. Most body surface benign tumors grow slowly, and the possibility of local recurrence or malignant transformation is low; thus, the repair with the skin soft tissue expansion is a good choice [25]. For some body surface malignant tumors including breast cancer, the disease progresses more rapidly, and the radical surgery should be usually performed as soon as possible after the confirmation of the diagnosis. The patients may also need to receive postoperative systemic chemotherapy or local radiotherapy, and there is a certain local recurrence rate and distant metastasis rate. For such patients, the local reconstruction and plastic surgery should be considered selectively after radical tumor resection and comprehensive treatment. The effects of the local or systemic comprehensive treatment on the skin soft tissue expansion still need to be studied further, and it should be more cautious to use the skin soft tissue expander in the patients after resection of malignant tumors and comprehensive treatment. In addition, the skin soft tissue technology is constantly developing; in addition to the traditional single or multiple expanders, in recent years, all the technologies such as staging expansion, the prefabricated expansion using island-shaped blood vessels or the anastomosed blood vessels, and the prefabricated organ reconstruction combined with prefabricated expanded skin flap make the repair technology of the skin tissue expansion become more and more perfect; it will eventually become the core means for the repair of defects after tumor surgery.

All surgical photographs published in this chapter have been approved by the patients themselves.

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Application of Vascular Surgical Techniques in Oncological Surgery

21

Chang Shu and Xiao Zhou

1 Overview

Before the twentieth century, the medical profession generally believed that if there was an intravascular foreign body, it might lead to intravascular thrombosis, and thus the blood vessel was blocked. Therefore, for the repair of vascular injury, it is mostly advocated that the vascular ligation is performed to treat the bleeding in early phase, but the ischemia necrosis rate of the distal tissue after vascular ligation is higher. In the late nineteenth century, Jassinowsk et al. began to try the interrupted suture to repair the vascular injury, but the suture line did not penetrate through the vascular intima. In 1900, Guthric and Cartel founded triple-point angioanastomosis; the blood vessels were sutured by means of whole-layer suture, which laid the foundation for vascular surgical techniques. In the early twentieth century, the technology of autologous vein transplantation achieved success. Thereafter, the vascular surgical techniques developed gradually.

The repair and reconstruction of blood vessels require meticulous, gentle, accurate, and noninvasive operations. The operational errors may result in serious consequences, such as different degrees of bleeding, thrombosis, distal tissue ischemia, and necrosis, and even endanger the lives of patients. The surgical operations including exposure, separation, blocking, incision, suture, anastomosis, and transplantation, in order to successfully complete the surgery and achieve good surgical effects, there must be a special set of vascular surgical instruments, including various sizes and shapes of noninvasive forceps, vascular tweezers, vascular scissors and vascular dissector, and various types of noninvasive suture needles and vascular suture lines.

The successful operations for repair and reconstruction of blood vessels, especially the repair and reconstruction of blood vessels during tumor surgery, must rely on the basic theory and operation technique of the general surgery, rigorous preoperative diagnosis, thorough preoperative preparation, and perioperative management. Good incision exposure and tissue separation, proper selection of the method for vascular reconstruction, complete hemostasis, and necessary anticoagulation therapy are important parts of vascular reconstruction techniques.

Due to the rapid development of the surgical technique, surgical instruments as well as blood vessel transplantation and suture material, after the 1950s, the vascular reconstruction techniques have been widely used and more closely combined with the techniques in other areas of the surgery, especially in the field of the oncological surgery over the past decade, so that the treatments of some diseases in surgical forbidden zones which were once thought to be inoperable achieve breakthrough progress. However, the surgical indications for artificial vessel replacement must be strictly controlled in patients [1].

2 Basic Techniques for Repair and Reconstruction of Blood Vessels

2.1 Surgical Instruments and Suture Material

When the blood vessels are repaired and reconstructed, in order to achieve the desired surgical effects, it is required to use the proprietary surgical instruments in vascular surgical procedures. The vascular tweezers is an important tool in the vascular surgery. It not only can firmly clamp the tissues but also will not damage the tissues. Meanwhile, it can cooperate with the surgical needle to carry out proper operation. The

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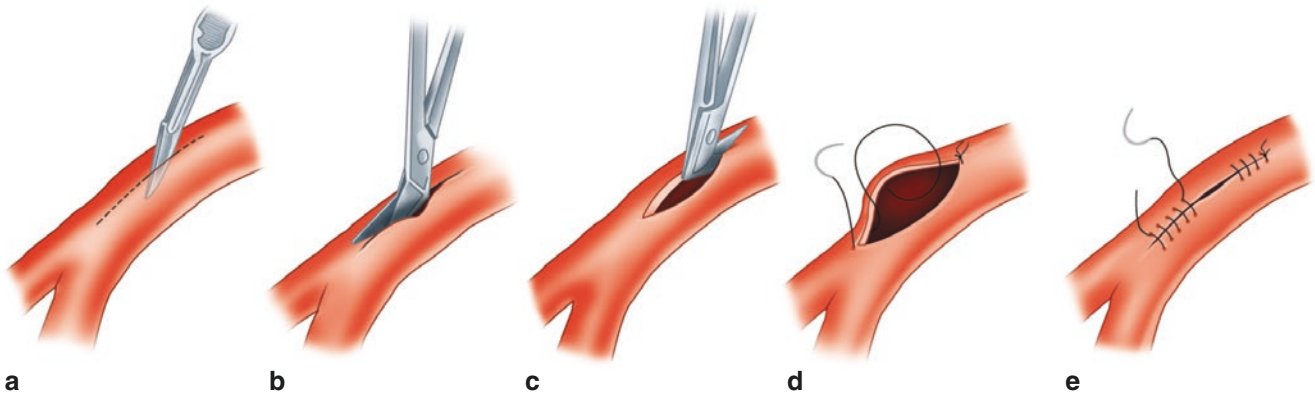

Fig. 21.1 Incision and suture of the blood vessels. (**a**) Incision of vascular wall. (**b**) Incision extension. (**c**) Excision of the lesion. (**d**) Suture start. (**d**) Suture completion

vascular scissors include various types and can successfully separate the perivascular tissues, extend the artery incision, or partially cut open the vascular wall. The vascular occlusion clamp is very important, and it is the main instrument in repair and reconstruction of the blood vessels; it must be safe and reliable to avoid both getting loose and damaging the blood vessels. Due to thinner vascular suture lines, the dedicated vascular needle holder must firmly clamp the tiny needle, without damaging the radian of the needle (Fig. 21.1). The surgical auxiliary instruments of vascular surgery include the endarterectomy devices, such as dissector for endarterectomy, various sizes of balloon catheters, and a variety of noninvasive vascular clamps, such as Bulldog and various vascular shunts.

The vascular suture materials are necessary for repair and reconstruction of the blood vessels, which need to maintain tension for a long time, and the nonabsorbable suture lines should be used. Currently, more commonly used suture lines include polypropylene line (Prolene), nylon line, and various polyethylene (dacron) noninvasive lines. The silk thread should not be used to suture the artificial blood vessels. For different vessels, it is very important to choose the right type of vascular suture line; generally, the 3-0 suture lines are used to suture the thoracic aorta; the 4-0 suture lines are used to suture the abdominal aorta; the 5-0 suture lines are selectively used to suture the iliac artery; the 6-0 suture lines are selectively used to suture the femoral artery and brachial artery; the 7-0 suture lines are selectively used to suture the visceral arteries, lower extremity arteries, and forearm arteries; and the 8-0 to 10-0 suture lines are selectively used to suture the arteries in foots and hands.

The artificial blood vessels are the commonly used method for repair and reconstruction of the blood vessels; the nylon material will be absorbed in the body, and thus it has been eliminated. Currently, more commonly used artificial blood vessels are polyester artificial blood vessels, ePTEF artificial blood vessels.

2.2 The Basic Operations for the Repair and Reconstruction of Blood Vessel

2.2.1 Basic Principles

1. Avoid damages to the vascular intima due to surgical instruments, and the vascular intima which has been damaged must be removed.
2. The vascular adventitia is clearly separated as far as possible; it should be avoided that the vascular adventitia is brought into the vessel lumen.
3. When the vascular intima is exposed, it should be avoided that the vascular intima is dry or has blood or blood clot, and it should be washed cleanly with heparin saline.
4. After the blood vessel is occluded, 0.5 mg/kg unfractionated heparin should be used to achieve partial heparinization and prevent the thrombosis when the blood flow is slow.
5. When the blood vessels are repaired and reconstructed, the vascular intimas must be aligned completely and are sutured with the suture line of proper size and the stitch length, and margin distance should be properly mastered; when there is a tension, the blood vessel transplantation must be carried out to eliminate the tension.

2.2.2 Basic Methods

1. Separation and exposure of the blood vessels. During repair and reconstruction of the blood vessels, the first step is to separate and expose the blood vessels. Under normal conditions, the vessel sheath is exposed firstly, and there is a vascular sheath or arterial sheath constituted by a thin layer of tissue around the blood vessels. The difficulty of separating the blood vessels often depends on whether the sheath is normal. The arterial sheath can be longitudinally incised; the blunt dissections along both sides of the blood vessel are carried out successively; when the rear wall is separated, special attention should be paid to avoid damage to the rear wall

or the branch issued from this site, which leads to uncontrolled bleeding. The performer must not be too hasty, after passing through the rear wall of the blood vessel; the vascular blocking belt is used to penetrate through and is lifted, and the artery sidewall can be separated toward the proximal and distal ends under direct vision.

When the tumor involves the perivascular tissue, due to perivascular fibrosis or tumor wrapping, the blood vessels are often difficult to identify or separate. A few milliliters of normal saline or procaine solution can be injected into the superficial layer of the vascular sheath, which is conducive to the separation of the vascular sheath. If the tissues surrounding the artery have lesions, extensive fibrosis, or significant inflammatory hyperemia, it will be difficult to separate the arterial trunk, and it is easy to damage its branches during the separation.

2. Temporary vascular occlusion. The temporary vascular occlusion includes the transverse vascular occlusion, partial vascular occlusion, and endovascular balloon occlusion. The vascular blocking belt or noninvasive vascular clamp is used to clamp the vascular wall to occlude the artery, the sidewall clamp can partially occlude the artery, and some blood can still flow through the blood vessel. Because there exist no completely noninvasive artery forceps, the medium-sized arteries such as the femoral artery, popliteal artery, and brachial artery can be occluded with the vascular blocking belt or rubber belt, and the large arteries such as the aorta and iliac artery can be occluded with the noninvasive vascular clamp. When the artery is incised or ruptured, the balloon catheter or Foley catheter can be inserted into the bleeding blood vessel, and the balloon is filled to occlude the blood vessels.

   The times of occlusion tolerances of the arteries are different owing to the different tissues and locations: the brain and kidney are most sensitive to hypoxia; the occlusion time of the thoracic aorta should not exceed 15–30 min, unless the sufficient collateral circulation has been originally formed; otherwise, it may cause paralysis; the abdominal aorta under the level of the renal artery cannot be occluded for a long time, because long-term striated muscle ischemia can lead to the serious myonephropathic-metabolic syndrome, thereby forming the myoglobinuria, renal failure, and even lower limb gangrene. In principle, the occlusion times of the main arteries should be minimized to the greatest extent; the internal bypass or external bypass and low temperature measure or extracorporeal circulation are applied if necessary.
3. The dissociation and harvesting of the great saphenous vein. The situation of the involved blood vessels to be repaired and reconstructed should be confirmed; simultaneously, it is required to confirm whether the great saphenous vein has lesions. According to the length of the blood vessel to be reconstructed, the skin incision is made along the running course of the great saphenous vein, and the great saphenous vein of proper length is harvested. When the great saphenous vein is dissociated, the operation must be gentle, even the very thin branches should also be ligated and cut off, and the ligation sites of the branches should have a distance 2–3 mm from the great saphenous vein; in order to avoid that, after the great saphenous vein is transplanted to the artery, the local stenosis is formed due to the expanded blood vessel diameter. After the great saphenous vein is harvested, it is infused slowly with heparin saline or plasma to expand it; if the leakage points are found, the 6-0 noninvasive vascular suture line is used for longitudinal repair. Attention must be paid to the direction of the venous valve during transplantation, or the venous valve is destroyed by the valvulotome.
4. Vascular suture technique. The methods for vascular suture include continuous suture ligation, interrupted suture, interrupted mattress suture, continuous mattress suture, and endovascular suture, and the selection of various anastomosis methods should be determined according to specific situation:
   (1) Direct vascular anastomosis: This surgical method does not require the use of blood vessel transplantation, including vascular incision anastomosis, end-to-end vascular anastomosis, and end-to-side vascular anastomosis. The end-to-end anastomosis of the blood vessels of above average diameter can be performed with annular continuous suture ligation; the end-to-end anastomosis of the small blood vessels can be performed with continuous suture ligation or interrupted suture. The blood vessels of large and medium size can be sutured with 3-0 to 6-0 vascular suture lines; the suture needle distance and margin distance are 2–3 mm, which are determined according to the thickness of the blood vessel wall and the situation of the lesions in blood vessels and surrounding tissue. The small vascular anastomosis must overcome vasospasm, the method of mechanical expansion is preferably adopted, the 6-0 to 9-0 suture lines can be selected, and both the needle distance and margin distance are less than 0.5–1 mm (Figs. 21.1, 21.2, and 21.3). The method for end-to-side anastomosis of the blood vessels is essentially the same method as described above (Fig. 21.4), which is generally applied in blood vessel bypass transplantation; the lateral opening of the front end should be cut into oval incision with about 30° oblique angle; the anterior angle cannot be too sharp. The longitudinal incision in the arterial wall of the trunk end should be greater than its diameter,

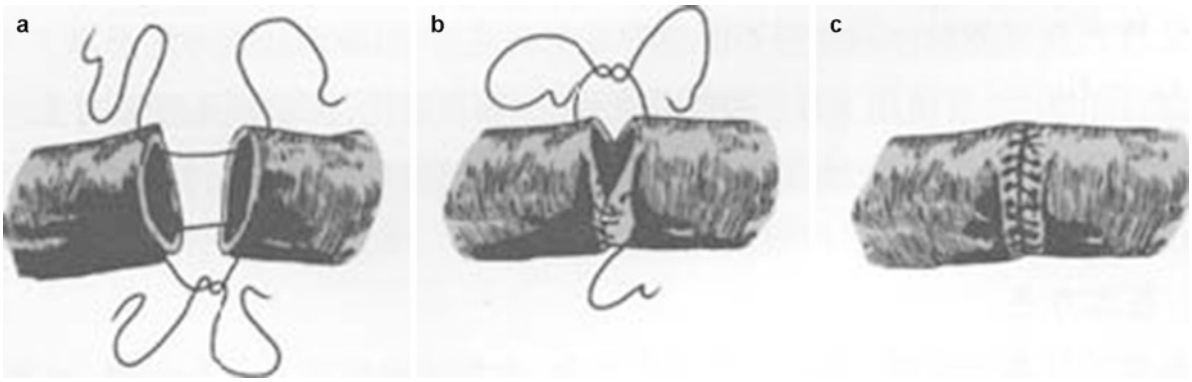

Fig. 21.2 End-to-end vascular anastomosis. (**a**) Anchoring. (**b**) Suturing. (**c**) Completion

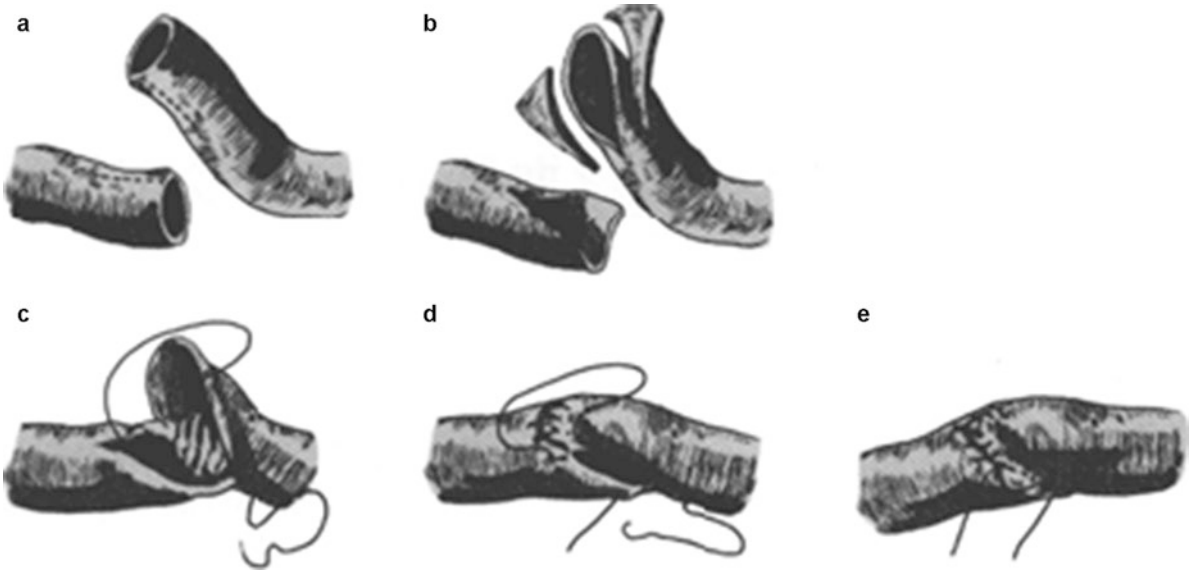

Fig. 21.3 Oblique end-to-end vascular anastomosis. (**a**) Preparation. (**b**) Oblique trimming. (**c**) Anchoring. (**d**) Suturing. (**e**) Completion

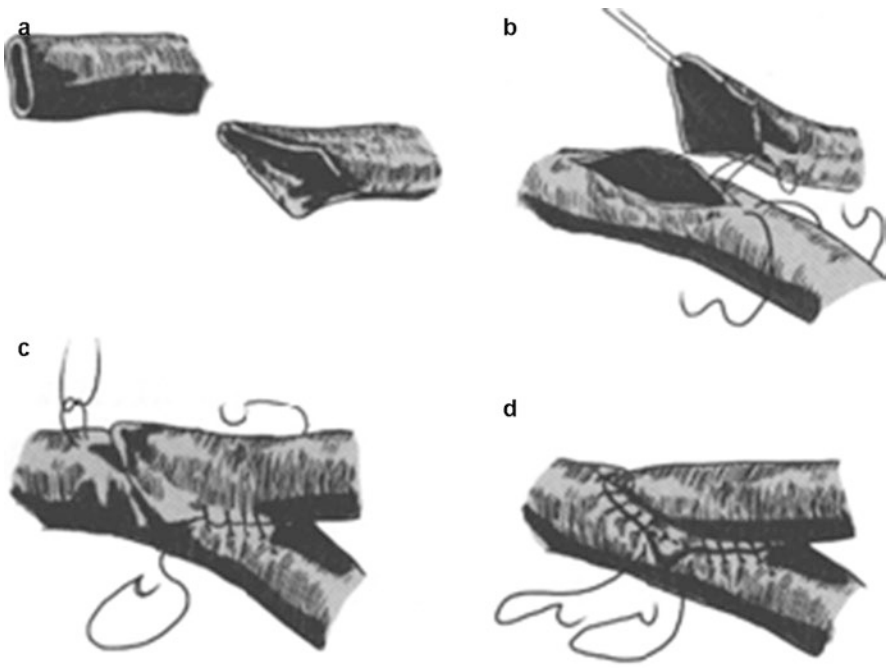

Fig. 21.4 End-to-side vascular anastomosis. (**a**) Preparation. (**b**) Anchoring. (**c**) Suturing. (**d**) Completion

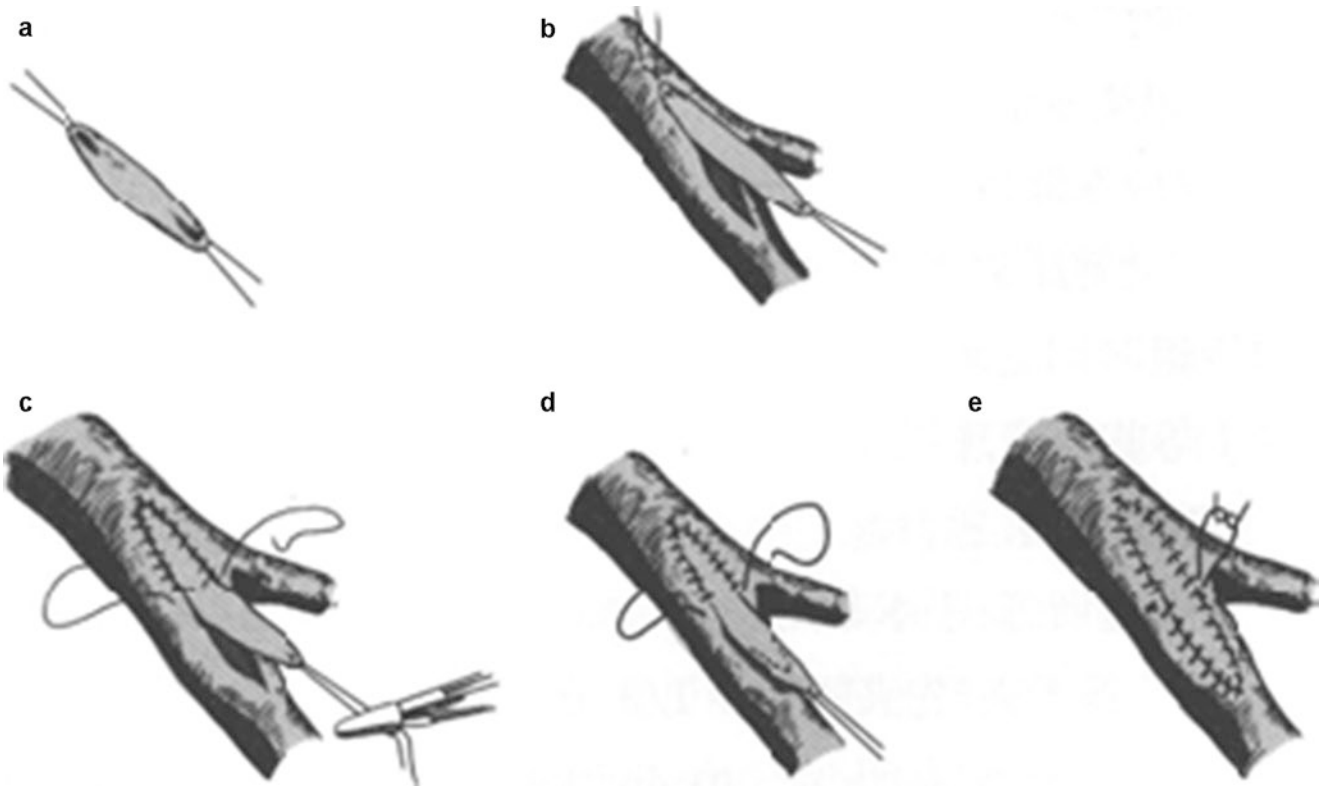

Fig. 21.5 Patch repair of vascular incisions. (**a**) Vascular patch preparation. (**b**) Incision. (**c**) Anchoring. (**d**) Suturing. (**e**) Completion

and the angle for carrying out bypass transplantation with the transplanted blood vessel should be less than 45°, which is more conducive to unobstructed blood flow.

(2) Usage of vascular graft material, including patch repair of vascular incisions (Fig. 21.5), end-to-end anastomosis, or end-to-side anastomosis between the artery and the artificial blood vessel or autologous vein. The patch material selectively used in patch repair of vascular incisions should have a length greater than the length of the arterial incision; after the patch operation is completed, the diameter of the vessel lumen after repair should be basically the same with that of the normal vessel lumen, thus ensuring the normal endovascular blood flow, while avoid forming the aneurysmal dilatation.

3 Clinical Application of Vascular Surgical Techniques

The surgical resection of the tumor involves the different parts of the body, including resections of various tumors in the head and neck, chest, abdominal and retroperitoneal area as well as limbs, and so on and so forth; of which, the surgical treatment of head and neck malignant tumors involving the carotid artery is a very typical part, and the surgery is complex, and the difficulty is greater. This section focuses on the surgical treatment of head and neck tumors involving the major blood vessels to explore the application of vascular surgical techniques in surgical resection of the tumor.

3.1 Application in Head and Neck Oncological Surgery

The head and neck malignant tumors involving carotid artery have always been a thorny problem, which had been a bottleneck limiting the treatment level of the head and neck surgery. The head and neck malignant tumors which have developed into the advanced stage often involve the carotid artery or the internal carotid artery; in order to radically treat the tumor, the treatment of the tumor body and the affected carotid artery has become the key to the treatment. Previously, the tumor is stripped off simply from the arterial wall in clinic, but the safety of the incisal margin is not high, 42% of the results of pathological microscopy show that the artery wall is infiltrated by the tumor, the postoperative local recurrence rate is as high as 50%, and thus the purpose of radically treating the tumor cannot be achieved, and the arterial wall also has the risk of rupture bleeding; if the tumor and the affected carotid artery are ligated and resected, the problems

required to be faced include the neurological complications and a higher mortality (the mortality rate of the patients undergoing emergency ligation is 50%). For this reason, the resection of the tumor body and carotid artery combined with the carotid artery reconstruction can eliminate the bottleneck limiting the improvement of treatment level of the head and neck surgery, and reduce the neurological complications and mortality rates, and increase the chance of patients receiving treatment.

3.1.1 The Resection and Reconstruction of the Carotid Artery

Due to the special nature of the carotid artery, when the tumor involving the carotid artery must be removed, under normal circumstances, it is advocated to carry out one-stage reconstruction. While, when the blood vessels are involved, the carotid artery has been compressed for some time; therefore, it itself has a certain anti-ischemic ability.

The basic method for preoperative assessment of resection and reconstruction: The carotid artery reconstruction often requires temporary occluding of the unilateral carotid artery, while the nonselective carotid artery occlusion can have 30–54% stroke rate. Therefore, the preoperative examination and evaluation of the vascular resistance have great significance for the establishment and decision of the operative plan.

(1) Carotid artery compression test:
   1) Matas test: As early as in 1911, Matas introduced the method that the common carotid artery is compressed externally to detect the tolerance of the carotid artery. The method is that the proximal end of the common carotid artery is compressed daily; the blocking time is gradually increased; when the blocking time reaches more than 30 min every time, there is no occurrence of symptoms of cerebral ischemia such as dizziness, which indicates that the collateral circulation of the brain has been established; the common carotid artery can be resected more safely. This method is simple and easy, but the arterial blood flow cannot be completely blocked through compressing the carotid artery externally using the fingers; the location of compression is inaccurate, the efficacy is poor, and the giant neck tumors and the history of previous surgery and radiotherapy make the local tissue have hard texture and severe adhesion, and thus the test is difficult to carry out. It is reported that Matas test is prone to causing the shedding of the small emboli in carotid plaque and the ischemic brain injury induced by reactive hypotension and bradycardia, and thus it has been rarely used in clinical practice.
   2) In vitro training of carotid artery compression device: The carotid artery compression device developed by Li Shuliang et al. has advantages that the effect in blocking the blood flow is definite and the patient has no pain. During training, the compression time is gradually extended to 30–40 min every time; the condition is qualified if the compression training is carried out for more than 20 consecutive days; there are no clinical manifestations such as dizziness, fainting, nausea, vomiting, and limb numbness, and the blood pressure is constant. However, due to longer compression training, the timing of treatment may be delayed or the good opportunity for surgical treatment may be missed.
   3) In vivo compression training of the carotid artery: Through the surgical exposure of the common carotid artery, Poppen clip is used as the training device for clipping the carotid artery in vivo. The carotid artery in proximal tumor is placed within the clip; firstly, one third of the vascular diameter is clipped and closed, and then the carotid artery is completely occluded within the following 6–7 days. The observational indexes are the same as those of in vivo compression training of the carotid artery. The carotid artery is clipped for 30–40 min every time; the condition is qualified if there are no symptoms of cerebral hypoxia for continuous 24–48 h. The in vivo compression is sustained and gradually increased, the pressure is constant and reliable, and the training time is short, but it requires surgical incision and may have the risk of infection, and its clinical application is subjected to certain limitations. And the vascular clips are exposed outside the skin; after the arterial wall is clipped close, the blood vessel becomes very thin, and it is very easy to be damaged by external forces to cause large bleeding.

   The later both carotid artery compressions also have disadvantages that they are prone to causing the shedding of the small emboli in carotid plaque and the ischemic brain injury induced by reactive hypotension and bradycardia.

(2) Balloon test occlusion: The balloon test occlusion (BTO) is currently the standard method to evaluate the cerebral ischemia tolerance, through intravascular occlusion of carotid artery system (the internal carotid artery or the common carotid artery) for a short time (15–30 min). Without clinical symptoms or signs, the patient can tolerate carotid artery removal or occlusion permanently. Otherwise, the patient must have the reconstruction of the carotid artery. The permanent internal carotid artery occlusion is carried out in three steps: the diagnostic angiography of carotid artery system and vertebral artery system, temporary occlusion of the internal carotid artery, and the permanent occlusion of the internal carotid artery. The diagnostic angiography can be carried out to learn the collateral

circulation situation of the intracranial blood vessels and whether the atherosclerotic lesions or anatomical abnormalities occur concurrently. When the balloon, which is placed at the first and second cervical vertebral levels, is filled fully and the internal carotid artery is completely occluded and is maintained for 15–30 min successfully, the electroencephalogram and the neurological symptoms and signs should be monitored in the process. After the patients can tolerate temporary occlusion, two balloons are placed, respectively, in the carotid siphon to permanently occlude the internal carotid artery, and the angiography is carried out again to determine the location of the balloons, and the postoperative close monitoring should be maintained for at least 12 h.

The complication rate of the balloon test occlusion is similar to that of the conventional intervention operation. The method improves the accuracy of the assessment of the tolerability to the resection of the carotid artery, but 5–20% patients who even have tolerated the method still have cardiovascular complications after the carotid artery is permanently occluded. This may be related to the decreased blood perfusion and slowed blood flow as a result of the carotid artery occlusion. On the basis of this method, the methods such as Doppler ultrasonic measurement of the blood flow velocity of the cerebral artery and cerebral perfusion imaging and the measurement of the carotid reflux pressure are combined, and the comprehensive judgment is conducive to the preoperative evaluation.

(3) Doppler ultrasound study of cerebral blood flow (CBF) velocity: The Doppler ultrasound is used to measure the blood flow velocity of the middle cerebral artery after the common carotid artery, or the internal carotid artery is occluded to learn the compensatory situation of cerebral blood flow after occlusion. It is generally believed that the average flow velocity of the middle cerebral artery (the average value of the systolic and diastolic blood flow velocities) or pulse index (the ratio of the difference between the average value of the systolic and diastolic blood flow velocities to the mean blood flow velocity) is reduced by less than 30%, which indicates good compensation; and if it is reduced by 50–60%, which indicates poor compensation, this is prone to occurrence of neurological complications, and the arterial bypass should be established before they are permanently occluded [2, 3].

Although BTO combined with ultrasonic Doppler method is convenient, this method has large individual differences. The in vitro ultrasonic positioning is imprecise, which has a larger relationship with the experience of the operator. Those measured by this method are hemodynamic parameters, which cannot truly reflect the functional state of the brain cells.

(4) Cerebral blood flow perfusion imaging: The normal cerebral blood flow (CBF) is about 50–55 ml/min per 100 g brain tissue; when the CBF is reduced to as low as 20–30 ml/min, the patient will have neurological symptoms. The brain CBF is less than 30 ml/min during BTO, which is correlated with the incidence rate of cerebrovascular complications; the patients with brain CBF less than this value have cumulative incidence rate of 30% in 1 month and up to 50% in a year after the internal carotid artery is permanently occluded.

1) SPECT cerebral blood flow perfusion imaging: After the radionuclide-labeled drugs which can emit the low-energy γ photons are introduced into the human body, the SPECT imaging can collect the low-energy γ photons emitted from different organs using SPECT probe and carry out the imaging processing. Because the quantity of the labeled drugs entering into brain cells is positively correlated with the local blood flow, the computer technology and physiological mathematical model can be used to calculate the local cerebral blood flow and the average whole-brain blood flow. Because the radionuclide-labeled drugs are combined with the brain tissue for a long time, SPECT examination can be carried out after the balloon is taken out.
2) PET cerebral blood flow perfusion imaging: After the positron-labeled tracers are introduced to the human body, they aggregate into the organs and emit a pair of high-energy γ photons showing an angle of 180° (511 keV) in the process of positron annihilation, which are collected by PET annular probe, and then imaging is developed after computer reconstruction. The commonly used radionuclides include ^{15}O, ^{11}C, ^{13}N, and ^{18}F. When the brain perfusion imaging is carried out, in the same way as SPECT, PET-CT uses the measured results to calculate the cerebral blood flow volume and estimate the state of the brain function according to the data model. Brunberg et al. drew a conclusion from the $[^{15}O]H_2O$PET cerebral blood flow volume measured by BTO in 22 patients with aneurysms: PET can quantize the cerebral blood flow volume and can effectively predict the tolerance to the arterial occlusion, while Chazono et al. [4] drew the opposite conclusion through research. Therefore, a multicenter clinical study is also needed further.

(5) The monitoring of reflux pressure of the internal carotid artery: this method is used to measure the reflux pressure of distal segment of the common carotid artery after occlusion to understand the brain blood supply. Hays set 6.67 kPa (50mraHg) as safe pressure, 73 patients with less than 6.67 kPa underwent surgery after occlusion of the carotid artery under the condition that the bypass surgery was not performed, and 50% of patients had

cerebrovascular complications. According to experiences of McCoy et al., after the common carotid artery is occluded, when the arterial blood pressure is reduced by less than 20%, the common carotid artery can be safely occluded. According to the experience of Ehrnefeld, the systolic blood pressure of the artery stump more than 9.33 kPa (70 mmHg) is the safe pressure; if the systolic blood pressure of the artery stump is lower than 7.33 kPa (55 mmHg), the cerebrovascular complications will occur. Since various hospitals adopt different standards, and the surgical methods are different, currently it is difficult to develop uniform standards.

(6) Monitoring of jugular venous oxygen saturation: The internal jugular vein blood comes directly from the cerebral vein; thus the jugular venous oxygen saturation (SjvO2) is used to replace the cerebral venous oxygen saturation. Under the condition that the SO2 and Hb are stable, SjvO2 can reflect the supply and demand condition of cerebral oxygen, and any factors increasing the cerebral oxygen consumption and (or) reducing the cerebral oxygen supply can lead to reduced SO2. The normal SjvO2 is 54–75%; when it is greater than 75%, it is indicated that the cerebral oxygen supply or the cerebral blood flow volume is increased; when it is less than 50%, it is indicated that the cerebral oxygen supply or the cerebral blood flow volume is relatively reduced, and the demand of cerebral oxygen metabolism cannot be met; if it is less than 40%, there may exist whole-brain ischemia and hypoxia, and the causes should be found and corrected. But the correctness of the measured value of $SjvO_2$ is affected by the following factors:
   1) Either the left or right internal jugular vein blood is not entirely true cerebral venous blood, which is often mixed with 3–7% extracranial blood.
   2) When the blood is collected from the bulb of internal jugular vein, the speed of withdrawing the blood will affect the correctness of the measured value of $SjvO_2$, and thus when the blood is withdrawn, the speed should not be too fast, and 4 ml/min should be appropriate.
   3) The position of internal jugular venous puncture and catheterization is the key to the accuracy of the measured value of SjvO2 [5].

1. Indications: It is used in the treatment of fixed primary cancer, lymph node metastatic cancer, and recurrent cancers which invade the cervical carotid artery.
2. Surgical method: For small carotid artery defects, they can be repaired directly or with the external jugular vein patch or the tongue-shaped flap of the external carotid artery. For a long segment of defect, it is required to use the following surgical methods:
   (1) The repair and reconstruction with coordinated transpositions of internal and external carotid arteries: The initial proximal end of the internal carotid artery is ligated; at the same time, the corresponding part of the external carotid artery is cut off according to the defect length, and then the proximal end of the external carotid artery is sutured with the distal end of the internal carotid artery; the end-to-end anastomosis is performed with 8-0 atraumatic suture lines under microscope.
   (2) Autologous vein transplantation: According to the location of the carotid artery defect and the carotid artery in the defect area, the free autogenous veins can be the external jugular vein, great saphenous vein, and cephalic vein.
   (3) The superficial femoral artery transplantation: The great saphenous vein cannot be used in approximately 20% of the patients for various reasons. Some scholars believe that the superficial femoral artery is superior to the great saphenous vein and has advantages such as high patency rate, high mechanical strength, and strong anti-infection ability. Jacobs et al. [6] used the superficial femoral artery to reconstruct the carotid artery in 11 patients. The superficial femoral artery defects were repaired with Gore-Tex artificial blood vessels, and all 11 cases of surgeries were successful, no cerebral ischemic complications occurred, and one patient underwent angiography at 14 months after surgery, which showed that the transplanted blood vessels were unobstructed.
   (4) Replacement repair with ePTFE unobstructed artificial blood vessel: This repair of repair and reconstruction of the artery with artificial blood vessel has broader clinical indications; the finished artificial blood vessels have different diameters and shapes; the intensity is larger than the arterial wall, the inner wall is smooth, and it is not easy to produce thrombosis within the wall which will lead to surgical failure. All anastomoses are basically end-to-end anastomoses. The disadvantage is the poor resistance to infection.
   (5) Bypass reconstruction of the intracranial and extracranial carotid artery: When the position of the resected carotid artery is too high and near the base of the skull, it can be considered that the bypass is performed at the cervical and petrosum segments of the internal carotid artery [7]. But because the artificial blood vessel in this method is longer and the anastomotic diameters at both ends are different, furthermore, the complex difficulty of the surgery is great and the patency rate is not high; thus, the long-term effect is affected.
3. Surgical methods
   (1) Anesthesia: The cervical plexus anesthesia is preferred. The patient is kept awake, and the conscious reaction after the occlusion of the carotid artery is observed, which provides an important reference for

Fig. 21.6 Surgical treatment of the common carotid artery invaded by mandibular mass (**a**). The mass was adhered to the common carotid artery (**b**). The carotid artery shunt was used to temporarily reestablish the carotid artery blood flow, and the artificial blood vessel was used to reconstruct the common carotid artery (**c**). The artificial blood vessel was used to reconstruct the common carotid artery

the performing or termination of the surgery. But for a wide range of tumor and lymph node dissection, the general anesthesia should be used to avoid the effects of the tension and noncooperation of the patient on the surgery. The general anesthesia can also have advantages such as reducing the brain metabolism, increasing the tolerance of the brain after carotid artery occlusion. The use of ice cap is more conducive to brain protection.

(2) Surgical steps: The reconstruction with cervical ePTFE artificial blood vessel is taken as an example. During surgery, the tumor is separated at first; the proximal and distal ends of the carotid artery without tumor adhesions are dissociated for reconstruction of the carotid artery. The common carotid artery, the subclavian artery, or the axillary artery can be selected as the proximal anastomotic site, while the distal anastomotic site is located in the internal carotid artery. After intravenous heparinization, the carotid artery is temporarily occluded, the carotid stump pressure is measured (greater than 50 mmHg indicates that the carotid artery resection and reconstruction are feasible), the vascular shunt is placed into ePTFE artificial blood vessel of suitable diameter and length, and the vascular shunt is used to establish a bypass passageway at the proximal end of the internal carotid artery and the distal end of the common carotid artery; while the hypothermic anesthesia and the brain cooling are carried out simultaneously, the tumor is completely removed along with the carotid artery. The end-to-end anastomosis between the artificial blood vessel and the autogenous arteria is carried out with 5-0 Prolene line; firstly, the proximal end is anastomosed, and then the distal end is anastomosed. When the anastomosis of the distal end is about to be completed, it is attempted to release the proximal occlusion to discharge out the gas and small emboli within the artificial blood vessel; the vascular shunt is removed, and the anastomosis is completed. The anastomotic stoma is washed with heparin saline from time to time and is kept moist to prevent thrombosis when the anastomosis is carried out. After anastomosis, it is determined that the blood flow can pass through smoothly; the vital signs are stable; the wound is closed layer by layer, if necessary; and the vascular surface is covered with myocutaneous flap (Fig. 21.6).

(3) Key points of intraoperative treatment:

1) Each electrode of the computerized rheoencephalography (CREG) is connected, and the detection is performed according to need at any time during surgery. EEG, transcranial Doppler ultrasound monitoring, and the measurement of the intraoperative reverse flow pressure of the internal carotid artery are reasonable methods.
2) The surgical instruments for harvesting and transplantation of vascular materials and the surgical instruments for tumor resection are used separately, and the intraoperative cross contamination is prevented.
3) During surgery, it should be avoided to enter into the upper digestive and respiratory tracts, because the wound infection and fistula formation may lead to failure of vascular reconstruction, particularly when artificial blood vessels are used.
4) For patients with high-position resection of the internal carotid artery, part of the petrosal bone tissue can be removed, the petrosal segment of the internal carotid artery (C5) is fully exposed, and 1 cm bone wall of the internal carotid artery canal is ground off with a round bur [8].
5) When the internal bypass technology is adopted, there can be sufficient time to carry out the extracranial extended radical surgery and completely remove the tumor and the affected carotid artery.

6) Since the local infection can cause rupture of the carotid artery or anastomotic stoma, the fatal bleeding occurs (generally occurs at about 1 week after surgery); when the carotid artery area is contaminated by oropharyngeal secretions during surgery, it should be avoided to carry out carotid artery reconstruction, and it is inappropriate to use artificial blood vessels.
7) The myocutaneous flap with a good blood supply is used to cover the wound after transplantation, and it can reduce the incidence rate of rupture and thrombosis in the carotid artery. The pectoralis major muscle (myocutaneous) flap can provide enough tissue coverage volume, and, therefore, the pedicled pectoralis major myocutaneous flap should be preferred for repair of neck tissue defect after carotid artery reconstruction.
8) When the occluded blood vessel is opened, the common carotid artery should be properly controlled to prevent the brain hemorrhage due to the impact of the high pressure of blood flow on the tiny intracranial blood vessels. The thrombolytic and cerebrovascular antispasmodic drugs are routinely prepared. Once the extracranial carotid artery thrombosis is confirmed, the most effective method is to carry out the emergency embolectomy, and thereafter the anticoagulation and thrombolysis are routinely carried out [9].

4. Postoperative treatment
   (1) Postoperative conventional treatment: The patient is transferred into ICU; the conventional anti-inflammatory and anticoagulant treatments are carried out after surgery. The patient is placed in the foot-high horizontal position within 48 h after surgery, the continuous CREG or transcranial Doppler monitoring is maintained, the vasodilators are appropriately used, and the timely symptomatic treatments are carried out according to the patient's condition.
   (2) Prevention of postoperative complications:
      1) Incisal tension hematoma: Since the intraoperative anticoagulant drugs are used, and the elderly patients may have liver dysfunction, their bloods are prone to occurrence of a persistent hypocoagulability. Treatment: The volume of drainage within 24 h after surgery is closely observed; if it is equal or greater than 80 ml/h, or the tension hematoma appears within the incision (due to tracheal compression, the asphyxia can occur at any time), the patient should be sent to the operating room emergently to stop bleeding.
      2) Carotid artery thrombosis: The carotid artery thrombosis often occurs within 7 days after surgery, and its causative factors include postoperative hypotension, prothrombotic state, etc., but it is mainly caused by the unskilled surgical operation. After carotid artery thrombosis, the patient will have symptoms and signs of severe brain damage such as irritability, delirium, paralysis, and coma within 15 min. Treatment: If the condition is still mild, the patient will be treated with dehydration, blood volume expansion, and blood pressure improvement, expanding the blood vessel to improve collateral circulation and applications of nutrient drugs for brain cells. The combined use of the hormonotherapy can improve the condition, and the hyperbaric oxygen treatment should be carried out if the condition permits to avoid the occurrence of serious complications [9, 10]; if there is an acute thrombosis and it is not relieved after conservative treatment, or the symptoms are severe, the exploration and embolectomy should be carried out immediately; if the blood flow can be restored within 2 h, the brain damage is reversible. In addition, the changes in cerebral blood flow can often be manifested before the appearance of the symptoms, and the early prevention can be carried out.
      3) Postoperative hypotension: The postoperative hypotension can be caused by the carotid sinus pressure receptor dysfunction; due to the inhibition of the central nervous system and sympathetic activities, the blood pressure is decreased secondarily, and the heart rate slows down. Thereby the carotid sinus is routinely closed.
      4) Pseudoaneurysm formation: It is commonly seen in artery patch angioplasty, and it mostly occurs within 30 days after surgery. The strength of the vein patch is low, the anti-infection abilities of the artificial materials are low, and all can cause rupture of the patch or anastomotic stoma site, and thus the pseudoaneurysm is formed. In cancer patients, the preoperative and postoperative chemoradiotherapies have great influences on the healing of anastomotic stoma; if there is a concurrent infection, the likelihood of pseudoaneurysm formation will be increased. Treatment: The emergency or elective surgery can be carried out according to the disease to the condition.
      5) Carotid artery restenosis after surgery: The vascular restenosis is one of the common long-term complications, and it is related to the surgical techniques, the graft materials, and the endometrial

hyperplasia of the blood vessel itself. Theoretically, it is speculated that the restenosis is inevitable. However, along with the increasingly skilled operation of the performer and the clinical application of methods such as standard anticoagulant therapy and removing blood stasis after surgery, the prevention of vascular restenosis has a bright future.

3.1.2 Carotid Artery Resection Without Vascular Reconstruction

Although the vascular reconstruction after carotid artery resection has become a standard surgical procedure for such type of operation, but in some clinical circumstances, the vascular reconstruction cannot be carried out or is not suitable to be carried out. For example, ① if the resection plane of the distal carotid artery is too high, there is no space for anastomosis; ② if the distal internal carotid artery is too thin, there is no appropriate transplant which is matched to the thicker proximal anastomotic stoma, and the expected patency rate after anastomosis is unsatisfactory; ③ if a series of chemoradiotherapies have been carried out, the vascular bed is not suitable for anastomosis, and serious complications can easily occur after anastomosis; ④ and there is infection or potential infection in the vascular bed. For such patients, through the studies of the recent years, we found that if the correct preoperative training and evaluation are carried out, intraoperative and postoperative treatments are appropriate; it is also relatively safe when the vascular reconstruction is not carried out, and obvious neurological symptoms will not appear. Moreover, the simple carotid artery resection has the following advantages: The surgical method is simple; the operation time is short; there are fewer occurrences of postoperative complications such as thrombosis, infection, or fatal vascular anastomotic rupture; and the postoperative adjuvant therapy can be carried out at an early stage.

1. The feasibility of the carotid artery resection. The cerebrovascular distribution has the anatomical basis of mutual communication on both sides; the internal carotid artery and the vertebral artery constitute the basilar artery ring at the base of the skull, while the external carotid artery communicates with the internal carotid artery via the ophthalmic artery; when the unilateral internal carotid artery is occluded, the abovementioned communicating branch provides blood supply to the affected side. Clinical practice has proved that the slow occlusion of the carotid artery can effectively create enough collateral circulation, but for a few patients who have undergone carotid artery reconstruction, no cerebrovascular complications appear when the transplanted blood vessel is occluded.
2. Patient selection for carotid artery resection. The patients with the following conditions should be strictly selected: the general condition is acceptable, the age is generally less than 65 years, and there is no anemia, no systemic hypotension, no serious atherosclerotic disease, and no history of cerebrovascular disease.
3. Preoperative assessment of carotid artery resection. The preoperative assessment of carotid artery resection is the same as that of the carotid artery reconstruction. The domestic Zhang Xuehui et al. advocate the use of multimode comprehensive evaluation:
   (1) The carotid artery compression training is carried out until the patient has no signs and symptoms such as dizziness, fainting, headache, nausea, vomiting, and limb numbness and has a constant blood pressure, and then the patient is considered to be qualified; after being qualified, the pressurization is carried out continuously during surgery for more than 30 min, and no abnormalities occur.
   (2) After occlusion of the carotid artery blood flow at the affected side, the transcranial Doppler examination shows that the blood flow velocities of the anterior cerebral artery and middle cerebral artery are basically normal, and the anterior and posterior communicating branches are opened well.
   (3) The digital subtraction angiography (DSA) examination shows that the cross filling of the blood vessels of the brain is good, the distributions of main branches of bilateral brain blood flow are basically the same, and the cerebrovascular disease is excluded. In order to more accurately understand the statuses of the collateral circulation establishment and cerebral hemisphere blood supply, in addition to the observation on clinical manifestations (dizziness, fainting, headache, limb dysfunction, etc.), the detection of the blood supply from cerebral collateral circulation with the neck ultrasonography, transcranial Doppler, and DSA is the effective measure for protecting the safety of operation and avoiding the occurrence of the cerebrovascular complications.
4. Surgical methods. The cervical plexus anesthesia is carried out; after the dissection of the carotid artery, the carotid artery is clamped close by Poppen clamp, and the observation is carried out for 30–40 min; when the patient has no discomforts such as headache, nausea, vomiting, and limb numbness, the surgery can only be performed. At the moment, if the surgical resection range is wide and the resection time is long, the general anesthesia can be carried out as a replacement. After complete resection of the tumor, the internal carotid artery is ligated at a position as high as possible to prevent the falling off of the thrombus. The continuous CREG and transcranial Doppler monitoring are carried out during surgery to detect the cerebral blood flow.
5. Postoperative management. It is basically the same as the carotid artery resection and reconstruction.

3.1.3 Problems and Discussion

The tumor involving the great vessels of the neck has been the forbidden area for tumor resection. With the development of vascular surgery and microsurgery, it is now possible to more safely remove the tumor and the carotid artery and reconstruct the carotid artery. Even so, the surgery still has certain complications, and the consequences are serious, which requires us to conduct deeper researches.

(1) In addition to the possible use of autologous blood vessels such as the great saphenous vein, a more suitable artificial material should be found for blood vessel transplantation to ensure the increased long-term patency rate and the reduced incidence rate of neurological complications.
(2) Scientists are exploring the tissue engineering blood vessels, which can be used to carry out the transplantation, improve the histocompatibility and anti-infection ability, and improve the long-term patency rate.
(3) Whether the artificial blood vessel can be designed according to the need of the operation. For the internal carotid artery reconstruction at a high position, the diameter of the carotid artery at the proximal anastomotic stoma is 5–11 mm, and the vertical segment diameter of the intrapetrous internal carotid artery at the distal anastomotic stoma is 4.0–7.5 mm (average 5.7 mm). There is a certain difference between the two, which not only makes the surgery difficult but also affects the hemodynamic changes and affects the long-term patency rate.
(4) Whether a more reliable and safe systematic preoperative evaluation program is found. At the present stage, there are many methods and different standards for preoperative evaluation, which make the surgical selection difficult. Numerous evaluations can affect the patient's body more or less and also delay the early resection of the tumor.
(5) How to carry out the systematic treatment of anticoagulation and removing stagnated blood to ensure the patency of the blood vessel.
(6) For effects of preoperative and postoperative radiotherapy and chemotherapy on the artificial blood vessel and its anastomotic stomas, the hospital where the authors work is carrying out a series of researches focusing on these aspects and has achieved initial results.

3.2 The Application in the Thoracic Oncological Surgery

The surgical operation is still the preferred method for the treatment of thoracic malignant tumors. The lung cancers account for 25–30% of thoracic tumors. Although the radical resection rate of lung cancers has increased to some extent, the early diagnostic rate of lung cancers is still lower, and 45–50% of patients undergoing lung cancer resection are above stage III. The lung cancers invading the superior vena cava and bilateral innominate veins have been the contraindications for the surgery, and the surgical resections of the mediastinal tumors are often abandoned due to the invasions of the superior vena cava and bilateral innominate vein. Spaggiari et al. [11] at abroad used the homograft pericardiac patch, the great saphenous vein, and the artificial blood vessel to replace the superior vena cava, which makes some patients whose superior vena cava and innominate veins are invaded by the tumors get a chance to receive radical surgery, while the postoperative comprehensive treatments also make patients have a good therapeutic effect. Spaggiari et al. carried out a study on the patients whose superior vena cava systems are invaded by lung cancer and lymph node metastases, and they considered that the prognosis of the extended radical tumor resection is better than that of the traditional local tumor resection. Peng Zhongmin et al. in China analyzed the clinical data of 31 lung cancer patients with involvement of the superior vena cava and undergoing surgical treatment; the methods such as the superior vena cava resection with artificial blood vessel replacement, the side wall resection of homograft pericardiac patch for repair, and direct suture are used to treat the superior vena cava after resection, and there is no operative mortality. When the lung cancer involves the superior vena cava, if the patient has a better general condition and can tolerate the surgery, and the tumor or lymph node metastasis is relatively limited, the surgical treatment can be considered. The pulmonary angioplasty was firstly used in the treatment of the lung cancer by the Berkley in 1968; it is used in conjunction with the bronchoplasty, which greatly improves the surgical resection rate of medium and advanced lung cancer and reduces the ratio of the pneumonectomy to the palliative surgery, so that both the survival rate and the qualities of life of the patients have been significantly improved. Currently at home and abroad, most applications of pulmonary angioplasty for lung cancer are limited to the wedge resection and sleeve resection with end-to-end anastomosis. Xiangning et al. in China used the azygos vein or autologous pericardium to manufacture the blood vessel to replace pulmonary angioplasty, and the short-term and long-term effects were good. The combined use of pulmonary angioplasty and bronchoplasty better reflects the treatment principle of the oncological microinvasive surgery such as "maximizing the tumor resection and maximizing the retention of normal tissue."

3.3 The Application in Abdominal Oncological Surgery

The traditional views show that the abdominal malignant tumors invading the inferior vena cava and abdominal aorta and its important branches are classified as the surgical contraindications. With the improvement of surgical skills and the application of vascular surgical techniques, especially the

widespread use of artificial blood vessels, the patients with abdominal malignant tumors invading major blood vessels and no distant metastasis who can tolerate surgery can be treated by radical tumor resection combined with vascular resection and reconstruction. Pawlik et al. [12] at abroad have proven that the patients with liver cancers invading the portal venous trunk or hepatic vein trunk or accompanied with inferior vena cava tumor thrombosis can be treated with embolectomy or partial vascular resection and repair. Zuo Zhaohui et al. also proposed the treatment methods for the primary liver cancer with portal vein tumor thrombus, namely, the tumor embolus in portal vein branch could be taken out (discharge method, suction method, and clamping method) via the hepatic cross section, and the main portal vein could be incised to take out the tumor embolus, and the liver cancer resection plus the removal of portal venous tumor embolus had a better curative effect than the simple surgical resection of liver cancer. Hemming et al. reported that the surgical treatment of the liver cancer involving the inferior vena cava surgery could prolong the survival time of the patient. Peng Shuyou et al. also reported the results of the study on the inferior vena cava reconstruction combined with hepatic resection for liver cancer; the methods for inferior vena cava reconstruction included suture in situ, patch repair, end-to-end vascular anastomosis, and blood vessel transplantation. The surgical resection of liver cancer directly invading the inferior vena cava is more complicated and difficult; the application of various liver surgeries to carry out inferior vena cava reconstruction combined with anatomical hepatectomy can effectively guarantee the safe implementation of the surgery to improve the radical cure rate and reduce postoperative complications and prolong the survival time of the patient.

In the recent years, the incidence rate of pancreatic cancer showed an increasing trend. When the pancreatic cancers are found and definitely diagnosed, most of them have already had local invasion and (or) distant metastasis, and the surgical resection remains the only potentially curative treatment for pancreatic cancer. The fact that the pancreatic cancer has invaded the adjacent blood vessels often becomes one of the important factors that hinder the implementation of effective radical surgery by the surgeon. The pancreatic cancers which can't be resected due to the involvement of the portal vein or superior mesenteric vein account for 30–40%. The preoperative imaging examinations suggest that the false-positive rate for the invasion of the portal vein or superior mesenteric vein is higher, and CT cannot distinguish between tumor invasion and inflammatory adhesion. The pancreatic cancer invasion of the surrounding blood vessels is not necessarily accompanied by widespread retroperitoneal invasion and metastasis. Therefore, the relationship between the portal vein or superior mesenteric vein and the cancer foci needs to be determined in the surgical exploration [13]. With the wide use of vascular surgical techniques and vascular materials, the pancreatic cancer with the invasion of the portal vein and (or) the superior mesenteric vein should not be taken as an absolute contraindication for radical resection of pancreatic head cancer, and patients should be persuaded to actively undergo radical resection to improve the pancreatic cancer effect. Peng Chenghong et al. considered that the indications for carrying out radical resection of pancreatic head cancer combined with the resection of invaded blood vessels include:

1. The systemic condition of the patient permits, and there is no abdominal ascites.
2. There is no peritoneal scattered planting of pancreatic cancers, and there are no hepatic and other distant metastases.
3. The patient can withstand the economic pressure and require urgent surgery and fully understand all kinds of unexpected and unpredictable consequences that may occur.
4. There are skilled professional surgeons.
5. It is estimated that the patients can survive and live a high-quality life for nearly a year or more than 1 year after tumor resection.
6. The local tumor spreads directly to the portal vein and (or) the superior mesenteric vein; the invasion length of portal vein and superior mesenteric vein is less than 4 cm, and the length of the trunk of the superior mesenteric vein at intestinal side which is available for dissociation is equal or greater than 1 cm.
7. There is no extensive involvement of the common hepatic artery, celiac artery, and superior mesenteric artery.

Howard et al. abroad [14] also believe that if the pancreatic cancer invades the portal vein and superior mesenteric vein, the active surgical treatment can prolong the life of the patient, ease the suffering of the patient, and improve the quality of life of the patient.

The retroperitoneal tumors mainly come from fat, loose connective tissue, fascia, muscles, nerves, lymph tissue, and residual embryonic tissue in the retroperitoneal space, the various organs which have been originally located in the retroperitoneal space are not included, and there are no obvious symptoms at the early stage; when many patients visit the hospital, the tumors have invaded the adjacent organs or major blood vessels. Because there are concerns about the treatment of the important blood vessels, the previous views suggest that once the retroperitoneal tumor invades the major blood vessels, it will be considered as a surgical contraindication, but with the progress of vascular surgical examination techniques and surgical techniques, for the patients with retroperitoneal tumors which invade the major blood vessels and have no distant metastasis, and current views suggest that tumor resection with vascular reconstruction can be carried out. Li Huili et al. considered that the tumor should be dissected and dissociated during surgery according to the principle of giving priority to the easy, after blood flow

occlusion, the tumor together with the blood vessels is resected en bloc, and then the vascular reconstruction is performed. Under the premise that the unobstructed blood flow will not be affected, the site where vascular wall is removed can be directly repaired; otherwise, the patch angioplasty should be carried out. After resection of the short blood vessel, the end-to-end anastomosis can be performed under the condition of the absence of tension or else the blood vessel transplantation should be carried out. When it is required to simultaneously remove the adjacent organs invaded by the tumor, the surgical procedure should be that the tumor and the organs to be removed should be completely dissociated after the occlusion of the blood vessels, and the blood vessels are finally removed. The vascular reconstruction is carried out at first, and then the organ reconstruction is carried out; the organ ischemia and congestion time is reduced to the largest extent. When both the arteries and veins need to be reconstructed, generally the veins are reconstructed firstly, and the arteries are reconstructed secondarily. The rupture hemorrhage of the presacral venous plexus is the most serious complication of radical resection of rectal cancer, and the mortality rate is very high. The presacral venous plexus is the vertebral venous system with the lack of valves. At present, the commonly used hemostasis methods include compression hemostasis, hemostasis by pressing of the stainless steel nail, bilateral internal iliac artery ligation, and suture under direct vision. Feaza et al. use the free muscle sheet plus gelatin sponge for compression and suture it with the surrounding tissue, or take a piece of the rectus abdominis muscle, use the vascular clamp to clamp, and compress the hemorrhagic spots; the effect of electrocoagulation on the vascular clamp leads to the appearance of the "boiling" phenomenon in the muscle blocks and bleeding veins, and the coagulation and adhesion are used to stop bleeding. During the radical resection of rectal cancer, the correct operation according to the presacral anatomical layers is the key to preventing the intraoperative presacral venous plexus hemorrhage.

The kidney cancer tends to invade the renal vein and inferior vena cava. Along with the progress of imaging techniques such as angiography, the widespread use of vascular reconstruction and the popularization of artificial blood vessels, the vascular resection, and reconstruction combined with radical nephrectomy can prolong the survival time and improve the quality of life of the patient [15]. Smaldone et al. reported that the kidney cancer patients with postoperative recurrence and invasion of the inferior vena cava were treated with partial inferior vena cava resection and repair (Fig. 21.7), and a satisfactory curative effect was achieved. In short, the kidney cancer invading the renal hilum and

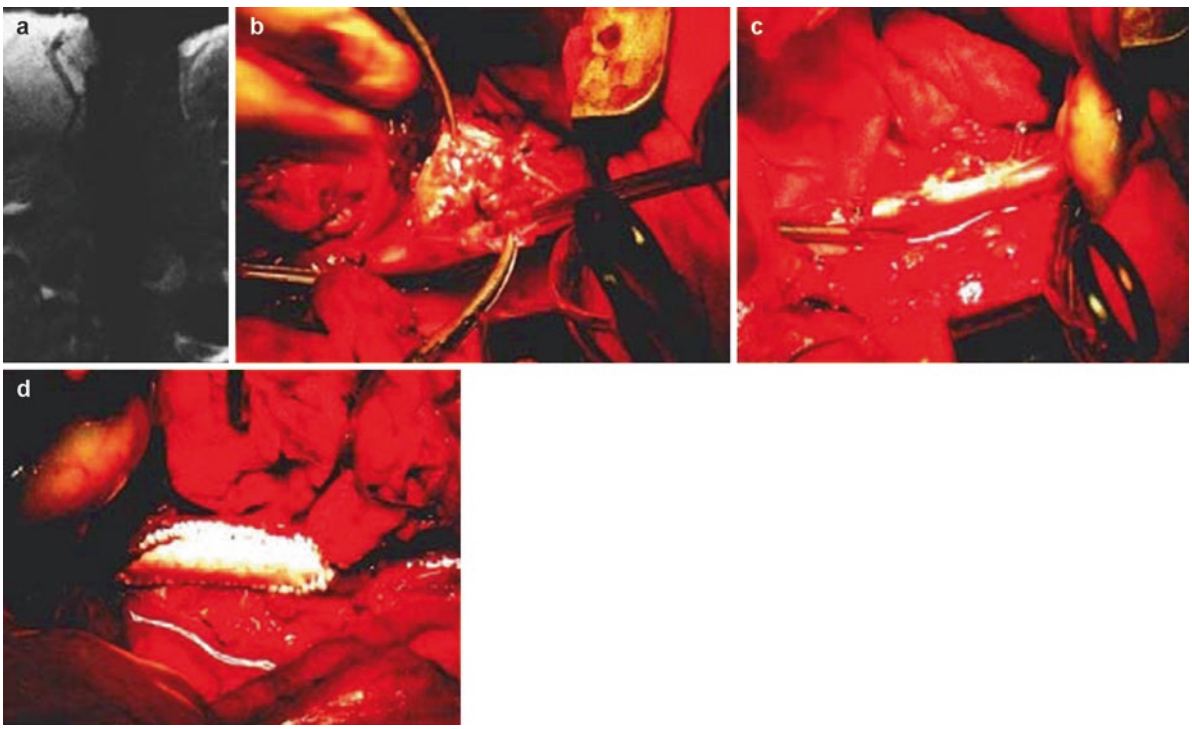

Fig. 21.7 The resection of the kidney tumor invading the inferior vena cava + reconstruction of the inferior vena cava (**a**). The angiography showed the filling defect within the inferior vena cava (**b**). After resection of the kidney tumor, the affected segment of inferior vena cava was separated and occluded, the inferior vena cava was incised, and it was observed that the vascular lumen was filled by the tumor tissue (**c**). The tumor and the affected segment of inferior vena cava were completely removed (**d**). The appropriate artificial blood vessel patch was selected, and the inferior vena cava was repaired and reconstructed

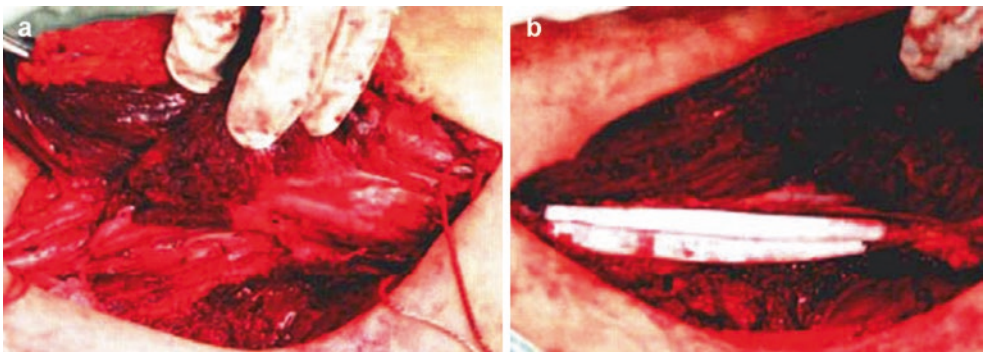

Fig. 21.8 The surgical resection of the thigh tumor involving the superficial femoral artery and vein + the vascular reconstruction with the artificial blood vessel (**a**). Exposure of the mass, superficial femoral artery, and superficial femoral vein surgery (**b**). The mass was surgically resected, and the affected segment of blood vessel was reconstructed with the artificial blood vessel

inferior vena cava cannot be easily defined as a surgical contraindication, and the surgeon should actively strive for radical resection to improve the curative effect.

3.4 The Application in the Oncological Surgery of the Trunk and Limbs

The bone malignant tumors have strong biological behaviors, and the malignant tumors in the trunk and limbs tend to invade the surrounding major blood vessels (Fig. 21.8); the vascular resection and reconstruction have an important significance for the treatment of the bone tumors and can improve the qualities of life and survival rate of the patients [16].

4 Effects of Perioperative Radiotherapy and Chemotherapy on Vascular Grafts

The radiotherapy and antitumor drugs against the malignant tumors often have significant effects and toxic or side effects on various systems, organs, and tissues of the body, and, therefore, they will have more incidental pathophysiological effects in the process of killing cancer cells, including their effects on the vascular grafts in surgical treatment of tumors.

4.1 The Effect of the Radiotherapy on Vascular Grafts

The radiotherapy includes two types of external radiotherapy and intracavitary radiotherapy; it is reported mostly that they lead to arterial damage and distal stenosis. The pathophysiological mechanisms which have been studied generally include the following types: ① the fibrous degeneration which is caused by repair response after arterial wall damage, ② the fibrous degeneration which is caused by the injury of the nourishing blood vessel of the major artery, ③ the fibroblasts and increased intimal collagen content, ④ and the atherosclerotic change caused by radiation.

After vascular bypass surgery or endovascular stent implantation, the intimal hyperplasia is the most important reason leading to vascular restenosis, thus affecting the long-term effects. The radiotherapy can cause the irreversible damage to cellular DNA of the body, leading to apoptosis and thereby inhibiting the intimal hyperplasia. Clinical studies have demonstrated that for patients with coronary artery surgery, the radiotherapy can significantly inhibit vascular stenosis in the short term, but long-term efficacy remains to be further studied. However, the irradiation can lead to vascular damage and malignant tumor at the same time, which should be noted in clinical application.

In terms of animal experiments, it has been confirmed that the close intracavitary irradiation can effectively inhibit the intimal hyperplasia secondary to vascular injury after balloon dilatation. Oh et al. further confirmed that the external exposure has a dose-dependent effect on the arterial intimal hyperplasia through the animal models of vascular injury after rat carotid endarterectomy.

There are fewer researches on the effect of the X-ray irradiation on the intima of the artificial vascular graft. Hoffman et al. carried out a retrospective research on the patients with severe lower limb ischemia who underwent bypass surgery with ePTFE artificial vessel under the groin and the anastomotic stoma. Within 24 h after surgery, the patients were irradiated at vascular anastomosis site, and its 1.5 cm side area. The irradiation dose was 20.4Gy, implemented 12 times within 2.5 weeks. The results showed that the probability of restenosis of the artificial blood vessel in patients receiving radiation therapy was significantly lower than expected, and the irradiation dose was safe and feasible, and there were no other side effects.

The hospital where the authors work has carried out a series of studies on perioperative radiotherapy [17–20]; the findings show that the fraction radiotherapy with a daily dose of 7Gy for the abdominal aorta after eFTFE artificial vessel implantment is carried out for 5 consecutive days,

which will lead to the crisp tissues surrounding the artificial blood vessel and the aggravated inflammatory response and can simultaneously inhibit the growth rate of the intima of the artificial blood vessel but cannot increase the risks of anastomotic rupture of the anastomosed blood vessel, anastomotic false aneurysm formation, and the artificial vascular infection. Experiments have confirmed that perioperative radiotherapy can have some effects on the patency rate of the transplanted inferior vena cava, but there is no statistically significant difference in the results compared with the control group.

In addition, the radiotherapy can also cause skin ulceration and cause damage to the autologous blood vessels in the corresponding area, thus leading to blood vessel rupture or pseudoaneurysm formation; therefore, the dosage and usage method of the radiotherapy and related issues such as safety assessment also need further research.

4.2 The Effect of Chemotherapy on Vascular Grafts

The antitumor drugs generally have strong toxic and side effects and have varying degrees of influence on the whole body system during their uses. The thrombotic occlusion vasculitis and phlebitis are more common complications of the chemotherapy, and arterial wall damage is relatively rare.

Due to its own characteristics of the malignant tumor, the blood tends to be in a hypercoagulable state and even a prothrombotic state, and there is a higher risk of occurrence of thrombotic diseases, which occur mainly in the venous system with a lower blood flow velocity, including lower extremity deep venous thrombosis and pulmonary artery embolism; in addition, the vena cava and the portal vein are the more frequently affected sites. Studies have shown that the chance of occurrence of venous thrombotic diseases in patients with malignant disease is four times that in the general population, and the chemotherapy can make the probability of malignant tumor patients suffering from thrombotic diseases increased more than six times that in the general population. Because the chemotherapy drugs are mostly alkaloid preparations or cytotoxic agents, they have a strong corrosive and irritating effects on the blood vessels, especially the long-term repeated perfusion of chemotherapy drugs that can easily lead to chemical phlebitis; if treated improperly, it can also lead to drug extravasation and trigger the tissue swelling surrounding the veins and pain and local tissue necrosis, and the debridement and skin graft treatment are required in severe cases.

There are still less studies of antitumor drugs on the arterial system, which can reduce the elasticity of the arterial system, cause the intimal injury, and thus lead to fibrosis and has an increased risk of platelet adhesion and thrombosis. In a study, 15 rats were infused with cisplatin (150 mg/m2 body surface area) through the iliac artery; another five rats were infused with normal saline, and they were taken as controls; 5 days later, the ipsilateral femoral artery was cut off and microsurgically anastomosed. At 5 days after surgery, the blood flow of the target vascular anastomotic stoma was observed with flow Doppler ultrasound, and the rat was sacrificed, and the results showed that there were no differences in arterial blood flow, pulse strength, and patency rate between groups, but there were a large number of inflammatory cell infiltrations in specimens of the chemotherapeutical group, and there was a significant difference compared with the control group. The hospital where the authors work carried out a study on the combined postoperative chemotherapy with fluorouracil and cisplatin in animal models undergoing artificial blood vessel replacement [21], and the study results showed that the chemotherapy regimen could promote the mural thrombus formation in artificial vascular grafts in animal models, but in the short term (at l2 weeks after surgery), the graft patency rate of artificial blood vessels was not being affected, and the probabilities of occurrences of infection, anastomotic leakage, and pseudoaneurysm formation in the vascular grafts were also not increased. Meanwhile the chemotherapy regimen had no significant effects on the intimal thickness of artificial vascular graft and the expression of PCNA.

However, the tumor classification is complex, and there are a wide variety of anticancer drugs; it is required to study the effects of all kinds of anticancer drugs on blood vascular system after tumor surgery, especially after carrying out repair and reconstruction of the blood vessels during surgery, and more detailed researches are needed.

With the continuous development of oncological surgery and vascular surgical techniques, the application of the technology of repair and reconstruction of the blood vessels in tumor surgery will become increasingly common. Before practice, the patient's condition must be analyzed detailedly; the methods for repair and reconstruction of the blood vessels must be seriously studied, understood, and grasped to learn to meet practical needs. The continued development and promotion of vascular surgical techniques and new vascular substitute materials broaden the scope of clinical application of oncological surgery and its research field and promote the overall development of the discipline at the same time.

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Tissue Engineering and Oncological Surgery

22

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The repair and functional reconstruction of tissue and organ defects after tumor resection are a major difficult problem currently faced by the oncological surgery. Except that some defects with a small area don't require special treatment, all defects with a large area require to be repaired with the transplantation of autologous or allogeneic tissues and organs. The autologous transplantation has the disadvantage that the wound repair causes a new wound, and the allogeneic transplantation has some disadvantages that the donor source is insufficient and there is the immunological rejection. For a long time, people have been dreaming that the body's tissues and organs can be produced on a large scale in the factory just like the machine parts; once the body's tissues and organs have problems, they can be replaced with new parts. The proposition, establishment, and development of tissue engineering provide the possibility to achieve this dream; a small amount of seed cells after in vitro amplification are compounded with biological materials to construct new tissues or organs, which are used to replace and repair the affected and defected tissues and organs and recover the physiological functions [1].

1 Overview

1.1 The Concept and Principles of Tissue Engineering

The tissue engineering research began in the early 1980s; in 1987, the tissue engineering was officially named and defined by National Science Foundation as follows: applying the principle and technology of life science and engineering, on the basis of correct understanding of the relationship between tissue structures and functions of mammals under two states such as normal and pathological states, the tissue engineering is the discipline that researches and develops the biological substitutes which are used to repair, maintain, and promote the functions and morphologies of a variety of tissues or organs after injuries. Its basic principle is that a sufficient amount of seed cells with specific biological activities which are obtained through in vitro culture and amplification are combined with appropriate biodegradable three-dimensional biological scaffold materials to construct the organs and tissues conforming to the normal physiological structure and function through specific construction techniques, which are used to repair or replace the impaired tissue and organs, thus achieving the purpose of defect repair and functional reconstruction (Fig. 22.1).

1.2 The Research Background of Tissue Engineering

The tissue and organ defects and dysfunction caused by a variety of diseases and trauma are one of the important causes for harmed human health; therefore, millions of patients around the world require surgery every year. Currently, the surgical repairs mainly adopt the following three modes:

1.2.1 Autologous Tissue Transplantation

As the most important repair method in more than a century, the autologous tissue transplantation has saved the lives of many patients; but in this method, the autologous healthy tissue with an appropriate size and even a larger range must be harvested, which causes new artificial damage and is called the repair mode "robbing Peter to pay Paul." And because the donor tissue is limited, especially for some special cases (such as large area of trauma and unique organ defects), sometimes the corresponding autologous donor tissue simply cannot be obtained.

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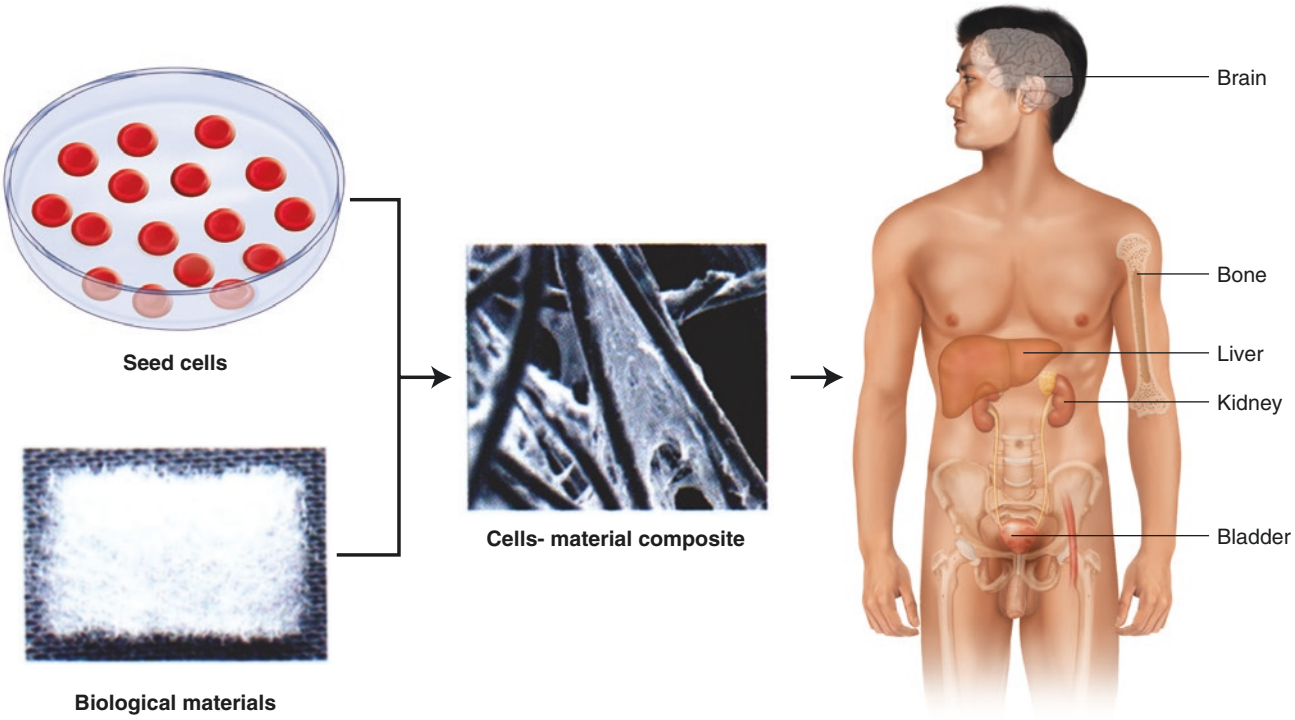

Fig. 22.1 Schematic diagram of the basic principle of tissue engineering

1.2.2 Allogeneic or Xenogeneic Tissue Transplantation

Although this repair method will not cause additional trauma to the body of the patient, the source of the donor is limited and tissue typing is difficult. Therefore, it is very difficult to obtain tissues or organs with exactly matched histocompatibility antigens, and more than half of the patients die when waiting for a transplant every year according to statistics. In addition, the long-term and wide application of immunosuppressive agents after transplantation will not only lead to serious complications, but the high medical cost also brings a heavy financial burden on the patients.

1.2.3 Artificial Substitute Materials

The artificial materials have achieved a good clinical effect in the repair of certain tissue (such as bone tissue) defects, but because they don't have biological functions, it is difficult to achieve real sense of clinical repair. As society progresses, people's requirements for quality of life continue to increase; to explore a repairing technique which causes a small wound and can also well recover the morphologies and functions of the tissues and organs has become one of the important research directions in reconstructive surgery; the tissue engineering technology is produced in such a background.

1.3 The Development Trend of Tissue Engineering

From the early 1980s, when Joseph P. Vacanti, the surgeon from Harvard University, and Robert Langer, the chemical engineer from Massachusetts Institute of Technology, commonly conceived of the feasibility that the cells were grown in biodegradable material to try tissue regeneration until now, the tissue engineering has experienced three stages of development. The first stage started from the late 1980s to the early 1990s; the preliminary explorations of the feasibility of tissue-engineered tissue construction were carried out; one of the most representative researches was that in 1991 Vacanti et al. used the bovine articular chondrocytes and biodegradable materials to successfully construct a mature hyaline cartilage under the skin of the nude mouse; this study demonstrated that the tissue engineering technology can be used to construct the mature tissue with morphological and structural features close to those of normal ones. The second stage started from the mid-1990s. Various types of tissue-engineered tissues (such as bone, cartilage, and tendons) were mainly constructed within the bodies of nude mice with immune deficiency, of which the successful construction of a cartilage with the precise shape of an auricle within the body of a nude mouse by Professor Cao Yili was taken as the main

mark. In the third stage of development of tissue engineering research, the researches focus on tissue construction, defect repair, and functional reconstruction within the bodies of mammal with intact immunologic functions, and the achievements of tissue engineering research are gradually promoted in clinical applications, and this is the current hot topic of the tissue engineering researches at home and abroad.

In recent years, the tissue engineering research has made some breakthrough progresses in many aspects. A variety of tissues with relatively simple structures have achieved success in defect repair models of higher mammals, some research results have been applied to clinical practice, and some researches on organs with relatively complex structures and compositions have also made significant progresses. Several kinds of tissue-engineered skin products developed by multiple global companies have been used in the clinical treatment of skin defects. With the advantages in the aspect of animal experiments, China has achieved the international leading position in the field of tissue construction. At present, the large animal studies on constructions and defect repairs of tissues such as the bone, cartilage, tendon, and skin have been completed, and the clinical applications of tissue-engineered bone and skin have been initially launched and have received good and stable curative effects. This not only confirms the feasibility of clinical application of tissue engineering technology but also demonstrates the broad application prospects of the tissue engineering.

2 Technological Factors of Tissue Engineering

The implementation of the tissue and organ reconstruction inevitably involves three essential factors such as seed cells, biological materials, and tissue construction, which are the core contents of the tissue engineering research. Only a sufficient quantity of seed cells with specific biological activity are obtained, and they are combined with the appropriate biological scaffold material. It is possible to reconstruct the tissues and organs with normal physiological structures and functions through specific construction techniques. In recent years, the tissue engineering research has achieved rapid development; it is reflected not only in the continuous deepening of research contents and continuous improvement of research means but also in the constantly extended and expanded traditional concepts of the tissue engineering as well as the multidisciplinary cross infiltration.

2.1 Seed Cells

The seed cells are the basis for the tissue construction. As the seed cells for tissue engineering, the cells must meet the following conditions: (1) the cells have a wide range of sources and are easily obtained with a sufficient quantity; (2) they have strong in vitro proliferation abilities, and the large-scale amplification can be carried out; and (3) they have specific biological functions.

The original conceiving of the tissue engineering is to take a small piece of homologous normal tissue to obtain a large number of target cells through the method of in vitro culture and amplification. But the results of many previous studies indicate that in vitro amplification of mature cells is difficult; the cells under culture conditions age quickly and lose the proliferation abilities and thus are unable to meet the requirement for tissue construction. For example, in the construction of cartilage tissue, most cells contained in the harvested cartilage tissue are mature chondrocytes; after digestion and culture, the cells after four or five generations of passage culture will be aging, the cell proliferation ability is decreased, and ultimately the enough amount of cells cannot be obtained to construct a cartilage tissue which is greater than the volume of the original cartilage. As we all know, the normal tissue has a physical ability of self-renewal and repair, and studies have confirmed that the main component participating in the renewal and repair are the tissue-specific stem cells. For example, the blood cell renewal is mainly participated by hematopoietic stem cells, the skin epithelial cell renewal is participated by the epidermal stem cells, and intestinal epithelial cell renewal is participated by the intestinal gland stem cells; even in some tissues with slow cell renewal, such as nerve tissue, the existence of tissue-specific stem cells is also confirmed. In recent years, due to the rapid development of stem cell research, a variety of tissue-specific stem cells have been found and successfully separated and cultured, which develops a new source for the seed cells for tissue engineering.

In general, the stem cells can be divided into embryonic stem cells and adult stem cells (namely, the tissue-specific stem cells) according to the different differentiation stages. The adult stem cells not only have certain abilities of in vitro amplification and differentiating into specific cells but also have the advantages of the autologous materials, thus avoiding the problem of immune rejection, and they have become the current research focus on seed cells for tissue engineering research. At present, the technologies including separation, culture, amplification, and induced differentiation of a variety of adult stem cells such as bone marrow stromal stem cells, adipose stem cells, epidermal stem cells, hair follicle stem cells, and limbal stem cells have been initially established. The bone marrow stromal stem cells come from the mesenchymal stem cells in the bone marrow, and they are involved in the bone metabolism and hematopoietic supporting functions under the physiological state. Some studies confirm that the bone marrow stromal stem cells can be differentiated into bone, cartilage, and fat cells under different

conditions for induced differentiation; the cells after induced differentiation can be compounded with the biodegradable materials and then are implanted into the body to form the bone, cartilage, and fat tissue, respectively. The bone marrow stromal stem cells after induced differentiation and in vitro amplification not only have successfully repaired the defects of tissues such as bone and cartilage within the animal body but also have achieved stable and reliable curative effects in clinical application. The adipose stem cells are the mesenchymal stem cells present in the adipose tissue; they have the cell phenotypes which are mostly the same as those of bone marrow stromal stem cells; meanwhile, they have the abilities to differentiate into bone, cartilage, and fat cells; and in vivo experiments confirm that they can also be used as seed cells participating in repair of bone and cartilage defects. The epidermal stem cells are the stem cells present in the epidermal tissue, and they participate in the renewal and repair of epidermal cells. The tissue-engineered skin tissue constructed with the epidermal stem cells has been used to repair the skin defects in clinic. The hair follicle stem cells can repair the skin defects and can also participate in reconstruction of skin appendages such as the hair, sebaceous glands, and sweat glands. The limbal stem cells are the progenitor cells of the corneal epithelial cells and are distributed in the margin of the normal cornea, and they participate in the renewal and repair of the corneal epithelial cells under the physiological state. The tissue-engineered corneal epithelium constructed with limbal epithelial cells can repair the corneal epithelial defect in animal experiments. The successful separation and cultivation of various different tissue-specific stem cells create the conditions for reconstruction of a variety of tissues and organs.

However, at this stage, the method using tissue engineering technology to repair defects is to use autogenous tissue stem cells, which is a completely individualized treatment means. From the perspective of the long-term development trend of tissue engineering, realizing the large-scale treatment is the development direction of the tissue engineering. How to develop from the individualized treatment to the large-scale treatment and realize the industrialization of the tissue engineering technology has raised a higher requirement to the seed cells. The development of the allogeneic stem cells and the seed cells of general type will be the main research direction of seed cells for tissue engineering. Some successful applications of allogeneic stem cells, such as the successful use of the allogeneic bone marrow stem cells to repair tissue defects, suggest the feasibility of allogeneic stem cell applications. The embryonic stem cells have become the most promising new seed cells because of their unlimited proliferation and totipotent differentiation capabilities. The embryonic stem cells are derived from the inner cell mass of the early blastocysts, can be amplified unlimitedly under appropriate culture conditions in vitro, and thus maintain an undifferentiated state; after the removal of the factors inhibiting cell differentiation, the embryonic stem cells can spontaneously differentiate to three germ layer cells. When the cells are injected into the mice with immune dysfunction, the teratoma comprising three germ layer cells can be formed, which demonstrates that the embryonic stem cells have the ability to differentiate into all somatic cells. Currently, there have been many reports on human embryonic stem cell lines, especially the successful clone of the human embryonic stem cell lines making it possible to establish individualized embryonic stem cell lines. And if the parthenogenesis technology can be used to successfully establish the homologous diploid embryonic stem cell bank of general type, it will make the tissue matching become simple and convenient just like the blood matching; it will completely solve the problem of seed cell source for tissue engineering and lay a foundation for the industrialization of tissue engineering.

In the process of tissue engineering material preparation, if the tissues are difficult to be drawn materials from or have only a small amount of stem cells, selecting and developing the homologous cells as the sources of seed cells is alternative to researching stem cell. For example, in the tendon tissue construction, the number of tendon cells is small, the amplification ability is poor, and there are no reports on successful separation of tendon stem cells. At this time, the homologous skin fibroblasts which are developed and obtained easily with a strong amplification ability can be used to replace the tendon cells to successfully repair the tendon defects in the animals. In the urothelium construction, the replacement of the urethral transitional epithelium with epidermal stem cells can successfully repair the urethral defects. The successes of these studies suggest the feasibility of application of developed homologous cells and find a new way for the source of seed cells.

2.2 Biological Scaffold Materials

The biological material is another core of the tissue engineering research. It is the three-dimensional scaffold the seed cells must rely on for survival and attachment prior to forming into tissues and provide spaces for physiological activities such as cell proliferation, differentiation, nutritional exchange, metabolism, and extracellular matrix secretion. The tissue-engineered biological materials, in addition to requiring the characteristics of general biological materials such as no toxicity, no adverse reactions, adequate sources, stable nature, easy storage, and easy disinfection, also must meet the following basic requirements:

1. The biological materials with good biocompatibility and tissue compatibility should be conducive to cell adhesion and proliferation, have no toxic effects on cells and no significant immunogenicity for the body, and do not cause inflammatory reactions.

2. The biological materials with biodegradability can be completely degraded within the organism, and the degradation products have no toxic effects on the organism. Furthermore, the degradation rate is controllable, and the different tissues require the scaffold materials with different degradation rates. Because only the degradation rate of the biological materials is consistent with the tissue formation rate, the space can be provided timely and accurately for extracellular matrix deposition and tissue regeneration, and the guided tissue regeneration can be carried out to achieve precise shape.
3. The biological materials have certain plasticity and mechanical strength to be pre-shaped and can be maintained to a certain size and shape to meet the operability of tissue transplantation and reconstructive surgery.
4. The biological materials have a certain porosity and pore diameters of appropriate size; it is generally required that the porosity is above 90%; the pore diameters should be uniform, and according to different seed cells, the pore diameter should be controlled generally between 150 and 450 μm, so as to ensure that the cells are evenly distributed into the surface and the inside of the scaffold materials.

There are a wide variety of tissue-engineered biological materials. The tissue-engineered biological materials are generally divided into two categories of natural materials and synthetic materials based on their origins, and both have their own advantages and disadvantages. The natural materials such as collagen, chitosan, coral, and acellular matrix have good cellular affinities and tissue compatibilities, but the properties are unstable. There are big differences in pore diameter, porosity, degradation rate, and mechanical strength among the same natural materials of different species and individual sources, and it is more difficult to form a standardized product. The artificial synthetic material, such as polylactic acid (PLA), polyglycolic acid (PGA), and their composite (PLA-PGA), has uniform and stable properties and good plasticity and reproducibility and can form into the standardized products, but both their cellular affinity and tissue compatibility are poor, and their implantation into the body can cause severe inflammation reaction. The organic combination of synthetic materials and natural materials can play the effect of learning from others' strong points to offset one's weakness, which has become a new development trend of tissue engineering materials in the future.

These mentioned above are only the most basic requirements for tissue engineering materials. For the material researches, in addition to developing new materials, carrying out the material surface modification processing to improve the cellular affinity, and using different manufacturing processes to produce the scaffold structures with different spatial structure, destination, and microstructure, the more important thing is to study the relationships between materials and cells and the effects of the researched materials on the tissue formation and their mechanisms. Because different tissues have different compositions and spatial structures which assume different physiological functions within the body, there are different requirements for the materials; only the relationship between the materials and the tissues is to be clarified; the tissue-specific scaffold materials with a certain biological activity which really meet the requirements of tissue engineering can be developed. For example, in the construction of the tissue-engineered bone, the spatial structure, pore diameter, and porosity of the material must conform to the normal bone structure, while the material should have a certain osteoinductive effect and can induce differentiation of bone marrow stromal cells and promote the formation of bone tissue; in addition, the degradation of the material must match the speed of new bone formation; both too fast and too slow degradations are not conducive to the formation of bone tissue; it is required that the formation of new blood vessels can also be promoted in the process of osteogenesis. As for the cartilage tissue construction, the bone marrow stromal stem cells are taken as seed cells; in the same way, the materials must have the chondrogenic inducibility and can promote the differentiation of bone marrow stromal stem cells into chondrocytes, while the structure of the material should be in accordance with the structural characteristics and can promote secretion of cartilage matrix in cells and inhibit the neovascularization. At present, although some biological materials which are suitable for construction of tissues such as the bone, cartilage, and skin have been developed, there is a considerable gap from the requirements of perfect tissue engineering materials.

In addition to the participation of materials scientists and cytologists in materials researches, the participation of the experts in other fields of computers and engineering further promotes the development of tissue engineering materials. For example, the invention of the three-dimensional printing technology, the computer technology will be used to record the three-dimensional structural analysis of the tissue defects, then the tissue engineering material which is matched exactly with the three-dimensional structure of the defected tissue and has the required pore diameter and porosity is produced through the 3D material printer, so that the effect of repair of tissue defect is more perfect. With the application of various new technologies, the creation of standardized, tissue-specific, and morphological structure-specific tissue engineering materials with specific biological activities will no longer be a dream.

2.3 Tissue Construction

When there are appropriate seed cells and biological scaffold materials, how to further implement the tissue construction is the key to repairing the defects with tissue engineering technology and is also the basis for the realization of tissue

engineering industrialization. According to different cultivation environments of constructed tissues, the tissue construction technology can be divided into two categories of construction in vivo and construction in vitro.

Methods of tissue construction in vivo:

1. After cultivated and amplified massively in vitro, the cells are mixed with the biological material, and then are implanted directly into the body.
2. After cultivated and amplified massively in vitro, the cells are seeded on the biological scaffold material. After being cultured in vitro for a short time, the cells and biological materials are completely adhered to each other, and then they are implanted into the body. By this time, the mature tissue has not yet been formed. Along with gradual biodegradation and absorption of biological materials by the body, the cells continue to differentiate into mature cells, secrete specific extracellular matrix, and, finally, form a tissue with specific function gradually within the body.

The advantages of in vivo tissue construction include easy operation, short in vitro culture period, no need for specific culture apparatus and culture environment, and complete dependence on the in vivo environment to promote tissue regeneration and maturation. Its main disadvantages are that it is difficult to observe the process of tissue formation, it is affected by the individual differences and the local microenvironments in the implantation sites, the difference in efficacy of the tissue regeneration is bigger, and the construction result is instable. According to different in vivo implantation sites, the in vivo tissue construction can be divided into ectopic tissue construction and in situ tissue construction. The ectopic tissue construction is to implant the tissue engineering material into non-original and specific physiological sites such as subcutaneous or muscle tissue, and the in situ tissue construction is to implant the cell–biomaterial composite into the corresponding tissue defect site; the defects are repaired along with the formation of the new tissue. Because the local tissue microenvironment directly affects the cell differentiation and the tissue regeneration and maturation, the in situ tissue construction is the main direction of research of in vivo tissue construction. However, the in situ tissue construction does not apply to all patients, especially for some patients with serious tissue defects and damaged or completely absent local tissue microenvironment; the method of in vitro tissue construction must be used to achieve tissue regeneration.

The general process of in vitro tissue construction is that a large number of seed cells cultivated and amplified in vitro are seeded on the corresponding scaffold materials; after in vitro culture for a long time, the biological materials are gradually degraded, and the cells differentiate and secrete specific extracellular matrix and finally form a mature tissue with morphological structure and function, and then they are implanted into the body to repair the corresponding tissue defect. The advantage of this method is that the process of tissue formation is carried out in vitro, which is convenient for observation and evaluation; the analysis on relevant influence factors is easy; the construction effect can be controlled. But the in vitro culture technology has a high requirement for culture environment, and the formation and maturation of different tissues require different microenvironments. The key of in vitro tissue construction is to simulate the in vivo microenvironment of the tissue as far as possible, and the in vivo microenvironment is a complicated synthesis, in addition to factors such as growth factors secreted by various cells, extracellular matrix, cell–cell interactions, and acid–base balance, and the local physical stimulations (including light, air contact, and mechanics) are also an important factor. Studies have shown that the growth and functioning of different types of cells require different stimuli; for example, the shear force has a direct relationship with the growth and maturation of vascular endothelial cells, while the cyclical expansion mechanical stimulation can accelerate the formation of vascular smooth muscle. The development and application of bioreactors have played an important role in the in vitro construction of tissue-engineered tissue. The bioreactor not only provides the necessary nutrients and growth factors for proliferation and differentiation of cells but also provides appropriate physics stimulation for tissue formation and maturation. Different bioreactors have been developed for construction of different tissues, and a variety of different tissue-engineered tissues such as the skin, tendons, and cartilage have been successfully constructed in vitro, but currently there is still a lack of in-depth research on physical stimulation parameters of the tissue construction, and the in vitro constructed tissue has not yet fully achieved the function of the normal tissue. With the optimization and improvement of various bioreactors, the in vitro culture conditions which conform further to the physiological state will be created to further improve the effect of in vitro tissue construction, make it closer to normal tissue structure, and play a normal physiological function.

The in vivo and in vitro constructions have their own advantages and disadvantages. Different construction methods can be chosen for different patients. For tissue engineering industrialization, the tissue-engineered finished or semifinished tissue products can also be produced to meet the needs of different patients.

3 Application of Tissue-Engineered Tissues

The ultimate goal of tissue engineering is to use the constructed tissue to repair the defects within the body; the breakthrough progresses have been made in repairs of the tissues such as the bone, cartilage, skin, tendons, and corneas [2, 3]. Not only the feasibility of tissue engineering is confirmed within the bodies of immunodeficient animals represented by nude mice, but also the tissue engineering achieves successes within the bodies of the large mammals with intact immune functions; what is even more gratifying is that some tissue-engineered tissues have obtained the good curative effects in the preliminary clinical application, which fully demonstrates the enormous potential of this technology in future medical application. The following section describes the construction and application of several tissues with relatively more mature technology.

3.1 Bone Tissue Engineering

At present, the bone tissue is one of tissues with the fastest tissue engineering research and development and is one of the tissue-engineered tissues closest to clinical application. On the basis of successful repair of bone defects in higher mammals, we have conducted a number of small-scale clinical trials in repair surgeries after resection of bone tissue tumors such as bone cyst (Fig. 22.2).

The seed cells for bone tissue engineering can be derived from the periosteum, cancellous bone, bone marrow, and other ectosteal tissues, of which the bone marrow-derived mesenchymal stem cells have a wide source, less trauma during drawing materials, fast proliferation, and strong osteogenic ability and have become the first choice of seed cells for bone tissue engineering. The separation, cultivation, and amplification techniques of bone marrow stromal stem cells have been more mature; there are also relatively more researches on

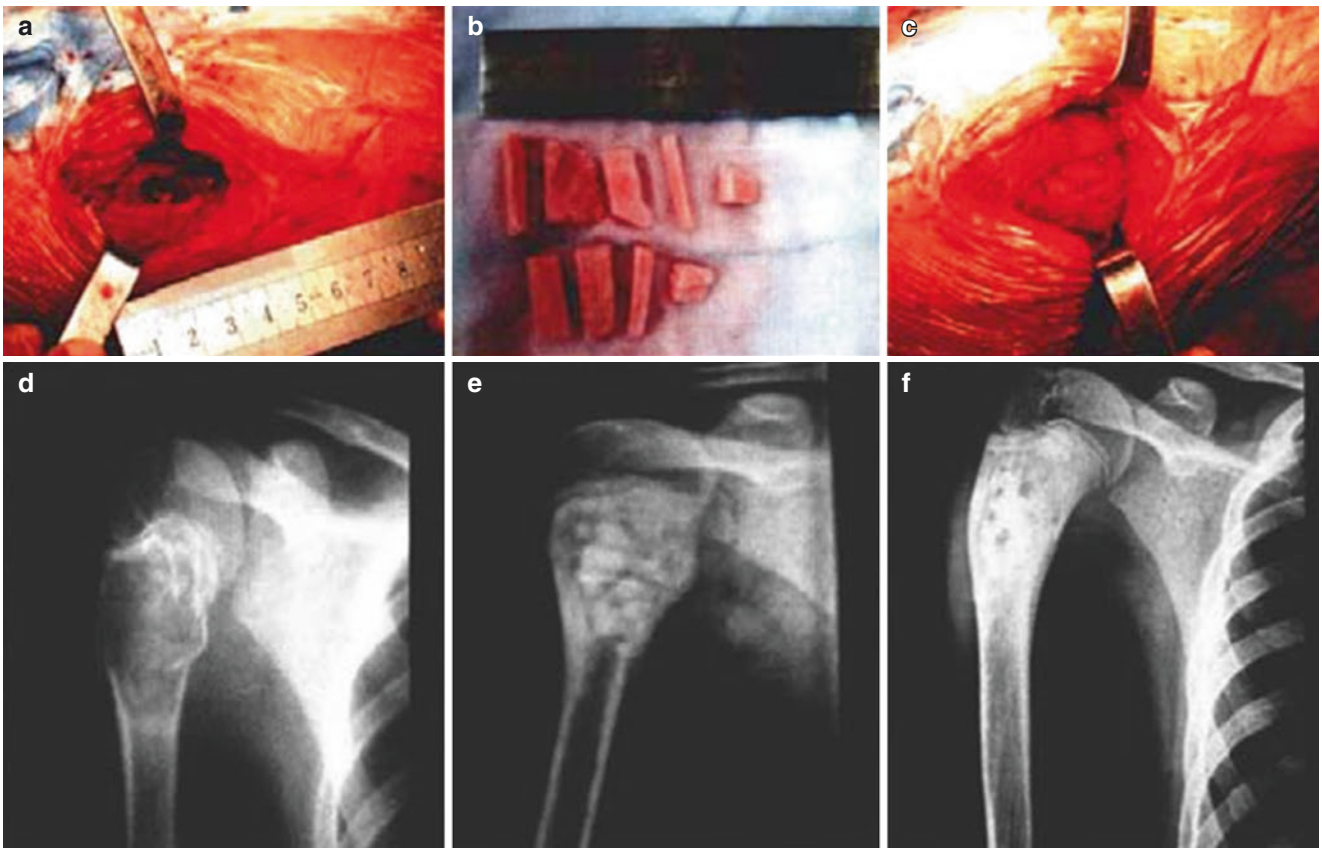

Fig. 22.2 Repair of the bone defect after resection of humerus cyst with tissue engineering technology. (**a**) The bone defect after resection of humerus cyst. (**b**) The constructed engineered bone tissues. (**c**) The engineered bone tissues were filled into the defect site. (**d**) The preoperative x-ray film. (**e**, **f**) The x-ray films at 3 and 10 months after surgery showed that the bone defect was repaired

osteogenesis differentiation, and the researches are also quite thorough. Usually if a certain amount of vitamin C, dexamethasone, and β-glycerophosphate are administered, the osteogenic induction effect can be achieved; in addition, the factors such as bone morphogenetic protein (BMP) and/or vitamin D3 can be added to strengthen the induction effect.

One of the main functions of the bones in the human body is load bearing; for this functional characteristic, in addition to that, the bone tissue engineering scaffold materials should meet the requirements of general scaffold material; more importantly, the bone tissue engineering scaffold materials should have a certain degree of mechanical strength and osteoinductive and osteoconductive capacities. The currently used bone scaffold materials can be roughly divided into a few categories such as biology, biological ceramics, polymers, and composite, and each category of biological materials have their own advantages and disadvantages. The biological materials mainly refer to allogeneic bone and heterogeneous bone, and they have obvious advantages in pore structure, composition, and biodegradability, but the main disadvantage is the poor mechanical properties. The more commonly used biological ceramics include tricalcium phosphate, hydroxyapatite, bioactive glass, and biphasic calcium phosphate ceramic. These materials have good biocompatibility and are conducive to histiocyte ingrowth and material metabolism. The main disadvantages are that the flexibility is poor, the quality is brittle and fragile, and the degradation rate does not match the rate of bone formation. The polymer materials include synthetic polymers (such as polylactic acid and polyglycolic acid) and natural polymers (such as collagen, fibrous protein, and alginate). The former have a poor hydrophilicity and a weak cellular affinity and may cause aseptic inflammation; the latter lack mechanical strength, and the degradation time is difficult to control. The composite materials are a variety of composites consisting of the abovementioned several kinds of materials, such as collagen–coral composite and tricalcium phosphate–hydroxyapatite composite. The recombination of different materials can improve the deficiency of a single material to a certain extent and make the best of the both worlds; for example, the natural materials are used to modify the synthetic materials to enhance the cellular affinity and the flexibility of the material, and the materials with different degradation rates are combined together to regulate the degradation rate and the mechanical strength of the materials. In addition, the choice of materials is also considered according to factors such as location, size, shape, and mechanical requirements of the bone defects; for example, the skull defect is often repaired with demineralized bone matrix or tricalcium phosphate, the alveolar bone defect is often repaired with calcium alginate, and the femoral defect is often repaired with coral.

Currently, the construction technologies of the bone tissue engineering mainly include the in situ construction, and the cell material composite is implanted into local defect site; it is formed into the new bone tissue through the induction, differentiation, and reconstruction of in vivo microenvironment, in order to achieve the purpose of repairing the defect. Additionally, the in vitro construction technology using the bioreactor may also be employed. Since the effective dispersal distance of the nutrient substance and oxygen of the static culture method is only about 200 μm, and therefore it is impossible to construct the large tissue block in vitro for clinical transplantation, the bioreactor can be used to overcome this deficiency and construct a larger volume of tissue-engineered bone. The bioreactors currently available for bone tissue engineering applications mainly include perfusion bioreactor, agitated bioreactor, and rotating wall vessel bioreactor, but these bioreactors have various problems such as uneven mixing and too large tangential force; therefore, we have developed a biaxial bioreactor which can carry out biaxial rotating simultaneously and play the role of perfusion. Our system study has found that the bioreactor can be used to construct larger tissue-engineered bone (2 cm or more). Furthermore, its construction effect is far superior to those of the static culture technology and the above three traditional bioreactors; concrete manifestations are that the cells grow faster, the three-dimensional distribution of cells is more uniform, and the osteogenic differentiation is better (Fig. 22.3). It provides a very good tool for in vitro construction of the tissue-engineered bone.

We have used the bone marrow stromal stem cells and bone tissue engineering materials to successfully repair the defects in non-load-bearing bones such as the dog skull and also repair the defects in load-bearing bones such as the dog mandible and sheep femur. More significantly, a small amount of autologous bone marrow of the patient is extracted. After in vitro amplification, the bone marrow stromal stem cells are compounded with bone tissue engineering scaffold material; they have been used to successfully repair various bone defects in the skull, alveolar bone, and limbs caused by congenital factor, trauma, and tumor resection in more than 50 patients; the long-term follow-up showed that the curative effect is stable. These achievements fully demonstrated broad prospect of clinical applications of the tissue-engineered bone [4]. The abovementioned projects have been assessed and approved by Hospital Ethics Committee.

Furthermore, in addition to the use of autologous cells for individualized treatment with bone tissue engineering technology, the bone tissue engineering technology is expected to be one of the tissue engineering technologies which use the allogeneic cells to carry out common treatment at the earliest, and because the bone tissue repair process is a process of creeping substitution, the exogenous cells can be replaced by autologous cells in the process of bone remodeling. We have successfully used allogeneic cells to repair the mandible segmental bone defect model of the dog, compared with the autologous cells for bone tissue engineering technology; its repair effect has no significant difference (Fig. 22.4), and the use of allogeneic cells have not caused long-term immune response (Fig. 22.5). In the

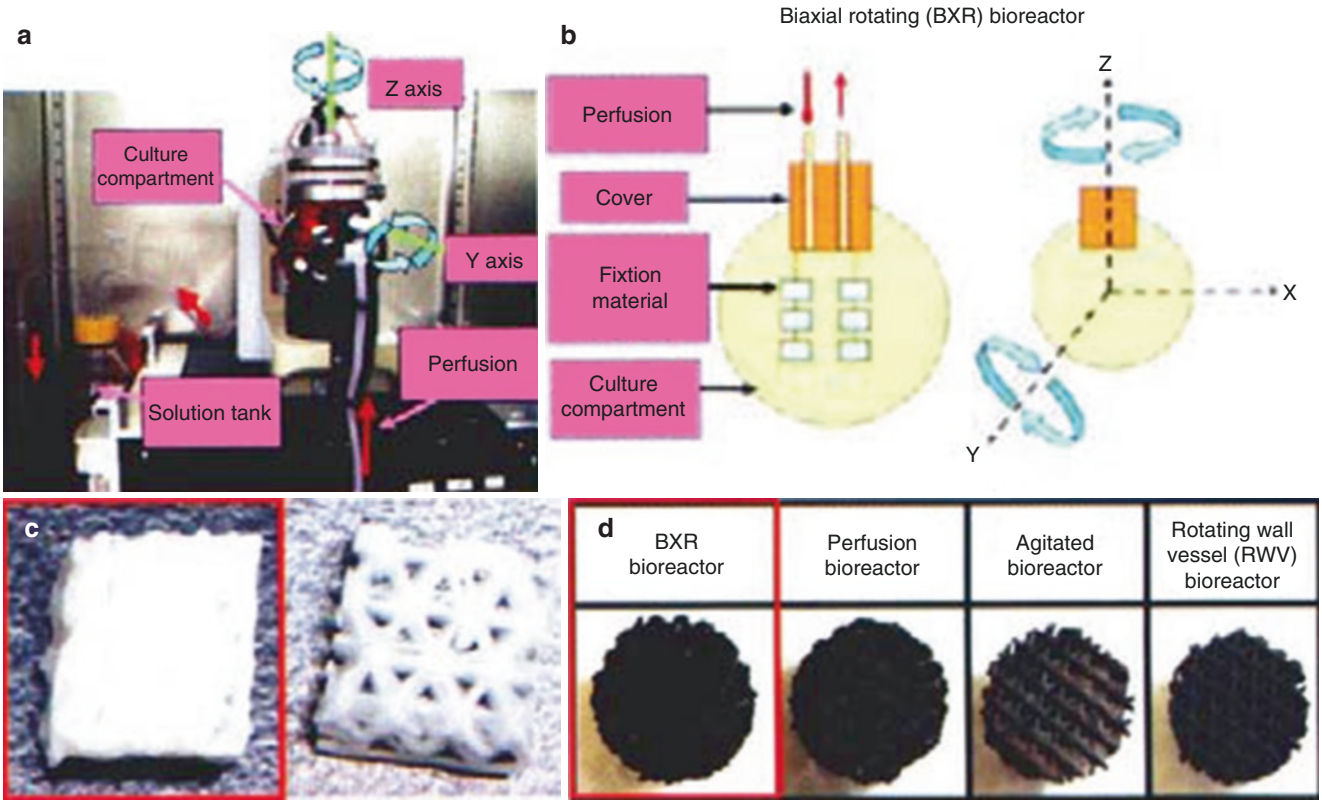

Fig. 22.3 Structure of biaxial bioreactor for in vitro construction of tissue-engineered bone. (**a**) Compared to static culture. (**b**) Compared to traditional culture reactor. (**c**) Comparison between biaxial bioreactor and static culture. (**d**) Von Kossa staining

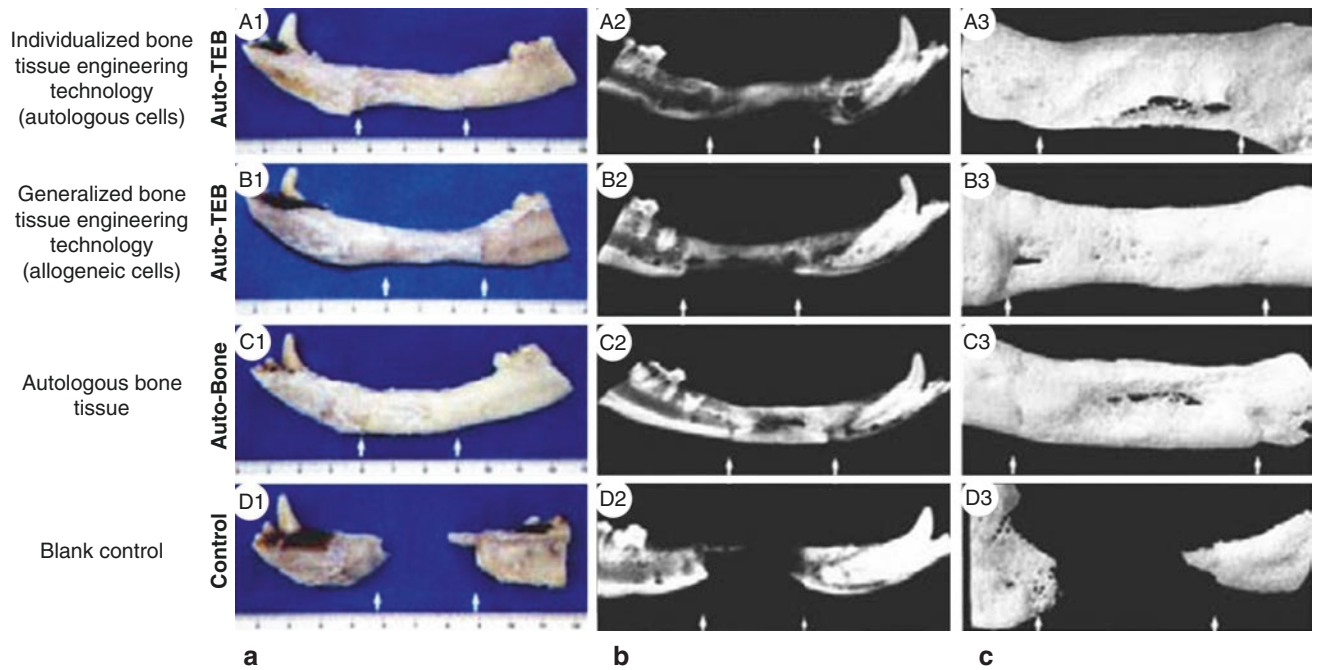

Fig. 22.4 Repair effect of bone defects with the generalized bone tissue engineering technology. (**a**) Overall appearance. (**b**) X-ray detection. (**c**) Microscopic CT detection

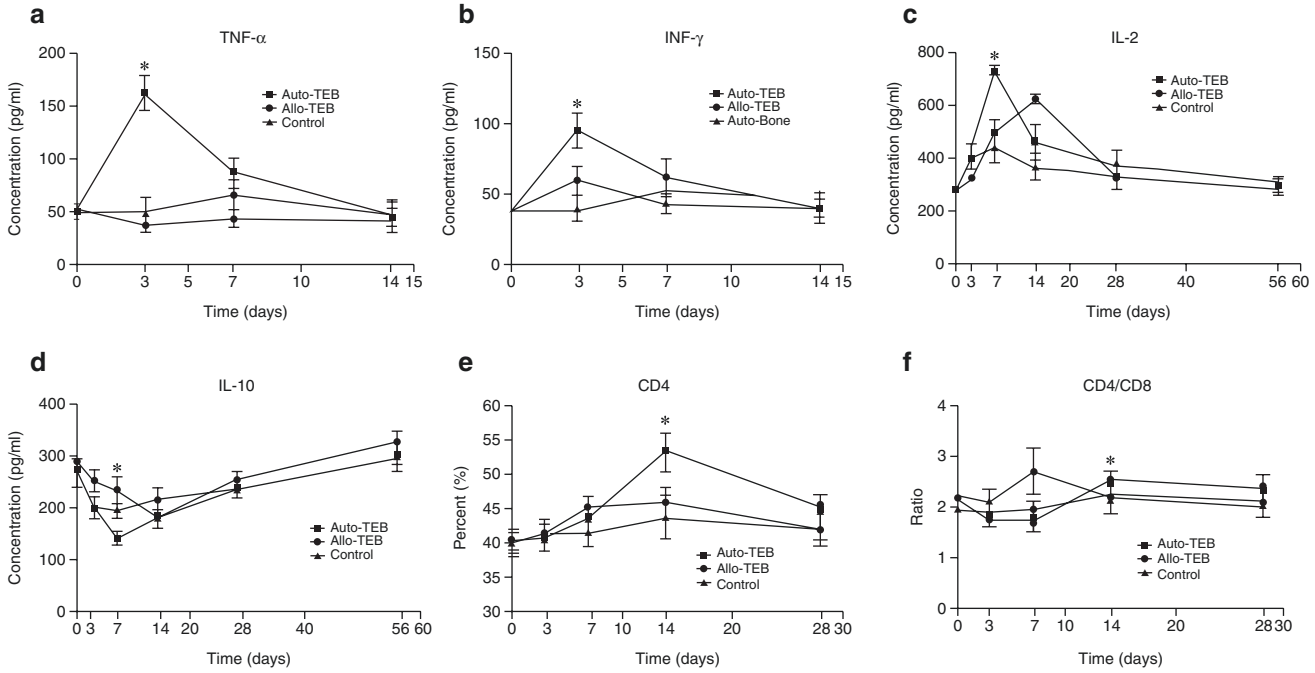

Fig. 22.5 The immune response of generalized bone tissue engineering technology

study of seed cells of general type, we also found that the embryo-derived mesenchymal stem cells (MSC) are more suitable for generalizing application of bone tissue engineering technology compared with the mesenchymal stem cells derived from adult bone marrow, fat source, and umbilical cord, and they have advantages such as higher osteogenic activity, strong amplification ability, and low immunogenicity (Fig. 22.6). The researches in this area can help develop the available generalized tissue engineering products; thus, it is not needed to wait before surgery, the treatment cost is reduced, the difference in efficacy between individuals is decreased, and the researches can also help promote the large-scale application of tissue engineering technology in clinic.

3.2 Cartilage Tissue Engineering

Because the cartilage tissue has simple structure, unitary component cells, and no complex structures such as blood vessels and nerves, it has become the tissue studied for tissue engineering at the earliest time. Recently, the repairs of cartilage defects within large animals have been successful, which has only one step away from the clinical application.

The sources of cartilage seed cells have been a bottleneck problem limiting the development and application of cartilage tissue engineering. Originally the seed cells used for cartilage construction are mature chondrocytes, and its in vitro amplification is difficult due to limited sources of chondrocytes; the cells are prone to aging under culture conditions and loss of chondrocyte phenotype; a sufficient amount of seed cells cannot be obtained. Although a lot of trials on inhibition of cell aging have been carried out, an effective method has yet been found. The development of stem cell research finds new hope for the sources of cartilage seed cells. The studies have found that the bone marrow stromal stem cells have the potential to differentiate into chondrocytes, under the combined induction of particular factors such as TGF-β, IGF, and the multiple factors such as dexamethasone; the bone marrow stromal stem cells can differentiate into chondrocytes, if the cells after induction are compound with materials and then were implanted under the skin, and the mature cartilage tissue can be formed; these studies confirm that the bone marrow stromal stem cells can become seed cells for cartilage construction. With the deepening of stem cell research, the adipose stem cells and embryonic stem cells have become thecandidates for the source of cartilage seed cells. The directional differentiation and application of these stem cellswill be the important direction of further research on cartilage seed cells.

Compared with bone tissue engineering materials, the materials used for cartilage construction have higher requirements to accurate shaping, in order to meet the needs of constructions of cartilages with different shapes. The biological materials used for cartilage construction at early stage were mainly natural materials such as collagen

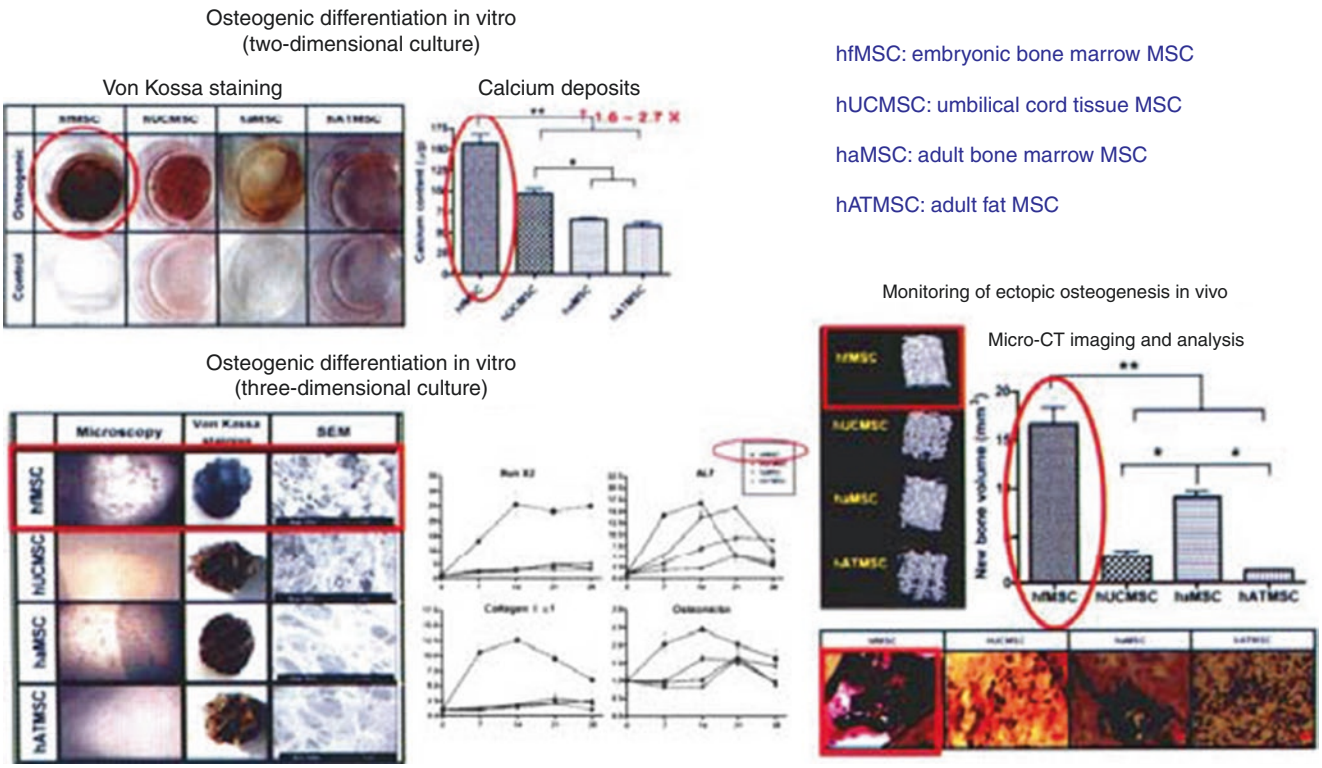

Fig. 22.6 Superiority of embryonic MSC as seed cells of general type

and fibrous protein. Although the cells grew well on the materials and could form into mature cartilage tissue, the natural materials were degraded and absorbed rapidly in vivo, the mechanical strength was poor, and it was impossible to maintain a specific spatial configuration, which greatly limited their scopes of application. In recent years, the application of the synthetic materials, such as polyglycolic acid and lactic acid–glycolic acid copolymer, in cartilage constructions both in vivo and in vitro have obtained certain achievements, but are still in the stage of experiment research and exploration. Looking for ideal scaffold materials and improving their preparation and processing technologies are still the urgent tasks faced in the research on cartilage tissue engineering.

The technologies for in vivo cartilage construction and defect repair are currently quite mature; all experiments in animals such as nude mice, rabbits, sheep, pigs, and monkeys are successful; the repaired defect types include the defects in the joints, trachea, meniscus, and epiphyseal plate; a breakthrough progress has also been achieved in the in vitro construction of the cartilage. The cartilage or bone marrow stromal stem cells are compounded with the materials, and then the composite is cultured in vitro for several weeks under the stimulation of specific inducing factors and can form into the cartilage tissue with a certain morphological structure, but the thickness of the cartilage tissue formed through simple in vitro culture cartilage tissue is limited, and the mechanical strength is poor; it is difficult to maintain the specific shape, and the cartilage tissue cannot meet the requirements for compressive strength when it is implanted in vivo. To solve this problem, the formed cartilage tissue in the bioreactor is imposed with appropriate dynamic or static mechanical stimuli (pressure or shear force), which can significantly improve the anti-compression mechanical properties of the constructed cartilage; at present, the researches in this area have also achieved certain results.

As the problems on source of seed cells are solved, the appropriate biological materials are developed, and the bioreactors are improved and optimized; the clinical application of the tissue-engineered cartilage is just around the corner, and it will be possible to carry out the tissue and organ reconstruction requiring the participation of cartilage tissue after tumor resection.

3.3 Skin Tissue Engineering

The tissue-engineered artificial skin is the first tissue engineering product which has achieved industrialization and commercialization, and currently it has been widely used in the repair and reconstruction of the large-area skin defects after burn injury, plastic surgery, trauma, and tumor resection.

The skin tissue is the double composite structure, and it is divided into epidermal and dermal tissues; the corresponding seed cell research also include two aspects of researches on epidermal seed cells and dermal fibroblasts. The dermal fibroblasts have a wide range of sources, have powerful in vitro amplification capability, and are not prone to aging frequently. The culture method is also simple and practicable, and the relevant technologies are relatively mature. The requirements for epidermal keratinocytes separation, culture techniques, and culture conditions are higher (requiring special enzymes and dedicated culture solution for keratinocytes); in order to maintain the phenotype and proliferative activity of epidermal cells, the cells must be added with the epidermal growth factor (EGF) and be cultured under serum-free condition. Apart from the epidermal stem cells, the hair follicle stem cells are another type of seed cells which have the ability to form the epidermis. Compared with the epidermal stem cells, the hair follicle stem cells not only have a strong multiplication capacity and can differentiate into keratinocytes but also can differentiate into various appendant organs of the skin, such as the hair, sebaceous glands, and sweat glands; they are seed cells which are more in line with construction of the tissue engineering skin.

The scaffold materials for skin tissue engineering require a certain strength and flexibility and can be sutured tightly with the wound margin. Due to differences in tissue structure between the epidermis and dermis, it is required that the pore diameter and porosity of the materials are distributed asymmetrically in two parts of epidermis and dermis, so as to meet their own requirements of epidermal keratinocytes and dermal fibroblasts. The epidermal tissue is mainly composed of keratinocyte at different differentiation stages; the number of cells is high, and the extracellular matrix is very few; therefore, the epidermal cells need to be seeded and grown on the surface of the materials with compact texture, smaller pore diameter, and lower porosity; this is conducive to the formation of a stratified epithelial tissue. For dermal tissue, the main components are the extracellular matrix such as collagen and proteoglycan. The number of cells is low, and therefore, the materials are required to have more loose structure, large pore diameter, and high porosity. So the cells can be uniformly distributed to the inside of the material, facilitating the secretion of extracellular matrix. Currently, there are many kinds of biological materials applicable to simple epidermis construction, including natural materials such as collagen, chondroitin sulfate, hyaluronic acid, fibrin glue, and chitosan as well as the synthetic materials such as polyglycolic acid and polyethylene propylene oxide, but there is no material which can really meet the requirements of composite skin construction. Therefore, the study of skin tissue engineering scaffold materials will focus on research and development of the composite materials.

The skin is the tissue with the most mature research and application in the field of the tissue engineering, and at present, its application has been expanded basically from animal experiments to clinical practice. The tissue engineering skin substitutes can be divided into the epidermal substitute, dermal substitute, and composite skin substitute. The cultured epidermal cell sheet is the first artificial epidermis, which is still one of the recognized treatment plans for treatment of large-area burn, but its implantation procedure is more difficult. To solve this problem, the researchers inoculate and culture the epidermal cell sheet onto the biodegradable or nonbiodegradable filmlike material scaffold and then attach it with the cell surface toward the wound, which has achieved good repair effect. Since the end of last century, the research and development of tissue engineering artificial dermis progress very quickly, and currently five commercialized artificial dermises have come out:

1. Integra: Integra is a sponge grid with certain pores which is covalently cross-linked by the collagen, glucosamine, and chondroitin sulfate, and then its surface is coated with a thin layer of silicone membrane to make an artificial dermal substitute.
2. Biobrane: Biobrane is a kind of double-layer membranoid substance; the outer layer is the thin silicone membrane, and the inner layer, integrating of a large number of collagen particles, can be attached to the wound quickly and closely.

   Both Integra and Biobrane do not contain cellular components, and therefore these two kinds of dermal substitutes are not really tissue-engineered dermis.
3. Dermagraft: The Dermagraft is the artificial dermis consisting of the fibroblasts, extracellular matrix, and biodegradable materials which is formed through inoculating the fibroblast acquired from neonatal foreskin into the biodegradable polylactic grid.
4. Dermagraft-TC: Dermagraft-TC is a tissue engineering dermal substitute which is formed through inoculating the fibroblast onto Biobrane.
5. AlloDerm: AlloDerm is a commercial acellular dermal matrix, but it is not the tissue-engineered dermal equivalent in real sense. The ideal tissue engineering skin should contain two layers of the epidermis and dermis. Apligraf (also known as Graftskin) is the first commercial composite skin containing both epidermal layer and corium layer; both its epidermal cells and fibroblasts are from the newborn foreskin tissue; the biological material is bovine type I mesh collagen scaffold. The fibroblasts are inoculated onto the scaffold at first, the epidermal cells are inoculated usually 3 days later, and the composite skin tissue containing epidermis and dermis structures is formed ultimately.

Although the tissue engineering skin plays a leading role in various types of researches and applications of tissue engineering, it still has problems such as too long in vitro

culture period, difficult angiogenesis, and regeneration obstacle of the skin appendages, with the application of hair follicle stem cells, the development of double-layer scaffold materials, and the improvement of in vitro construction technology; the range of clinical application of tissue engineering skin will be further expanded, and the effect of skin defect repair will be improved.

3.4 Other Tissue-Engineered Tissues and Organ Research

In addition to the tissue-engineered bone, cartilage, and skin introduced in the above text, the construction technologies of single tissues such as tissue-engineered tendon, cornea, and blood vessels are relatively mature, and they are not introduced here one by one; however, the construction of tissue-engineered organ is still relatively backward, and it can be said that there is no breakthrough progress so far; the main reason is due to the complexity of the organ structure. Firstly, a single organ contains many different cells, and there is currently a certain technology difficulty in the simultaneous separation and amplification of several different cells; secondly, in the construction process, how to carry out three-dimensional spatial arrangement on the biological material for different seed cells in strict accordance with the normal anatomical structure and simultaneously maintain the strict three-dimensional structure during tissue formation is a problem which cannot be solved by the existing technological means. For example, in the liver tissue, only the piping system includes multiple structures such as hepatic arterial and venous systems, portal venous system, and biliary system, and the component cells include various cells such as liver cells, smooth muscle cells, vascular endothelial cells, and biliary endothelial cells, and carrying out correct in vitro combination of cell arrangement and tissue structure still cannot be realized by existing technology. The researchers have separated and implanted the kidney progenitor cells in the early embryo onto the biological materials; after implantation in vivo, the kidney progenitor cells gradually differentiate and eventually form into structures similar to the renal tubules and glomeruli of a normal kidney. This study suggests that applying the principles of developmental biology and the characteristics of stem cells, making the stem cells spontaneously differentiate and form into organ structures in an appropriate in vivo environment, might be a feasible way to construct organs.

4 Issues and Challenges

Development up to now, the advantages of the tissue engineering research have been fully reflected, but generally speaking, the tissue engineering research is still in its infancy; now just the clinical application of tissue engineering technology to the repair of simple tissue defects can be carried out, many basic scientific problems limiting the applications and development of the tissue engineering still have not been clarified clearly, and many new technologies and new fields still need to be further developed. In addition to expanding the source of seed cells, accelerating the development of tissue-specific materials and exploring the reconstruction of the complex organ, it is also required to strengthen the researches on basic problems in tissue engineering. For example, how do the evolvement rules work in the process of in vitro or in vivo formation of the tissue-engineered tissue? What are the similarities and differences between these evolvement rules and the process of the development, regeneration, and wound healing of the normal tissue? What are the relevant factors and mechanism of action that affect the process of formation and maturation of the tissue-engineered tissues? What is the mechanism of action for the biological materials affecting the cell differentiation and tissue formation? By what means does the mechanical stimulation promote the cell differentiation and tissue maturation? These problems involve the effectiveness, stability, and safety of the clinical applications of tissue engineering technology and are the basic problems limiting the further development of the tissue engineering technology. Only a series of important issues and the internal mechanism tissue in the process of formation, maturation, and in vivo outcome of the tissue-engineered tissue are systematically clarified; it may be possible to further optimize the tissue construction technology, accelerate the development of new materials, achieve the industrialization of tissue engineering technology, and truly realize the dream of replacing the tissue and organ at any time just liking replacing the parts of the machine.

For the oncological surgery, the purpose of application of tissue engineering technology is not just to fill tissue defects after tumor resection; the ultimate purpose is to construct complex organs in vitro, especially those life-threatening important functional organs; therefore, even if these organs are affected by fatal diseases like cancer, there is a potential to achieve complete reconstruction and cure. To achieve this purpose, although there is still a long way to go, once the success is achieved, it will become a milestone in the development history of human science.

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Prospects and Problems of Oncoplastic Surgery

23

Zhou Xiao and Wang Wei

The oncological surgeons have the responsibility to eradicate the tumor and have more obligations to make the patients live a healthy and beautiful life. In the twentieth century, the oncological surgery had improved the technological level of surgical resection of tumor to a considerable height, and the contemporary oncological plastic surgery will achieve the perfect combination of resection and repair.

1 The Characteristics of the Modern Oncological Plastic Surgery

The modern oncological plastic surgery has the following characteristics:

1. Under the premise of adhering to the principles of oncological surgery, using the technologies and concepts of aesthetics and reconstruction in modern microsurgery, aesthetic plastic surgery, a wealth of repair methods for the defects after thorough resection of the tumor focus is provided to guarantee the simultaneous completion of the difficult tumor resection and complex tissue defect repair, thereby increasing the efficacy of tumor radical surgery [1–3].
2. The surgeons should strictly abide by the principle of the oncological surgery in the process of operation, use the modern pathological diagnosis means to timely diagnose the extent of lesions during the operation, develop a scientific and rational radical surgery program, maximumly preserve the morphology and function with minimal trauma and minimal tissue and organ defects, and carry out local aesthetic reconstruction according to the actual situation.
3. The digital medical means is applied to preoperatively simulate the scope of the tissue defect after radical resection of the tumor focus, and the best donor site is simulated and selected in the human body to carry out fine tissue defect repair and organ reconstruction.
4. It is noted that the new achievements in the field of tissue engineering and regenerative medicine are introduced, and the new materials and new technology are studied to repair the tissue defects after tumor resection, so that the operative wound of the oncological plastic surgery is smaller and the efficacy is better [4]. The treatment of the oncological plastic surgery should pay special attention to scientific research achievements of modern radiotherapy and chemotherapy, and the sequential treatment of the tumor is carried out. These achievements of modern medicine will make the efficacy of surgical treatment of tumor medicine reach a new level.

As an emerging science, we want to establish an evidence-based research model, and taking this mode as the guiding ideology, carry out further summarization and specification on problems in several aspects such as the selection of clinic treatment plan of oncoplastic surgery, the definiteness of safety and efficacy, and the ethical review. Looking to the future, with the development of the oncoplastic surgery, the quality of life of patients will be further improved, and the survival time will be prolonged, and the harmonious unification of the medicine and aesthetics can be achieved.

2 The Current Problems to Be Solved by the Oncoplastic Surgery

In the process of development of the oncoplastic surgery, currently it is required to solve the following problems:

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2.1 Training of Oncological Plastic Surgeons and Establishment of Oncological Plastic Surgery

At present, the majority of tumor hospitals in China do not set up the department of plastic surgery and train the plastic surgeons or oncological surgeons who have the qualifications of the attending physician in plastic and aesthetic surgery. On this issue, we believe that this can be resolved through the following three ways: firstly, the masters or doctors major in plastic surgery are enrolled in the tumor hospital to carry out works of the oncological plastic surgery. After three attending physicians who have the qualifications in plastic and aesthetic surgery are enrolled, the appropriate equipments of plastic surgery are purchased, the related works of oncological plastic surgery are carried out, and the hospital administers may apply to the administrative department in charge of health at the provincial level to set up the department of oncological plastic surgery in the tumor hospital. Secondly, the oncological surgeons engaged in head and neck surgery or breast surgery which is closely associated with plastic surgery receive related training in plastic surgery and then carry out the clinical researches on oncological plastic surgery and the experience exchange. If a surgeon has been trained in the plastic surgeon training base designated by Ministry of Health for 1 year, has worked in clinic for more than 6 years and has obtained the attending physician qualification, and has passed through the national qualification examination of aesthetic chief diagnostician, then the surgeon can obtain the qualification certificate. Thirdly, the tumor hospital invites the plastic surgeons in the general hospital to attend the consultation or participate in oncological plastic surgery, but this mode is not conducive to the concentration of the oncological plastic surgeons on deeply developing the basic and clinical researches of oncological plastic surgery.

2.2 Establishment of Demonstration Base of the Oncological Plastic Surgery

The development and growth of the oncological plastic surgery are inseparable from the attention and support from all walks of life. The relevant professional workers should explore the feasibility plan for establishment of the department of oncological plastic surgery in various tumor hospitals; we should strive to establish the department of oncological plastic surgery in each grade 3 level A tumor hospital as early as possible. On this basis, under the guidance of the health administration department, the demonstration base of the oncological plastic surgery is established.

2.3 Professional Training and Academic Exchange of Oncological Plastic Surgeons

Under the guidance of the Chinese Medical Association and the China Anti-Cancer Association, the discussion on oncological plastic surgery is further strengthened in various branch associations, and the special column of oncological plastic surgery is established in the relevant medical journals. The Oncological Plastic Surgery Group of Plastic Surgery Branch of Chinese Medical Association was established in the 3rd Congress of the World Association for Plastic Surgeons of Chinese Descent in Xi'an on October 12, 2012. The Oncological Plastic Surgery Group provides a professional platform for academic exchange of the oncological plastic surgery, and, henceforth, the broad masses of medical workers engaged in the oncological plastic surgery can exchange experiences through the platform and learn the latest medical developments at home and abroad. At the same time, a series of books on oncological plastic surgery have been coauthored, and the training classes of different specifications have been held.

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