Rajen Gupta

Phacoemulsification Cataract Surgery

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With the editorial assistance
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Preface

> Good, Better, Best.
> Never will I rest,
> until my good Phaco is better and
> my better Phaco is deemed my best.
> Adapted from T. Duncan

Learning how to safely perform phacoemulsification is one of the key surgical techniques for an ophthalmologist. Training on how to master the art of removing a cataract independently in an efficient, slick manner with a low overall complication rate and produce good visual outcomes takes practice. Initial cataract training can be hindered by a combination of factors including the lack of surgical opportunities, a change in required technique, setback induced by perceived poor technique or surgical complications. Training may be stressful not only for the trainee but also for the trainer, theatre staff and the patient during the novice training stage.

This book is not intended to describe cataract assessment, biometry evaluation or machine settings, nor the complications that may occur during surgery. It does not attempt and is not meant to be a complete guide on managing the plethora of different types of cataract encountered surgically or the different techniques used for such cases. Instead, this book is primarily aimed at the novice surgeon and as a companion teaching guide for the supervising ophthalmologist.

A *Manual for Cataract Phacoemulsification Surgery Training* was adapted from a series of handouts developed over many years of supervising the novice surgeon new to surgery and surgeons struggling to make progress. Common technique issues were identified and each chapter written to fill the void in cataract surgery understanding. Although comprehensive, the overall emphasis is to explain cataract surgery steps in a simple fashion, with clear terminology rather than an encyclopaedic attempt to cover every technique.

The specific technique during a procedure will remain the responsibility of the trainer; however the chapters serve as examples of how a trainer's own particular technique could be broken down into bite-sized surgical learning points.

The framework and order of chapters will serve as a curriculum guide for training for the complete novice. For the surgeon who has some experience, but still lacks confidence in certain parts of the procedure, the chapters will serve to explain the fundamentals to aid understanding. As skills are developed, the techniques suggested can be adapted and refined. Most of all however, I hope the book will serve as a useful ad memoir to teaching and learning phacoemulsification surgery in an enjoyable fashion.

Newcastle upon Tyne, UK Rajen Gupta
2017

Acknowledgements

I am grateful to all of my trainers during my career who have helped me develop my skills. Many of the phacoemulsification techniques I use and teach today were passed verbally to me and I fully acknowledge that the original source of the technique may not be referred to.

I am indebted to all my consultant colleagues at the Newcastle Eye Centre (NEC) for their helpful comments and to the theatre staff at the NEC for helping acquire the side profile corneal images and draping preparation images in Chaps. 14 and 15. The images in Chap. 7 were all taken with the assistance of Sally Gupta.

My friend Martin Beed deserves a huge acknowledgement. Without his initial encouragement and proofreading of all the chapters, this book undoubtedly would have remained a series of handouts.

Finally, I need to say thank you to my wife Sally and my children Tara and Roshan. I have only been able to compile all the images and chapters with your support.

Abbreviations

AC	Anterior chamber
BSS	Balanced salt solution
CCC	Continuous curvilinear capsulorhexis
IA	Irrigation aspiration
IOL	Intraocular lens implant
LH	Leading haptic
Phaco	Phacoemulsification
Rhexis	Capsulorhexis
SLM	Soft lens material
TH	Trailing haptic

Contents

1 Understanding the Phacoemulsification Surgical Learning Process

Cataract phacoemulsification training poses a unique challenge of learning a delicate, complex task in which only one person can operate at any given time. The majority of patient's remain awake during surgery and training usually has to proceed in a setting of service provision [1].

Not only is an understanding of how the process of phacoemulsification surgery will be taught is important for the novice surgeon, it is equally important for the experienced surgeon embarking on a phacoemulsification teaching role to determine how to teach the novice surgeon. Given the plethora of techniques possible for every stage of the cataract procedure, the Trainer may no longer perform surgical steps in a basic fashion. Instead advanced skills, developed over years of practice will be applied to complete their own cases. Though important to ensure acquisition of a broad repertoire of skills by the end of training, the novice surgeon needs to be taught basic, fundamental phacoemulsification skills initially. The novice surgeon may fail to perform advanced intraocular movements if their confidence or skill level has not developed sufficiently, consequently it may not be appropriate to mimic such techniques. Surgical steps should not be 'challenging' but rather remain well within the Trainee's competency and comfort level. The book aims to provide a framework for phacoemulsification training: concepts are introduced over the course of the book and a training program for the Trainer to follow. Important concepts will be repeated in successive chapters to reiterate the concept for the Trainee.

The Trainer and novice surgeon need to be aware of preconceived assumptions that may influence training progress (Tables 1.1 and 1.2. Such assumptions are easily overlooked and both Trainer and Trainee need to agree on a surgical development plan before training commences.

The Trainer and novice surgeon should clarify terminology that will be used during training, as misunderstanding instructions can lead to operating being stressful. This can be avoided by developing a common language for instruction. Suggested terminology will be covered in each chapter.

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Table 1.1 Novice surgeon assumptions

Trainer will continue coaching in a similar style to previous Trainers
Not true
Trainer will not change Trainee's technique
Depends on Trainee's ability and change may be required
All instructions or rules apply to every scenario
Basic, fundamental rules apply, but need to be adapted as experience is gained
Whole phacoemulsification cases should be attempted as quickly as possible to progress
Not true
As numbers performed increase, more challenging cases should be attempted
Surgery should not be challenging at the novice surgeon stage but rather perceived as a comfortable progress; if novice finds cases too challenging then they should not have attempted to do it Ask yourself "Could I immediately operate on another case?" If mentally or physically the answer is no, or if the Trainer found supervising stressful, then stick to straight forward cases until more progress has been made
Trainer enjoys supervising
Not necessarily true
Trainer is able to teach surgical phacoemulsification skills in a fundamental basic fashion and avoids the temptation to teach advanced skills that they themselves would use if performing the procedure
Remember they have had years to perfect their technique style and their perfect intra and extra ocular bimanual movements

Table 1.2 Trainer assumptions

Trainee is open and transparent about prior surgical experience and areas of perceived difficulty
It is better to inform a Trainer about how much surgery has been done so expectations are met and appropriate learning opportunities are given
Trainee will disclose what aspects of procedure they have previously found tricky or the stages when take over is usually required
A Trainer will eventually note areas of concern but training time is wasted and it is better to tackle the issues early on
Trainee will not chase numbers or whole cases
Trainee understands and uses same terminology for "anatomical direction" when performing intra operative movements as Trainer
Trainee understands and uses same terminology for surgical instruction as the Trainer
Trainee will stop operating immediately when asked
Trainee has spent time reflecting on surgical technique

With a novice surgeon, modular step-by-step training can be performed. For Trainees who have surgical experience but are struggling, identification of the root cause of surgical issue is required. The Trainee needs to highlight one or more of the parts of the operation causing anxiety. Often, the surgical step identified by the Trainee is not the step causing the problem. A good Trainer can use the Trainee's concerns however, to identify the true root cause and focus on a solution.

1.1 Theatre Training Time

Theatre training time can be wasted by not spending a little bit of time thinking about non-patient events. Box 1.1 highlights steps that the Trainee is advised to review and reflect on. The number of learning opportunities can be drastically reduced by events that hinder and reduce available training time. A few minutes wasted per case may mean the difference in gaining additional surgical opportunities during the same theatre list. Time should not be made up by trying to rush surgery.

Box 1.1 Trainee Surgical Steps that Can Maximise Theatre Training Time

- Hand washing and donning of gown/gloves.
  Tip: make sure you have been shown how to scrub, apply gown, in a sterile manner. Ensure gown and gloves are ready before scrubbing in order to avoid waiting for sterile packs to be opened.
- Ensure staff know how your name is spelt for their record keeping - preventing queries whilst operating.
- Preparation of microscope/ chair adjustment.
  Tip: ensure microscope lens surface is clean and view is good before you start. Residual dried splashes from previous surgery may hinder the view. Reset and centre microscope before operating (or even better, at the end of each procedure in preparation for the next).
- Ensure microscope pupillary distance is correct. If Trainer and Trainee's inter pupillary distance differs, adjust before you start or ensure microscope caps are available.
- If recording surgery, ensure recording device is ready before you scrub up.
- Ensure correct instruments available in a timely fashion.
  Tip: Tell staff what instruments you prefer (if different from current Trainer) so they are available from the start. Ensure microscope lens surface is clean and view is good before you start. Residual dried splashes from previous surgery may hinder the view. Reset and centre microscope before operating (or even better, at the end of each procedure in preparation for the next).
  Tip: Ensure that the surgical flow is not interrupted by requesting items that were anticipated at pre-operative assessment (for example; intracameral phenylephrine for patients on Tamsulosin). Good pre-operative handover is essential.
- Simulation practice: Discuss with your Trainer what simulation practice for each part of the procedure should be done as well as the level of simulation competency required before live patient surgery.

1.2 Training Progress

Training progress should proceed smoothly. A whole case can be broken down in to modules (each module covered by a chapter in this book). A stepwise approach is recommended throughout training. As small parts of the procedure are learnt (competently) these can be combined until a whole case is performed. It is important that Trainees don't try to progress too quickly to perform whole cases. If a module cannot be performed competently, then errors will be compounded as the case progresses, leading to difficulty and potential adverse events. Though tempting to shift attention from one surgical module to another, the agreed step should be focused on. Variation reduces consistency in the training regime and it will be noticeable that the novice surgeon is unable to maintain surgical technique from week to week, with cases often requiring the Trainer's intervention. As a consequence, both novice and Trainer could get frustrated with progress. The ideal training progress pattern deviates for a Trainee in difficulty (Fig 1.1).

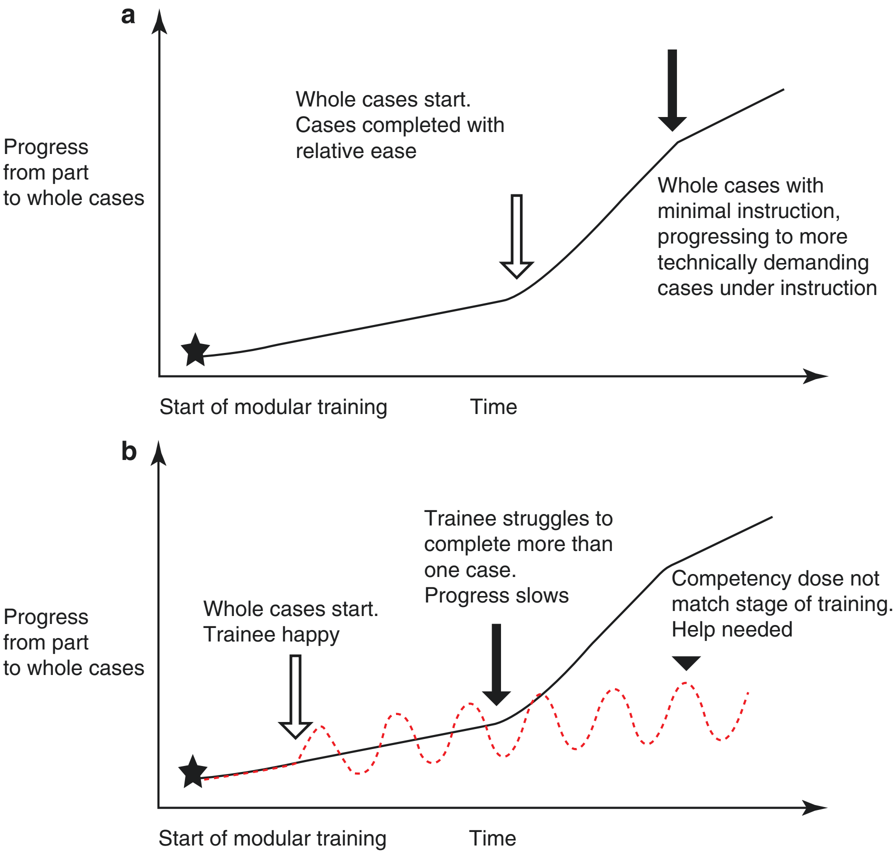

Fig. 1.1 Training progress. (**a**) Ideal surgical progress for a novice surgeon (*solid line*), whole cases with instruction (*open arrow*) progressing to cases with minimal instruction (*solid arrow*). (**b**) Training curve for a trainee in difficulty. Ideal training progress (*solid line*), Poor training progress (*dotted line*). Start of modular steps (*black star*), start of whole cases under instruction (*open arrow*). Surgical progress slows and Trainee struggles to complete whole cases without regular intervention (*solid arrow*). Assessment point at which Trainee in difficulty is recognised and surgical competency expectation is not met (*arrow head*)

Trainees can often be self-aware if they are not progressing and it is often worth asking such a question to judge whether insight is appreciated. It is important to recognise a surgeon struggling to make progress as soon as possible. Delay results in wasted training time and compounds the difficulties. In some instances the supervising Trainer may not be able to identify the problematic root cause but appreciates the Trainee is struggling. In such instances, a fresh perspective from a new supervisor may be required.

Once difficulties are recognised and a root cause identified, additional modular training is required to correct technique. This can feel like a step backwards for a novice surgeon, especially if previously performing intermittent whole cases.

1.3 Understanding Modular Training

Given the complexity of cataract surgery, an assumption that whole cases are performed after some period of modular training is made. Each module or task can be taught based on 'Peyton's four-step approach' to learning a skill in theatre [2]. This model defines four clearly defined instructional steps:

Step 1: *Demonstration*, (the Trainer should demonstrate the task at a normal pace without comment.

Step 2: *Deconstruction* (the task is deconstructed and each sub section is described as it is performed).

Step 3: *Comprehension* (the Trainee describes each sub step task and the Trainer follows the Trainee's instructions).

Step 4: *Performance* (the Trainee performs the task).

The book chapters are written to help the Trainee deconstruct and facilitate comprehension of fundamental principles in phacoemulsification surgery. The Trainer is required to demonstrate their own surgery and help the Trainee deconstruct any specific differences. Once comprehension is checked the Trainer can ensure learning opportunities arise within theatre.

The concept of the bipolar learning graph [3] can be applied to learning a new surgical task. It is useful to understand and apply to cataract surgery training: When learning a new skill, initial concepts are grasped (quite easily) in a relatively short period of time. This enables the Trainee to gain confidence quickly when trying a new task. However, they soon hit a point where the rapid learning slows down and confidence can diminish as they try to master further aspects of that particular operative skill. Effort is needed to continue the learning process and maintain and reproduce the surgical task in every case competently. Eventually as skills become more familiar a point of inflection is reached and the task "clicks" into place. A rapid acceleration of learning occurs indicating proficiency. This graph can be applied to the individual major components of cataract surgery that need to be learnt (Fig 1.2).

Each new task should only be introduced when the previous task inflection point is reached and not during the period of slowed learning and reduced confidence. The Trainer is responsible for this judgement.

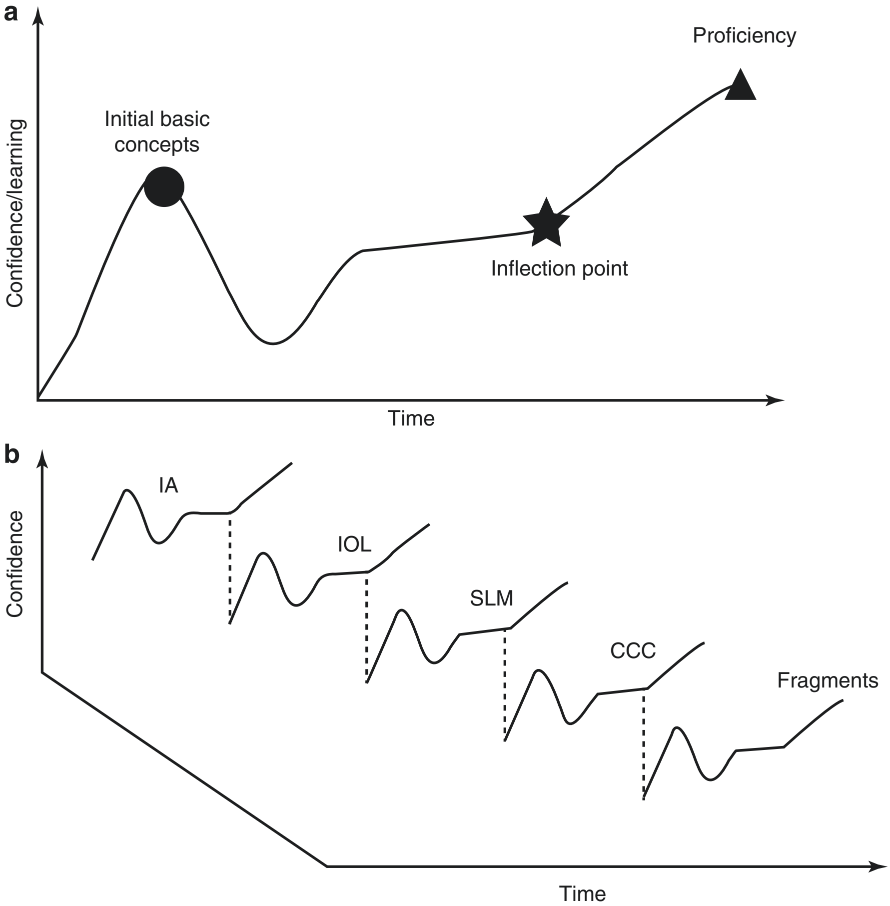

Fig. 1.2 Concept of bipolar learning graphs. (**a**) Bipolar Learning Graph. Confidence in initial basic concepts are gained quickly (*circle*), confidence drops as learning slows down until inflection point of good concept understanding is reached (*star*), learning then accelerates to point of proficiency (*triangle*). (**b**) Each task is assigned a learning curve (*solid lines*) and introduced at the point of inflection of the previous task (*dotted line*). IA irrigation aspiration, IOL intraocular lens implant, SLM soft lens matter, CCC continuous curvilinear capsulorhexis

Within each surgical task, the overall surgery can be further broken down into smaller surgical tasks, each with it own inflection point. The complexity of the task can therefore be broken down into small manageable parts. Each part can be taught and new tasks progressively introduced at each inflection time point as determined by the Trainer at a pace that is individually tailored for the Trainee.

As the smaller parts of each module are progressively performed and new tasks introduced, the novice will be expected to perform the previously learnt tasks so that proficiency is maintained in those parts whilst new ones are introduced. As competency in each module develops, the whole operation can be done by combining the separate modules. This is the key to smooth, efficient, phacoemulsification training.

When Trainees struggle, it is likely that examination of their training logbook will suggest that they have performed steps in a non-continuous fashion, skipping from one part of the cataract operation to another. During this phase Trainee confidence can be low in more than one aspect of the procedure and this results in forced errors in these areas. A compound effect occurs and Trainee and Trainers' expectation of ability are not met as invariably surgical take over increases and less learning opportunities are given.

1.4 Modular Training

A backward technique approach has been shown to minimise surgical complications and improve patient outcomes [4]. The method of modular phacoemulsification training demonstrated in this book follows this approach and is 'rear-ended'. The Trainer starts the cataract procedure and completes sections accordingly before handing over the agreed latter steps to the Trainee. The Trainee will therefore master most of the steps in reverse order. This ensures that potential problems in the initial stages are not compounded. For example, a badly constructed corneal incision can pose difficulty during the reminder of the procedure. The only exception to this rear-ended approach is that that capsulorhexis and hydrodissection are taught before phacoemulsification. This allows the Trainer to cope with surgery following any small or irregular sized capsulorhexis created whilst the novice surgeon becomes proficient in these steps. Figure 1.3 and Box 1.2 show a suggested rear-ended training flow chart and suggested modular training regime respectively.

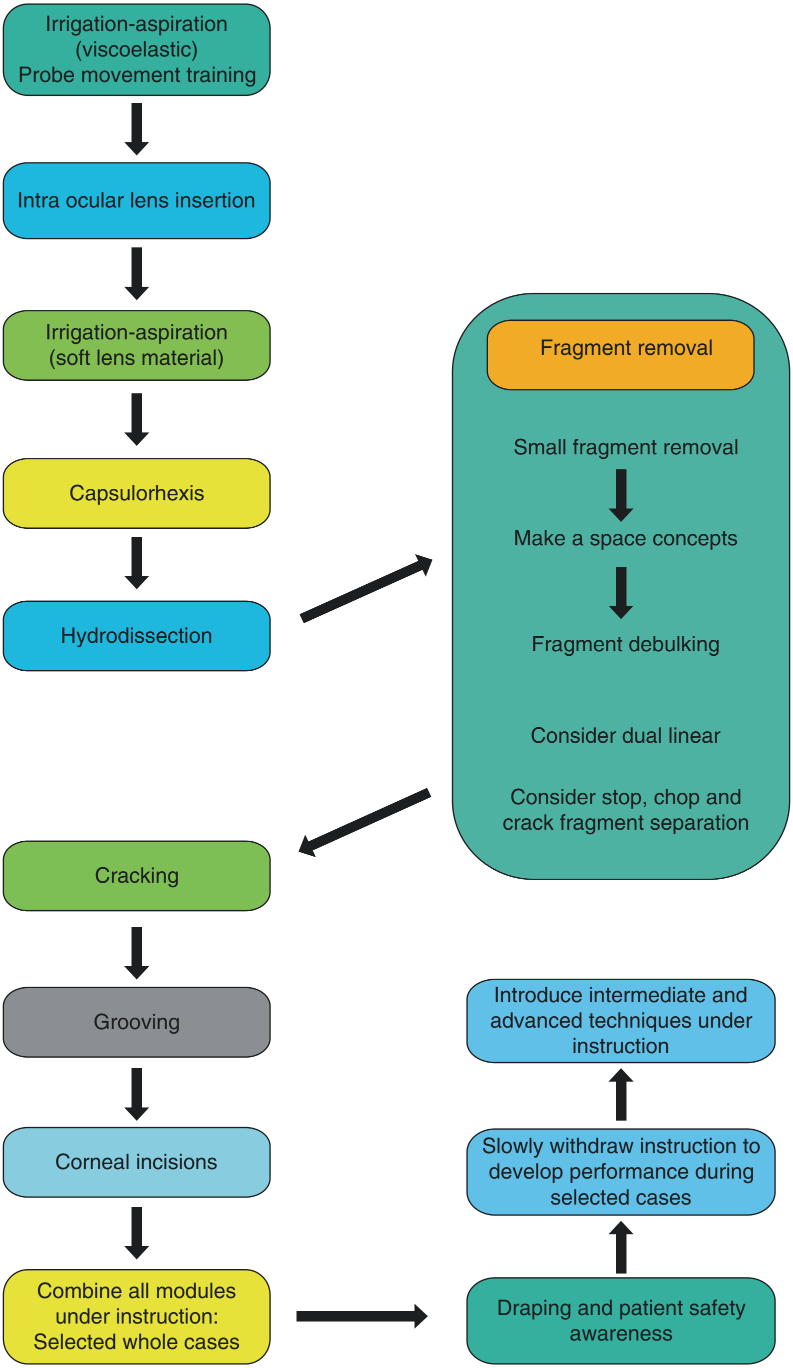

Fig. 1.3 Flow chart of suggested rear-ended training

Box 1.2 Suggested Modular Training (Described in More Detail in Following Chapters)

When performing a new step, the Trainee is expected to continue to proceed and perform previously learnt steps, such that they are continuing the operation from that point forward. The Trainer is expected to perform all the preceding steps unless stated.

1. Insertion of irrigation aspiration probe and demonstration of tip movements required for soft lens matter removal and reformation of anterior chamber and application of intracameral antibiotics.
2. Removal of visco elastic anterior to the implanted lens and reformation of anterior chamber and application of intracameral antibiotics.
3. Removal of residual visco elastic from beneath the implanted lens and reformation of anterior chamber and application of intracameral antibiotics.
4. Insertion of lens into the bag.
5. Insertion of viscoelastic into the bag.
6. Removal of soft lens material in stages (Trainer has removed some areas of soft lens material before hand over).
7. Removal of all soft lens material.
8. Introduce palming instrument technique.
9. Introduce closed forceps concept to aid view of cornea.
10. Continuous curvilinear capsulorhexis (CCC).
11. Trainee fills eye with viscoelastic and performs CCC, (Trainer does hydrodissection and phacoemulsification).
12. Hydrodissection, (Trainer does phacoemulsification).
13. Phacoemulsification *fragment removal* (Trainer to perform preceding steps and split lens into separated pieces (ideally 6) with initial small fragment extracted from bag). Trainee to remove fragments and develop phaco control. *Low rate of take over expected*. Trainee to complete remaining procedure.
14. Phacoemulsification *fragment removal* (Trainer to perform preceding steps and split lens into separated pieces (ideally 6) with initial small fragment rotated directly opposite section but not extracted from bag). Trainee to remove initial and remaining fragments and develop phaco control. *Low rate of take over expected*. Trainee to complete remaining procedure.
15. Phacoemulsification *fragment removal* (Trainer to perform preceding steps and split lens into separated pieces (ideally 5) with initial small fragment not rotated directly opposite section). Trainee to remove rotate ideal fragment for extraction into position before starting emulsification process. *Low rate of take over expected*. Trainee to complete remaining procedure.
16. Phacoemulsification *fragment removal* and debulking of large fragments with second instrument. (Trainer to perform preceding steps and split lens into separated pieces (with at least x1 large piece or asymmetrical cracking). Trainee to remove initial and remaining fragments and develop

technique for creating smaller fragments using second instrument. *Low rate of take over expected*. Trainee to complete remaining procedure.

17. Phacoemulsification *initial grooving, rotation and fragment creation and removal* (Trainer may do preceding steps to allow for overall surgery time to remain low) low *rate of take over expected* to complete lens removal and then Trainee completes procedure.
18. At this stage recommended Trainee may also performs previously taught parts of procedure on other selected cases but not necessarily phaco part to ensure time efficiency within theatre whilst to maintaining skills.
19. Corneal section and side port creation and remaining operation
20. Draping and anaesthetic block (if needed).
21. Mastering intermediate phacoemulsification techniques.
22. Mastering advanced phacoemulsification techniques.

Table 1.3 Suggested detailed training schedule

Week 1 to 2	**Week 2 to 3**	**Week 3 to 4**	**Week 4 to 6**
Module (Trainee to repeat on several cases on a list)			
		Soft lens material removal part	Soft lens material removal full
	Lens insertion		
Irrigation aspiration with IA manoeuvres Lens implant in situ	Irrigation aspiration with IA manoeuvres above lens		Irrigation aspiration with IA manoeuvres
AC reformation and wound hydration			
Notes on module			
All preceding parts done by Trainer unless stated including draping and anaesthetic block		Trainer to remove sub incisional and some of lateral areas of SLM before hand over	Trainer to gradually increase amount of SLM for Trainee to remove
Trainer to consider additional training			
Consider teaching sub lens implant visco elastic removal depending on Trainer's usual technique			
Week 6 to 8	**Week 9**	**Week 10 to 11**	**Week 11 to 13**
Module (Trainee to repeat on several cases on a list)			
	Burping of viscoelastic and hydrodissection	Fragment removal small segments	Fragment removal small segments plus rotate initially
Continuous curvilinear capsulorhexis			
Soft lens material aspiration full			
Lens insertion			
Irrigation aspiration with IA manoeuvres			
AC reformation and wound hydration			

Table 1.3 (continued)

Week 6 to 8	Week 9	Week 10 to 11	Week 11 to 13
Notes on module			
Trainer does initial AC fill with viscoelastic and advises on top up as needed. With progression Trainee fills AC with viscoelastic		Trainer to split lens into 6 small pieces and extract smallest from bag before hand over. With progression Trainer to leave smallest fragment in bag but rotated opposite to incision	Trainer to split lens into 6 small pieces before handover without rotating smallest fragment opposite incision. Trainee to rotate segments and extract smallest from bag
Trainer to consider additional training			
May involve use of vision blue in selected cases	Trainee to learn how to palm instrument	It may not be possible to do fragment removal on every case but Trainee to continue performing other modules	
Week 13 to 15	**Week 15 to 16**	**And on Week 15**	**And on Week 16**
Module (Trainee to repeat on several cases on a list)			
	Grooving and cracking	Corneal incision	Side port incision
Fragment removal with debulking of larger fragments with second instrument			Whole case on 1 to 2 cases on list[a]
Continuous curvilinear capsulorhexis			
Soft lens material aspiration full			
Lens insertion			
AC reformation and wound hydration			
Notes on module			
Trainer to split lens into 4/5 fragments of unequal size. Trainee to rotate segments and extract smallest from bag and then continue but debulk larger fragment during phacoemulsification	Trainer may do initial CCC and hydrodissection on initial case for this module, but subsequently Trainee does own CCC and hydrodissection etc	Trainer may take over after corneal incision depending on case and AC shallowing in initial cases	Select case if Trainee to do all of case

(continued)

Table 1.3 (continued)

Week 13 to 15	Week 15 to 16	And on Week 15	And on Week 16
Trainer to consider additional training			
It may not be possible to do fragment removal on every case, Trainee to continue performing other modules where possible	Consider switch to dual linear before attempting groove and cracking and perform prior modules	Note Trainee may struggle to insert phaco into Trainee made incision	Trainee to perform part of modules on other cases to maintain skills. Precise modules to be agreed on beforehand

AC anterior chamber, *IA* irrigation aspiration

[a]Subsequent weeks, Trainee to learn how to drape and perform anaesthetic block. Aim to perform 1 to 2 full cases plus part on others

A suggested detailed training schedule is shown in Table 1.3.

The mode of ocular anaesthesia used during surgery performed under supervision needs to be agreed by Trainer in an individual's learning plan.

It is suggested the Trainee familiarises themselves on the agreed step to be performed and describes the required technique to the Trainer during the surgical scrub. The Trainer can actively demonstrate the technique before the Trainee actually performs the task. Constructive feedback should occur post surgery. Reviewing recordings of any surgery can prove very useful in feedback. As progress is made the Trainer can start to describe the "step" ahead of the Trainee's given surgical step, this combined with the relevant chapter reading before the next theatre session will ensure a good grounding in the fundamentals of each step. Over time as progress is made, less instruction will be given and the Trainees will become more independent and use their own judgement on how to proceed.

Though the following chapters describe a basic technique on each step, the guidance is just one method of performing that step and the patient's care and Trainee's surgical learning plan remain under the responsibility of the Trainer. The fundamentals should remain relevant regardless of the Trainer's own personal training preference. It is suggested that the Trainer tries to break down their own surgical technique in a fashion akin to the descriptions in this book. This will help Trainees under their supervision to understand and acquire surgical skills needed in bite-sized steps.

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2 Irrigation/Aspiration

Irrigation/aspiration (often orally abbreviated to IA) is the application of fluid irrigation to maintain the anterior chamber, combined with surgeon-controlled aspiration to remove unwanted anterior chamber material. The two key materials that require removal include residual cortical soft lens material (SLM) and viscoelastic. Irrigation/aspiration can be performed manually using a Simcoe cannula, bimanually (using separate fluid irrigation and aspiration instruments), or using coaxial IA (a single instrument that allows fluid irrigation and aspiration via separate ports).

The principles described can be applied when performing supervised surgery, or can be adapted if the surgeon is already familiar with IA. The following description is for a right-handed surgeon—transposition of instructions will be required for left-handed surgeons. Fundamental IA principles that describe the most common method (coaxial) are introduced below in a stepwise fashion. Though manual and bimanual techniques are not described, the fundamental principles of aspiration technique remain the same. Recommendations for Trainers are suggested at the end of the chapter.

When rear-ended modular training is applied to IA, it is recommended that novice surgeons gain skills in IA removal of viscoelastic material whilst simultaneously learning the IA probe movements required during SLM removal training. Continuity of performing training steps is maintained by progressing to the IOL implant insertion module after viscoelastic material IA removal training. Whilst competency in inserting the lens is achieved, the novice is recommended to continue performing IA tip movement practice above the inserted IOL in continued preparation for when actual SLM removal training commences. For clarity, this chapter deals with all of the IA probe movement training details whilst Chap. 3 relates to IOL insertion and Chap. 4 with SLM removal.

Electronic Supplementary Material The online version of this chapter (doi:10.1007/978-3-319-59924-3_2) contains supplementary material, which is available to authorized users.

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2.1 Irrigation/Aspiration Fundamentals

The technique requires four stages to be learned:

1. Removal of viscoelastic after lens insertion.
   a. Above lens implant
   b. Removal of residual viscoelastic below IOL implant.
      (*Reduces risk of myopic shift*)
2. Probe tip movements necessary for SLM removal
   (*Performed above IOL implant*)
3. Removal of soft lens material
4. Aspiration polish of the posterior capsule (*if required to reduce the risk of posterior capsule opacification*) and removal of epithelium remnants from the anterior capsule lens (if needed to reduce risk of capsule phimosis)

2.2 Terminology

2.2.1 Orientation

A system of orientation is required during surgery when making intraocular movements. This is especially true during training. Fixed reference points, for example the nose and the temple, can be used for nasal and temporal movements respectively. However, for other directions, a clock face description is commonly used, with positions on the cornea described by "hours". Unfortunately, for novice surgeons, this may lead to confusion and hesitation. This is particularly true when the changing between the right and left eye, or if changing from superior to temporal based corneal incisions (or vice versa). To avoid this, when looking down a microscope it is suggested that the corneal incision, regardless of its position once created, is always deemed to be 12 o'clock. This ensures a fixed reference point is always used, even when changing from superior to temporal based incisions. The *cardinal* points of orientation (3, 6, 9, and 12 o'clock) can then be easily understood and matched by both Trainer and Trainee (Fig. 2.1).

2.2.2 The 'Safe Zone'

The safe zone is the deepest part of the anterior chamber and the centre of the capsulorhexis (Fig. 2.2). It is the area in which the risk of catching the iris or capsule is lowest, allowing maximum aspiration to be performed.

2.2.3 Soft Lens Material

Following phacoemulsification of the lens nucleus, a thin layer of SLM remains adherent to the inner anterior and posterior surface of the capsular bag (Fig. 2.3).

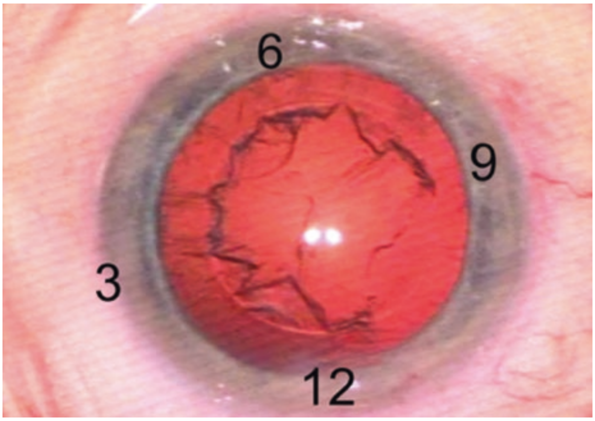

Fig. 2.1 Cardinal points. Cardinal points (3, 6, 9, and 12 o'clock) of orientation. The corneal incision acts as a fixed reference for the 12 o'clock cardinal point regardless of where it is located

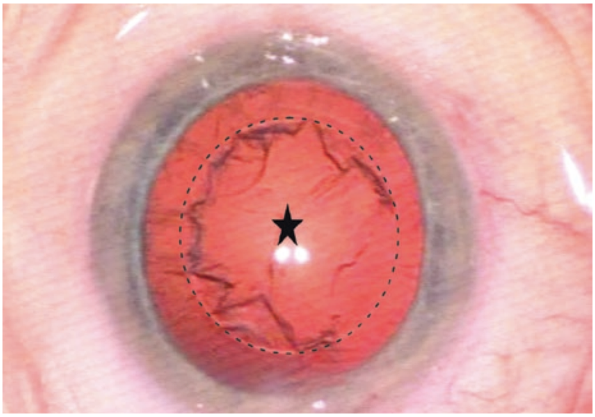

Fig. 2.2 The safe zone. Centre (*star*) of the capsulorhexis (*dotted circle*). Nucleus has been removed

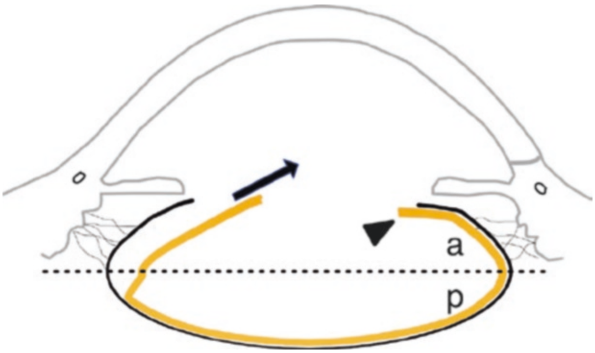

Fig. 2.3 Cross section of anterior chamber. Direction of pull when peeling soft lens material (*arrow*), overhanging soft lens material (*arrowhead*) beyond capsulorhexis edge (*solid black curvilinear line*), division between (*a*) anterior and (*p*) posterior soft lens material (*dotted line*)

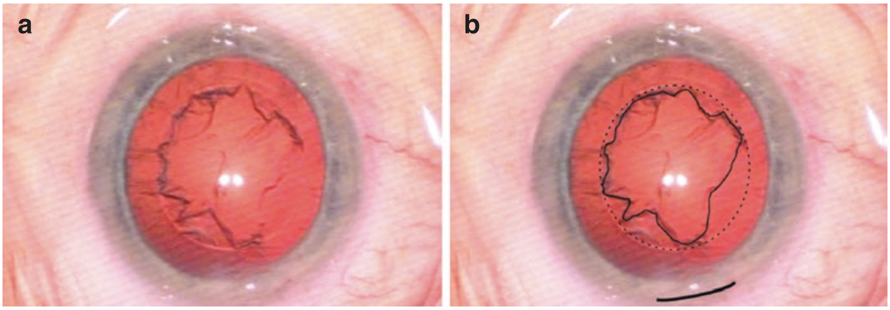

Fig. 2.4 Differences in red-reflex. Red-reflex differences allow outline of CCC and SLM to be distinguished. (**a**) *Colour* image (**b**) annotated image, CCC (*dotted line*), outline of SLM overhanging CCC edge (*solid line*), corneal incision (*curved line*). CCC capsulorhexis, SLM soft lens material

This is also referred to as the cortex layer. The SLM needs to be removed before the IOL implant is inserted.

The SLM can be visualised as redundant material and creates an alteration in the red-reflex (Fig. 2.4). As SLM is removed, an area of clear red-reflex is produced. The effect of the SLM on the red-reflex appearance can be used to help identify an area of SLM to remove by intentionally grasping the redundant anterior portion that overhangs the capsulorhexis edge. The improvement in red-reflex can help the surgeon avoid accidental aspiration of the capsule where it is devoid of any SLM, reducing the risk of capsule damage or zonular dehiscence.

2.2.4 The Soft Lens Material Capsule Interface

Following removal of the lens nucleus a thin layer of soft lens material remains in situ, loosely attached to the inside of the lens capsule. The SLM capsule interface anchor points holding the SLM in place are easily overcome by pulling the SLM off the capsule surface.

2.3 Aspiration Control

The amount of aspiration control is determined by the amount of foot pedal depression. This is akin to foot pedal acceleration control whilst driving a car—the greater the depression the greater the aspiration. The maximum setting is pre-set by the surgeon, (Fig. 2.5). It is important to appreciate and recognise the sound the equipment makes when engaging irrigation/aspiration. Each machine will have a slightly different sound setting. However, in general, the pitch produced will alter in a linear

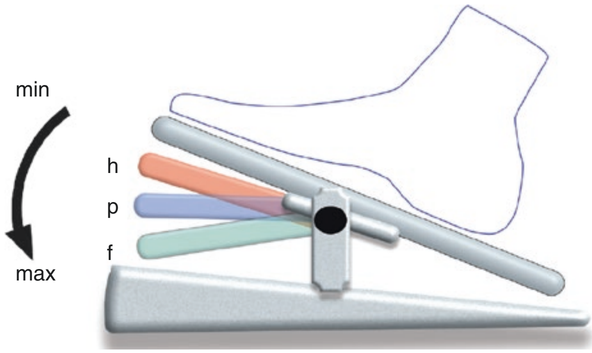

Fig. 2.5 Aspiration foot pedal control. (**a**) Linear aspiration corresponding to pedal depression. (**b**) Linear aspiration scale with corresponding machine sounds and effect on soft lens material. *H* Holding aspiration, *P* peeling aspiration, *F* foot down maximum aspiration

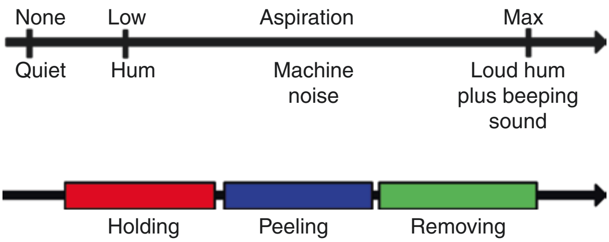

Fig. 2.6 Aspiration foot pedal control sounds

fashion as the foot pedal is depressed (e.g. the louder the sound, the greater the aspiration). Maximum aspiration is commonly indicated by an intermittent beeping sound (Fig. 2.6).

2.3.1 Terms That Are Useful for Aspiration of SLM Include

"*Holding aspiration*": the amount of aspiration that *engages* SLM into the probe aspiration port without fully removing the SLM from the anterior chamber.

"*Peeling aspiration*": the amount of aspiration that can hold engaged SLM *and* allows the SLM to be peeled off the capsular bag as the probe is moved within the eye. Aspiration is just greater than the adhesive resistance of the SLM capsule interface anchor points but not enough to completely aspirate the SLM from the eye.

"*Foot down aspiration*": the amount of aspiration required to actually remove material from the anterior chamber.

The aspiration is maintained at maximum or near maximum. Foot down aspiration should occur with the IA probe tip within the safe zone area, with the port kept away from the iris or capsule to avoid accidental damage.

Box 2.1 Aspiration Training Tip

- In time, the sound produced by foot pedal depression will provide the surgeon with additional feedback, allowing them to carefully control the amount of aspiration.
- There will be times when the IA tip fails to engage soft lens material, even despite high aspiration pressures. This may either be due to a higher "holding" aspiration amount being needed, or due to the port being blocked.
  Tip: check the port tip for debris. The port can usually be cleared by applying maximal aspiration within the safe zone, or by removing the probe and wiping any occlusion away from the blocked port.
- During supervision, Trainers can combine their observations with the sound of the IA in order gauge whether too much or too little aspiration is being used by the Trainee.

2.4 The Irrigation/Aspiration Instrument

Various coaxial IA probe tips are available, and each ophthalmic unit will stock those preferred by their surgeons. The IA probe is composed of a tip with an aspiration port on its superior aspect and irrigation holes on each side (Figs. 2.7 and 2.8).

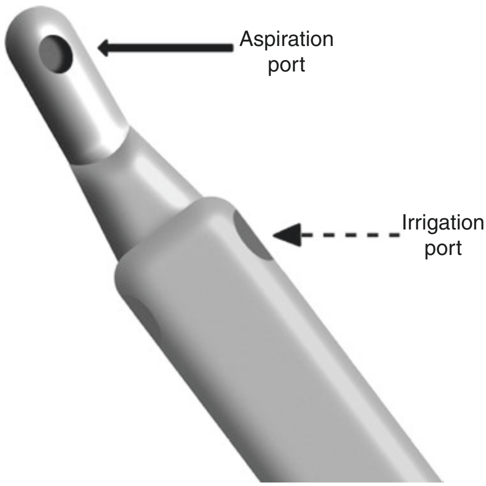

Fig. 2.7 Irrigation/aspiration tip in the port-up position. Aspiration port (*solid arrow*), irrigation port (*dashed arrow*)

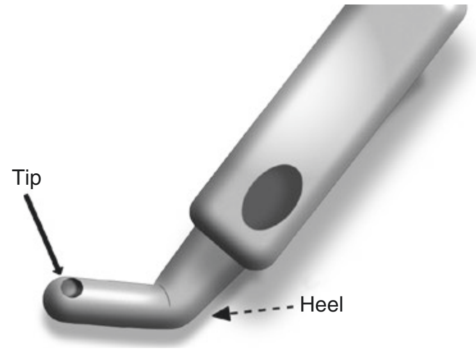

Fig. 2.8 Irrigation/aspiration tip in side profile. The angled section of the tip (*solid arrow*) is termed the "*heel*" (*dashed arrow*)

The 45-degree angled probe tip is the most commonly used; although both straight and 90° IA probe tips are also available.

The IA tip is termed "*port-up*" when the irrigation port is clearly visible (and therefore facing upwards, away from the posterior capsule). In side profile, the angled portion of the tip is termed the "*heel*". Pivoting the heel up, down or in a rotary fashion will allow the tip to make a variety of movements within the eye.

2.5 Irrigation/Aspiration Movement Terminology

A common terminology to describe the movements is required to prevent misinterpretation when surgery is performed under instruction. Suggested terms are provided below, but ophthalmic units or indeed individual Trainers may use alternative IA movement terminology. It is preferable for the novice to use standardized terms where possible when transferring between Trainers for training supervision. Each of the movements performed, either independently or in combination, is used to peel the SLM off the capsule before it is fully aspirated and removed from the eye.

2.5.1 "Wind-on-a-Stick"

"*Wind-on-a-stick*" describes rotation of the IA tip, either clockwise or anti-clockwise (Fig. 2.9).

The purpose of this movement is to increase the dragging or pulling effect on any soft lens material engaged in the port, without the need to move the IA tip laterally (Fig. 2.10).

As the SLM is wound around the tip, adhesion between the SLM and capsule is overcome. The direction of the rotation will depend on the SLM area to be removed, but will always be in a direction away from the targeted SLM capsular bag anchor points.

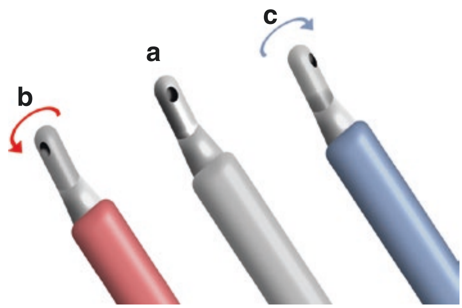

Fig. 2.9 Wind-on-a-stick movement. (**a**) Port-up position, (**b**) anti-clockwise, (**c**) clockwise

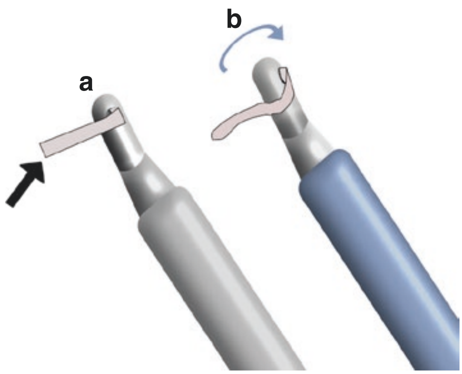

Fig. 2.10 Wind-on-a-stick movement: dragging and winding. Soft lens material (*arrow*) is dragged and wound around the irrigation/aspiration tip during movement from (**a**) port-up position to (**b**) clockwise rotation.

2.5.2 Lateral Movement

In lateral movement, the IA tip is pivoted about the corneal section in a lateral or oblique direction (Fig. 2.11). This can be to the right, the left, or obliquely away from the centre. In a lateral movement, the IA aspiration port is maintained in the port-up position. The pulling or dragging lateral movement causes shearing of adhesion between the SLM and capsule.

2.5.3 Combination of Lateral and "Wind-on-a-Stick" Movement

Lateral and rotational movements can be combined (Fig. 2.12). The combined effect increases the tension on any held SLM, which facilitates stripping the SLM off the capsule. The amount of aspiration used during a combined movement will vary from initial holding to peeling aspiration. As the SLM is peeled from the capsule, the resistance to SLM stripping is overcome. Increasing aspiration will ensure SLM held within the IA port is not accidentally released.

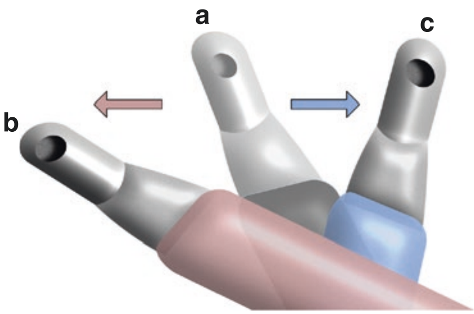

Fig. 2.11 Lateral movement. Lateral movement from (**a**) the primary position to (**b**) left lateral and (**c**) right lateral

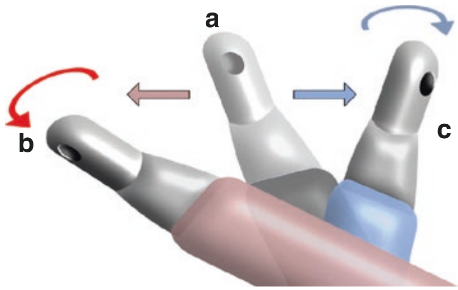

Fig. 2.12 Combination of lateral and "wind-on-a-stick" movements. Lateral movement (*straight arrows*). Wind-on-a-stick rotation (*curvilinear arrows*). (**a**) Primary port-up position. (**b**) Left lateral plus rotation, (**c**) right lateral plus rotation

2.6 Removal of Viscoelastic

Following intraocular lens insertion, the anterior chamber and capsule bag remains filled with viscoelastic material. Viscoelastic removal is necessary to prevent a post-operative rise in intraocular pressure, and anterior uveitis. Viscoelastic material above the lens is straightforward to aspirate and remove. It is easily done during the IA movement training required for SLM removal. Any viscoelastic material remaining under the lens implant may, however, be more stubborn to remove. Residual pockets of viscoelastic may be released when the IA probe is removed from the eye. The anterior chamber should then be carefully examined for any residual viscoelastic. Where it is present the IA probe should be reinserted to ensure complete viscoelastic aspiration takes place. In order to encourage the viscoelastic to escape from beneath the lens, the lens implant may require rocking, tilting or moving slightly with the tip or heel of the IA probe.

A more direct approach to remove viscoelastic under the lens is to place the IA probe tip under the lens implant edge and aspirate the viscoelastic directly. The technique for this is covered in the section: "Aspirating under the lens (*port-up, with tip under edge of lens implant*)."

2.7 Irrigation/Aspiration Movement Training

It is recommended that novice surgeons perform IA SLM pseudo-removal movements, above the implanted lens, during viscoelastic removal training. Initially, one or more movements can be introduced and performed during viscoelastic removal training. New movements may be added with subsequent cases, until the full repertoire of movements has been covered. Novice surgeons need to be able to follow the Trainer's instruction with little or no hesitation, and non-instructed movements should be avoided at this stage of training.

During sub-incisional practice movements, the IA probe aspiration port may not be visible. During subsequent rotation and movement back to the safe zone the surgeon will be able to appreciate the location of the aspiration port. By observing where the port is located, the novice surgeon will focus their observation on this point during the movement. If possible, 360-degree rotation of the IA tip in the sub-incisional area should be avoided. Instead, a rotation of up to 180-degrees can be employed, with the movement then reversed back into the central area. Then, if required, rotation may be performed in the opposite direction. See Video 2.1.

Box 2.2 Recommended Modular Movement Training

1. Port-up, with probe held still in the safe zone (Fig. 2.13). Surgeon should be able to hold position for 10–20 s without moving the tip around.
2. Port-up, with lateral movement to the left and right—each movement returning to the safe zone with port-up (Figs. 2.14 and 2.15).
3. Port remaining in the safe zone, but rotated as if winding imaginary SLM in both clockwise and counter-clockwise directions (Figs. 2.16 and 2.17). Each movement ends within the safe zone with port-up. Avoid complete 360-degree rotation.

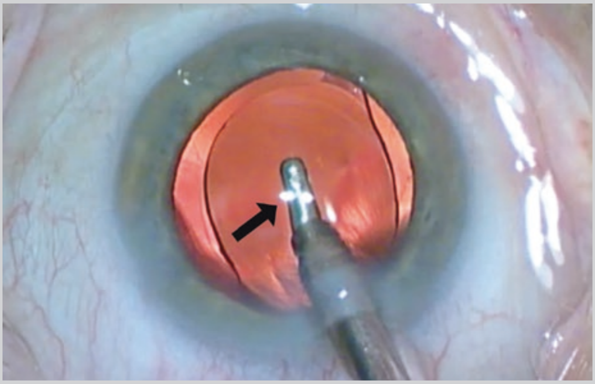

Fig. 2.13 Port-up. Light reflection (*arrow*)

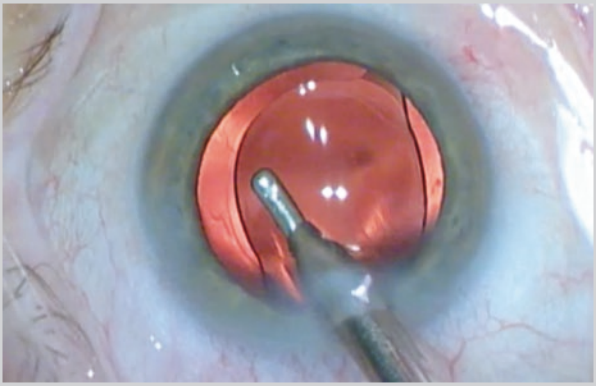

Fig. 2.14 Left lateral movement

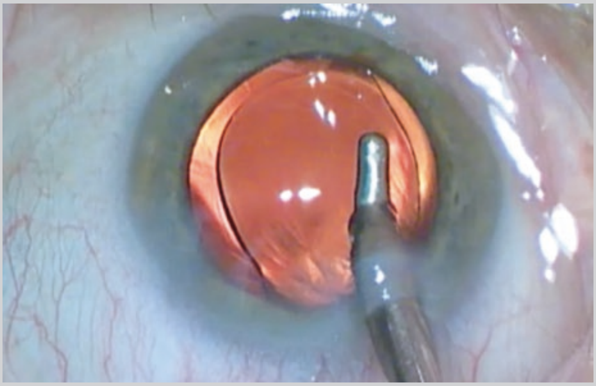

Fig. 2.15 Right lateral movement

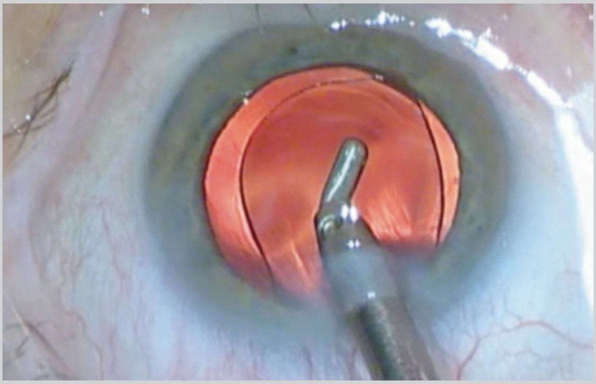

Fig. 2.16 Clockwise “wind-on-a-stick” movement

4. Lateral movement with port-up, to the right followed by wind-on-a-stick rotation. The tip is subsequently rotated back to the port-up position and returned to the safe zone (Fig. 2.18). The movement is then repeated to the left (Fig. 2.19)

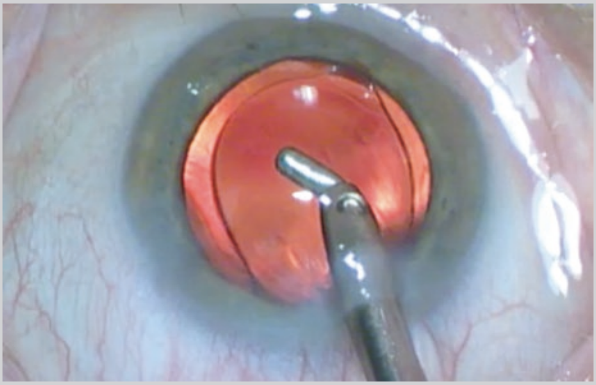

Fig. 2.17 Counter-clockwise "wind-on-a-stick" movement

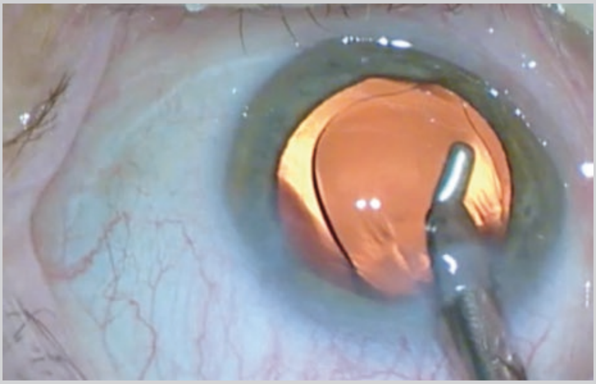

Fig. 2.18 Right lateral movement followed by "wind-on-a -stick" rotation

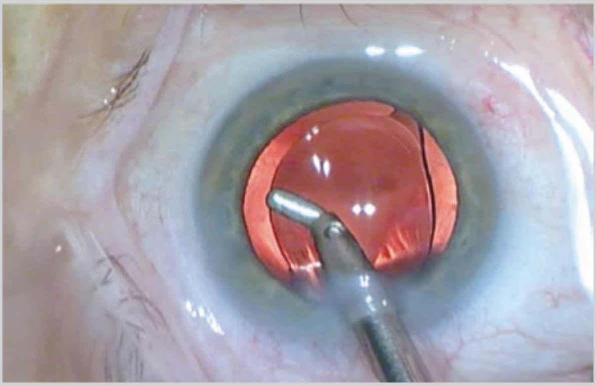

Fig. 2.19 Left lateral movement followed by "wind-on-a- stick" rotation

5. Sub-incisional movement. Rotate aspiration port anti-clockwise within the safe zone, so that the probe tip is held with the port almost facing the corneal section. The tip is moved towards the sub-incisional 12 o'clock area followed by reversal of the movements back to the centre (Fig. 2.20). Sub-incisional SLM pseudo-removal movements are performed without any applied aspiration. Repeat in a clockwise direction (Fig. 2.21).

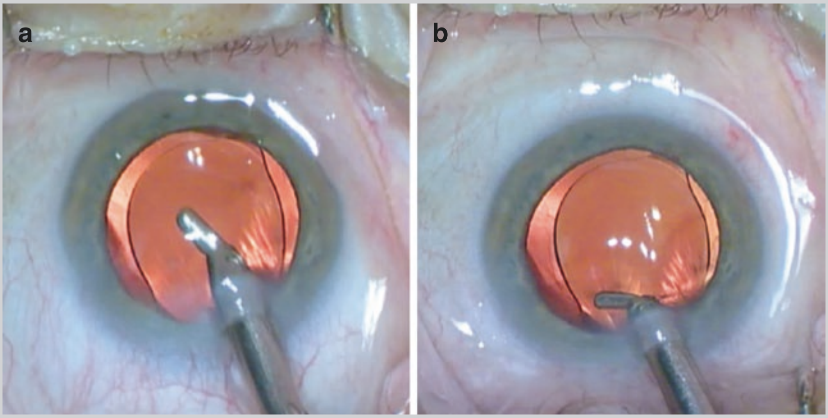

Fig. 2.20 Sub-incisional movement technique-1. (**a**) Probe tip held in safe zone and rotated anticlockwise, (**b**) rotated probe tip is moved towards sub-incisional area

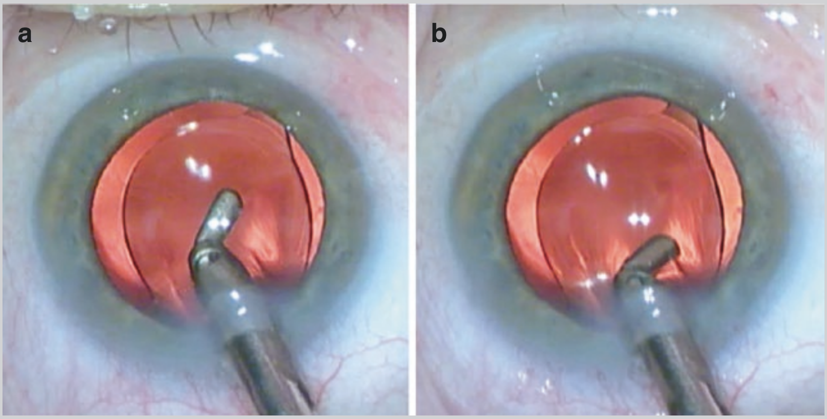

Fig. 2.21 Sub-incisional movement technique-2. (**a**) Probe tip held in safe zone and rotated clockwise, (**b**) rotated probe tip is moved towards sub-incisional area

6. Sub-incisional movement-direct drag. The probe tip is positioned in the sub incisional area with the port rotated towards the rhexis. It is returned to the central area, however the port is not rotated back to the port up position but rather maintained so that it faces the rhexis (Fig. 2.22). The probe is then rotated back to the port-up position. No aspiration used during practice movement. Repeat on the opposite side.
7. Sub-incisional movement-circular motion. The probe tip is positioned in the sub incisional area with the port rotated towards the rhexis. The tip is returned to the central area following a trajectory that allows the port to continually face the circular edge of the rhexis for a few clock hours before it is rotated to the port-up position. No aspiration used during practice movement. Repeat on the opposite side.
8. Port-up, with tip under edge of lens implant.

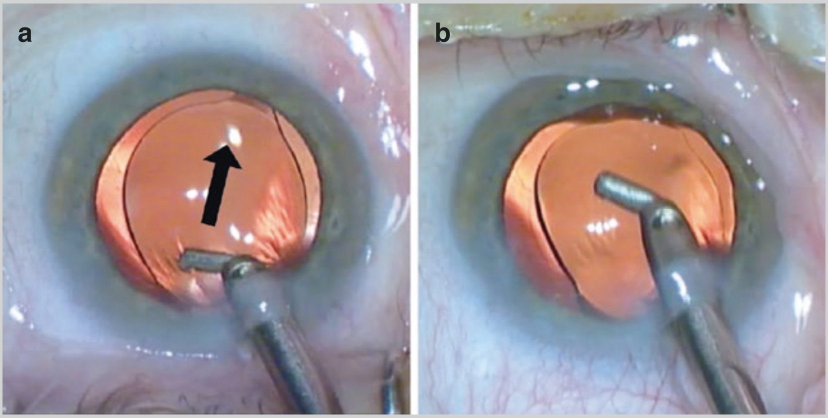

Fig. 2.22 Sub-incisional movement technique-3. Direct drag. (**a**) Probe tip held in safe zone with port facing rhexis. Intended movement (*arrow*). (**b**) Probe maintains rotated position and port still faces rhexis at end of movement

2.8 Aspirating Under the Lens (Port-Up, with Tip Under Edge of Lens Implant)

It is important to remove all the viscoelastic from beneath the lens implant (to avoid unintentional myopic shift in refractive outcome). Furthermore, on occasion, unwanted residual material may be trapped under the lens and this will need to be aspirated. It is therefore recommended that surgeons are familiar with using the IA to aspirate beneath the edge of the IOL implant.

After insertion of the IOL implant into the capsule bag, after it has fully unfolded, the lens usually requires centring. Before the lens is centred, a potential gap exists

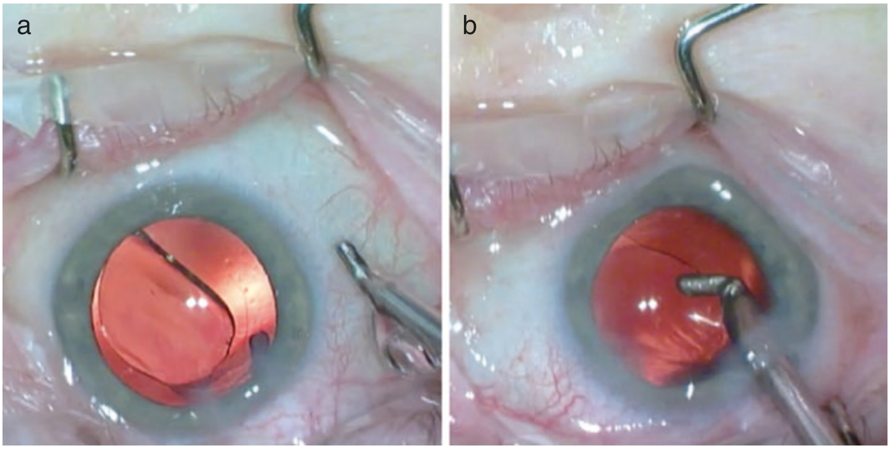

Fig. 2.23 Irrigation/aspiration of viscoelastic material beneath lens implant. (**a**) Following insertion of the lens as it fully unfolds, a gap between the right hand side of the lens optic and rhexis exists. (**b**) Probe is directed beneath optic. Rotation into the port-up position is needed before aspiration is applied

between the capsulorhexis edge and the optic edge. The IA tip can be directed into the gap and inserted under the optic edge. The optic can be lifted up a fraction and the IA port rotated so the aspiration port is visible. Once the port faces upward, the IA tip can be pivoted along its long axis in a circular fashion as required. Viscoelastic removal from beneath the lens can be commenced using gentle controlled aspiration (Fig. 2.23).

If the lens has already centred or if the pupil becomes miosed, it may not be possible to insert the IA tip under the optic edge. However, the surgeon can gently move the lens to one side using a lens-dialling instrument, or using the IA heel to create the gap required to insert the IA tip under the optic.

Although unlikely in the port-up position, it is recommended that the surgeon pay careful attention to the IA tip to ensure no portion of the posterior capsule is aspirated into the port. The IOL implant should not be lifted or pushed too far to one side, as this can stress the capsule and associated zonules. Only a slight upward tilt is required to allow the viscoelastic material beneath the IOL to escape as it is aspirated. After the viscoelastic is removed, the IA tip is manoeuvred from beneath the lens optic to allow the IOL to fall back into the capsule bag. The IOL can then be centred using the IA heel. A further application of aspiration above the lens will help remove any residual traces of viscoelastic. See Video 2.2.

Novice surgeons should appreciate that their Trainer may not routinely perform aspiration of viscoelastic material from beneath the lens implant. Alternatively, Trainers may avoid this procedure if they do not yet have confidence in novice surgeon's foot and instrument control. Consequently, the Trainer may prefer to only supervise aspiration of viscoelastic above the IOL implant, encouraging a technique whereby trapped viscoelastic is released by gently rocking and moving the IOL during aspiration.

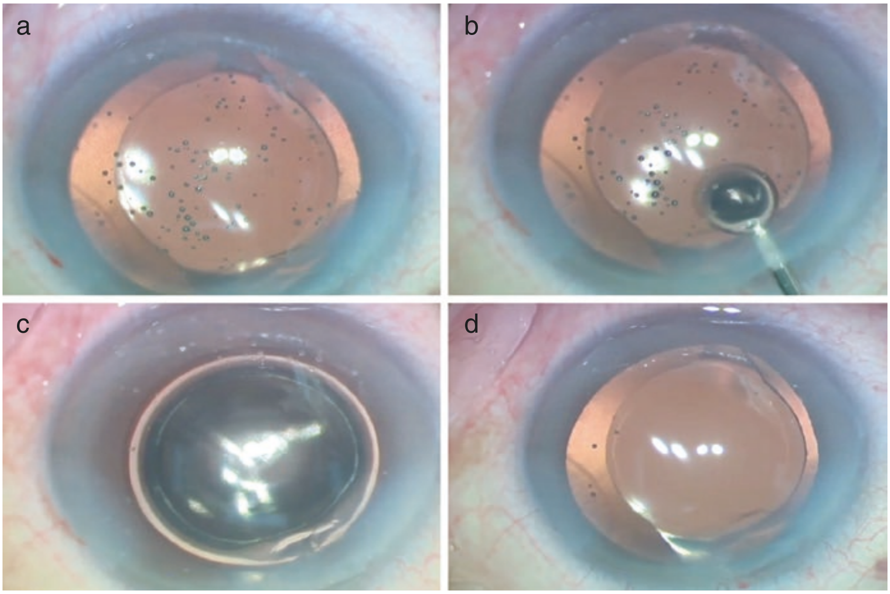

Fig. 2.24 Unwanted minute air bubbles. (**a**) Unwanted minute air bubbles following lens insertion, (**b**, **c**) large air bubble injected, (**d**) appearance post aspiration

2.9 Removing Tiny Air Bubbles at the End of Surgery

At the end of surgery, re-inflation of the anterior chamber with balanced salt solution is required. Occasionally minute champagne-like bubbles within the solution can enter the eye and stick to the endothelium. These are not harmful if left in situ, since the bubbles will resolve. However, many surgeons prefer it if they are removed. Unfortunately, bubbles often can prove difficult to aspirate completely (requiring unwanted risky aspiration close to the endothelium or movement of the eye to dislodge the bubbles off the endothelium). Rather than waste surgical operating time moving the eye, or risking endothelial damage, it is better to simply inject an air bubble into the eye. The smaller bubbles will immediately coalesce with the larger, and subsequently a quick aspiration is all that is needed to remove them (Fig. 2.24). See Video 2.3.

2.10 Stromal Hydration at the End of Surgery

For completeness, the novice will need to ensure the anterior chamber is correctly inflated and the corneal incisions are self-sealing.

It is common for surgeon to use stromal hydration to help ensure main corneal wound does not leak. The effect only lasts for a few hours and the use of stromal hydration will depend on the Trainer's preference. Stromal hydration is performed by inserting the balanced salt solution cannula tip obliquely into the side edge of the

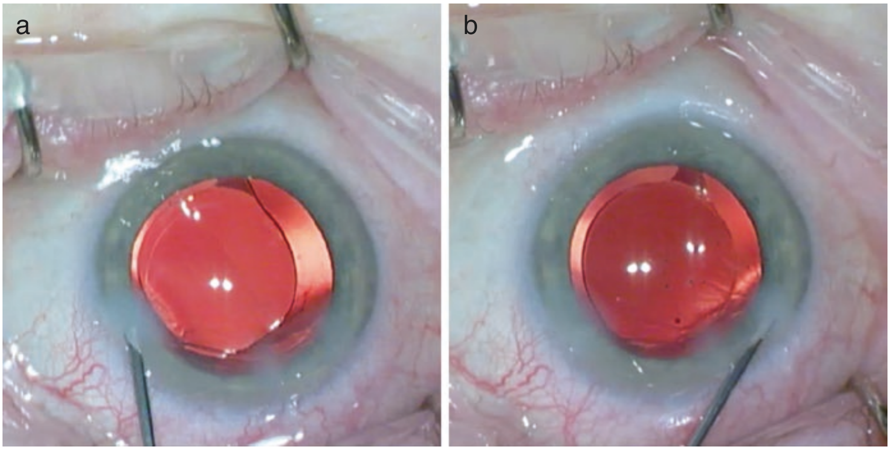

Fig. 2.25 Wound hydration. (**a**) Paracentesis hydration. (**b**) Main incision hydration. The cannula is positioned obliquely to the wound so the cannula tip is pushed against the corneal stroma

incision. Fluid is then gently injected to hydrate the stroma. This is then repeated on the opposite side of the wound and the side port paracentesis incision if required (Fig. 2.25). Care is needed not to over hydrate the stroma and the posterior lip of the incision should not be depressed (avoids anterior chamber collapse).

The Trainer will instruct if stromal hydration (and how much depending on any pre-existing hydration that has occurred during surgery) is required or if placement of a suture (unlikely as the Trainer will have performed the incision) to secure the wound.

Gentle pressure on the on the side of the eye (on the opposite side of the paracentesis) can help the surgeon gauge the firmness of the globe and if it has been over inflated. If judged to be too firm fluid can be allowed to escape by pressing on the posterior lip of the incision.

2.11 Intra Cameral Antibiotic at the End of Surgery

As part of common standard practice an injection of an intra cameral antibiotic will be required. This can be done via the main wound or side port. If injecting via the main incision, the surgeon should try to lift the anterior lip of the wound with the cannula tip. Pressure on the posterior aspect of the wound will allow fluid to escape from the eye and may cause the anterior chamber to collapse.

Box 2.3 Trainer Teaching Pearls

With modular training, it is recommended that irrigation/aspiration is the first intraocular technique performed by a novice surgeon on a patient.

Whilst performing surgery under supervision, novice surgeons may suffer from spatial disorientation. Several factors contribute to this problem during initial training: miscommunication between the Trainer and the novice surgeon; not understanding instructions relating to intraocular movements; switching from the right to the left eye in sequential cases; variation of the operating position; and whether or not the novice has a dominant hand which is opposite to that of their Trainer. Each ophthalmic unit should agree on the orientation terminology to be used and the terms given for IA movements. This text provides useful suggestions in that regard.

It cannot be assumed that the novice surgeon will know what to do simply by observing the Trainer beforehand. Precise instructions, using simple key phrases, need to be expressed so that novice surgeons can easily perform the required steps during surgery. A pre-planned surgical learning plan can identify any terminology differences.

It is important to establish the ability of novice surgeons to follow instructions without making too many unnecessary independent instrument movements within the eye. This is important, as Trainers must be confident that the novice will listen and stop when instructed. Training can then be adapted accordingly and the novice educated to ensure patient safety is maintained.

At the start of training, novices need to appreciate that the Trainer will anticipate potential complications and instruct on how to avoid them, whereas the novice will not have the surgical experience to do this. It is important to explain to novices that independent operating without instruction will only develop over time. It is suggested the Trainer (at the start of viscoelastic training above an implanted IOL) instructs the novice to aspirate in the central safe zone for 10–20 s without moving the IA tip. This is a good way to determine ability of novice to follow instructions.

Another recommendation is that IOL insertion is taught before SLM removal. This stepwise training approach is recommended to ensure continuous surgical training may occur without the Trainer having to take over between steps. As the novice's confidence increases with each task, new steps can be introduced. Trainers can decide how much to break down the irrigation/aspiration module into individual components.

Although surgical lists may comprise cases of varying complexity, as the initial parts of the procedure is performed by the Trainer, once the IA stage has been reached it is likely that some of the remainder of the operation will be suitable for novices. In this fashion, novices may perform the predetermined surgical IA steps on the majority of cases even when they may not have been able to perform any other stage of the procedure.

It is not recommended that the Trainer allows the novice to deviate from the pre-planned IA surgical step. For example, it would be easy to allow the novice surgeon an attempt at capsulorhexis if the case looks ideal. Instead, it is considered preferable that novices become fully competent at the skill they are assigned before attempting an additional step (which they may potentially fail, decreasing their confidence in the IA skills they have obtained).

By the end of viscoelastic removal and IOL insertion training the novice surgeon should be capable of demonstrating the movements needed for SLM removal above the lens implant. It is recommended that IOL insertion is taught after the start of viscoelastic removal training. Pseudo SLM removal movement practice should be performed during IOL insertion training and continued during SLM training module above the lens implant. This will aid understanding and encourage purposeful movements during actual SLM removal.

2.12 Summary

The end of the cataract operation is recommended as the start of phacoemulsification training for the novice ophthalmic surgeon. Removal of viscoelastic from the anterior chamber provides an ideal opportunity to gain skills in instrument, foot pedal and microscope control. IA probe movements required for SLM removal can be practiced using the IOL implant to keep probe movements at the same horizontal level within the anterior chamber and make use of it as a posterior capsule safety barrier during the viscoelastic removal and IA probe movement training. Anatomical ocular orientation and terminology for movements can be reinforced whilst the Trainer completes the majority of the procedure. This rear end approach will allow the novice to observe the key stages of the operation, provide time for the Trainer to explain the steps and ensure Trainee understanding before they actually perform the step themselves.

3 Intraocular Lens Insertion

Following the removal of any residual soft lens material, the artificial intraocular lens (IOL) implant is inserted into the empty capsule bag. Common practice is to use a pre-loaded injector system to insert the IOL into the eye. There are many injectable systems on the market, and each manufacture has their own lens and injector design. Thus, each device system will have a recommended IOL preparation and implantation technique. Novice surgeons will need to be familiar with the injection device and implant used in their unit. Trainer and Trainee should discuss the precise specifics before surgery.

Refractive choice, biometry calculation, IOL materials and design, and IOL types are an essential part of phacoemulsification training. However, it is unlikely novice surgeons will implant any multi focal, toric or anterior chamber lenses in the early stages of training. As a result, only the fundamentals of mono-focal, single piece IOL insertion are described below.

3.1 Terminology

3.1.1 Phakia

Phakia is the presence of the patient's own natural lens.

3.1.2 Pseudophakia

Pseudophakia is the replacement of the natural crystalline lens with an artificial lens during cataract surgery. An appropriately selected IOL can be placed in the capsular

Electronic Supplementary Material The online version of this chapter (doi:10.1007/978-3-319-59924-3_3) contains supplementary material, which is available to authorized users.

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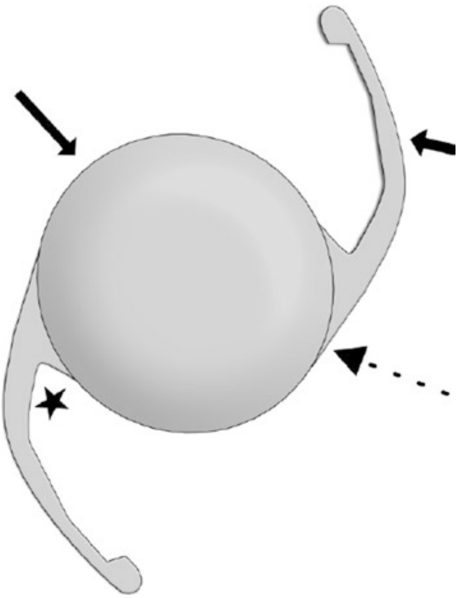

Fig. 3.1 Intraocular lens anatomy. Optic (*long arrow*), haptic (*short arrow*), optic haptic junction (*star*), shoulder of lens (*dotted arrow*)

bag, the ciliary sulcus or the anterior chamber. During uncomplicated surgery, standard practice is to place the IOL into the capsular bag at the end of surgery.

The IOL consists of the central *optic* and attachments called *haptics*. The flexible haptics provide support to hold the optic centrally within the capsular bag. The point where the *internal* curve of each haptic meets the optic is the *optic haptic junction*. The meeting point of the *outer* haptic curve and the optic form what is known, for the purposes of surgical instruction, as the *shoulder* of the lens (Fig. 3.1).

3.1.3 Haptic Terminology

The artificial lens is housed within an injector cartridge system. This ensures a folded lens can be inserted through a small corneal incision. Following injection of the IOL within the eye, the aim is to ensure the optic and haptics are placed within the capsular bag. Before the IOL unfolds completely, it can be directed through the capsulorhexis opening. As a result, it is simple to place the *leading* haptic, the associated shoulder and leading optic edge within the capsular bag. It may be harder to achieve complete placement of the opposite shoulder, trailing haptic and part of the optic (Fig. 3.2).

For complete in-the-bag placement the remaining part of the IOL (namely, the optic and the trailing haptic) will require manipulation into the bag. This is

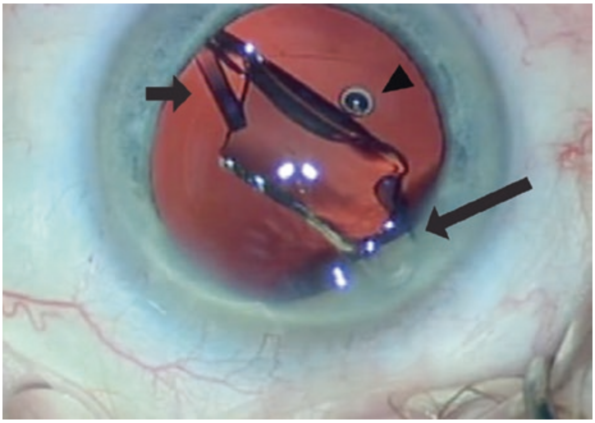

Fig. 3.2 Incomplete IOL in-the-bag placement. IOL has just been injected and is starting to unfold. Leading haptic (*short arrow*), trailing haptic (*long arrow*). Air bubble artefact (*arrow head*)

commonly referred to as *dialling*. Occasionally, if the lens is injected above the capsulorhexis then the whole lens may unfold outside of the capsule bag. In this instance, both haptics as well as the optic will need to be dialled into the bag.

3.2 Lens Implant Orientation

Modern lenses have aspheric design (to minimise spherical aberration) and are commonly vaulted slightly backwards. In view of this, the IOL ideally needs to be orientated correctly within the capsular bag. During insertion, however, the IOL may inadvertently flip over. Although it is possible to place an upside-down lens in the bag, it is not ideal as this can affect the final refraction. An upside-down lens can be recognised as the haptic and optic of an upside-down lens will form the letter “S” (Fig. 3.3). If this happens, the surgeon should stop and manipulate the orientation of the IOL accordingly. Reorientation before in-the-bag placement is performed by gently rotating the lens implant, either by pivoting the IOL using the trailing haptic as a handle, and/or by directly manipulating the optic within the eye (Fig. 3.4).

3.3 Step-by-Step Technique

The aim of IOL placement is to inject the lens into the anterior chamber and ensure it is correctly placed into the capsular bag via the capsulorhexis opening. Care is required to ensure the capsule, zonules or other ocular tissues are not traumatised during the process.

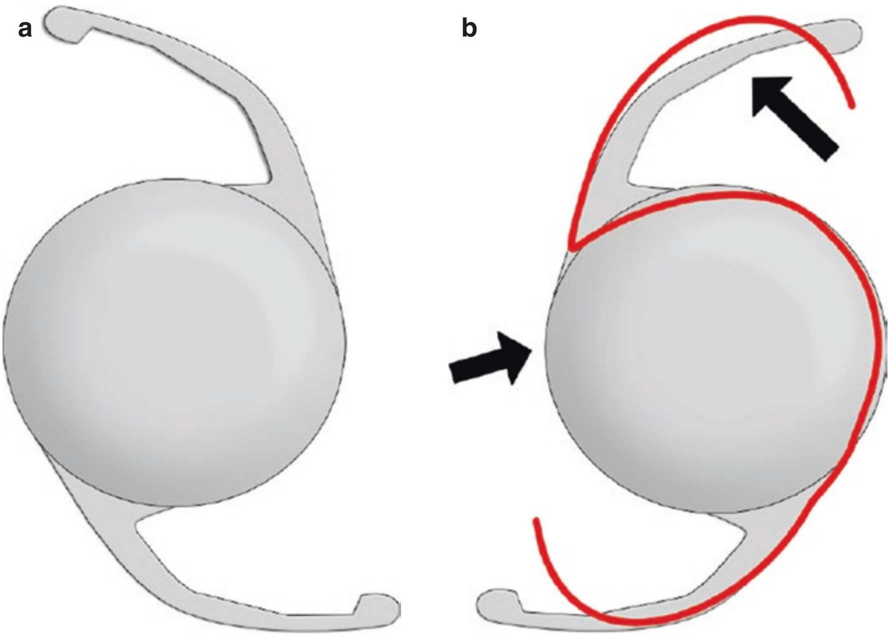

Fig. 3.3 Intraocular lens orientation. (**a**) Correct placement, (**b**) incorrect placement with upside down implant. Haptic (*long arrow*) and optic (*short arrow*) form letter S when implant is upside down (*solid line*)

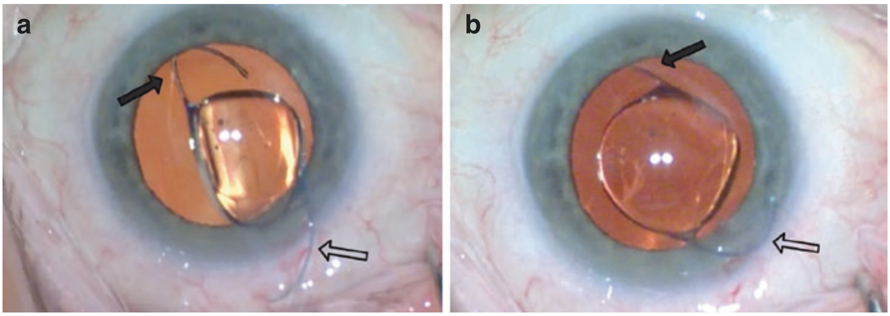

Fig. 3.4 Intraocular lens orientation. (**a**) Upside-down orientation of 3-piece IOL. Leading haptic (*solid arrow*) is partly under the capsulorhexis edge, trailing haptic (*open arrow*) has not been inserted into the eye. (**b**) Intraocular lens correctly orientated. Leading haptic (*solid arrow*) is under the capsulorhexis edge, trailing haptic (*open arrow*) has not been inserted into the eye

3.3.1 Step 1

The injecting cartridge system is prepared as per the manufacturer's guidance.

It is preferable to only leave a small amount of viscoelastic within the cartridge nozzle ahead of the lens when priming the injector. Too much viscoelastic in the nozzle can lead to overfilling of the capsule bag as the lens and accompanying viscoelastic is injected into the eye. The surgeon should avoid priming the injector excessively as this may result in partial exposure of the lens from the injector nozzle tip. In this situation it may not be possible to insert the injector nozzle into the eye. Conversely if the surgeon decides a small top up of viscoelastic is required (despite filling the eye previously with viscoelastic) a greater quantity of viscoelastic can be left within the nozzle before the lens is injected. The Trainer will advise on this.

3.3.2 Step 2

The capsule bag needs to be filled with viscoelastic. This buffers and protects the ocular tissues (especially the capsular bag) as the IOL is inserted. If a small amount of viscoelastic is expelled just before the cannula is inserted into corneal section any air trapped in the cannula hub is flushed out. This avoids inadvertently injecting any air, if the viscoelastic syringe has not been primed, (an example of an air bubble within the anterior chamber is shown in Fig. 3.2). Air bubbles do not hinder the insertion of the IOL and can be directed to the periphery, to avoid obscuring the central view, simply by injecting more viscoelastic. Following lens implantation, any bubbles are easily aspirated during viscoelastic removal.

Before viscoelastic is inserted, the posterior aspect of the bag is commonly visible and in-focus (Fig. 3.5a). The viscoelastic will push the posterior capsule away

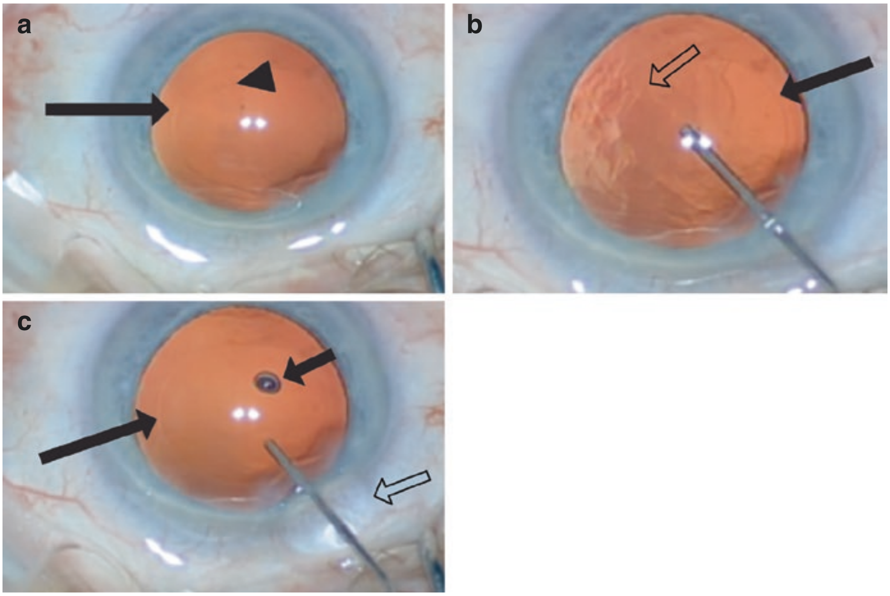

Fig. 3.5 Viscoelastic insertion. (**a**) Empty capsular bag following soft lens material removal. (**b**) Injection of viscoelastic into the eye. (**c**) The capsular bag is full and ready for the lens to be inserted. The posterior capsule is out of focus, capsulorhexis edge (*long arrow*), posterior capsule (*arrow head*), viscoelastic material (*open arrow*), air bubble (*short arrow*)

(Fig. 3.5b) and consequently it will go out of focus as the bag is filled (as the microscope focus remains at the level of the capsulorhexis).

It is recommended that a continuous amount of viscoelastic material is injected into the eye as the viscoelastic cannula tip is inserted. This is to ensure the posterior capsule is not inadvertently damaged. Once the capsule bag is full, the viscoelastic starts to leak out of the corneal incision (Fig. 3.5c). This is a good sign to watch for, as it usually indicates the bag is full and additional viscoelastic injection is not needed. Lens insertion can then begin.

3.3.3 Step 3

The injector cartridge tip should be correctly placed in the centre of the capsulorhexis before IOL injection commences. It should be held at an angle so that the leading haptic is directed down into the bag, rather than over the surface of the anterior capsule (Fig. 3.6).

As the lens is injected into the eye, a feeling of resistance should be expected, along with the sensation that the injecting tip wants to slip back out of the corneal incision The injector should be held firmly in place, otherwise the IOL may be released in an uncontrolled fashion which can cause the optic to unfold in an unpredictable way. By ensuring the tip stays in the eye until the lens is fully injected, the leading haptic and optic can be directed into the capsular bag rather than allowing any part of the IOL to try and unfold within the corneal wound.

3.3.4 Step 4

After the IOL is fully released, the trailing haptic will remain folded on the surface of the optic for a brief period, after which it will start to unfold. Whilst the trailing haptic is still folded over, a potential opportunity for easy lens insertion into the bag

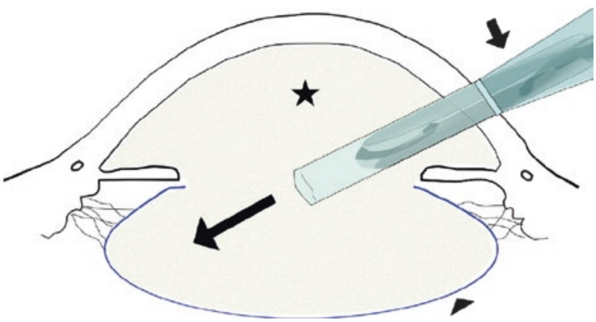

Fig. 3.6 Correct orientation of injector cartridge during lens insertion. Lens cartridge with preloaded lens (*short arrow*), viscoelastic within anterior chamber (*star*), injection direction (*long arrow*) into the capsular bag (*arrow head*)

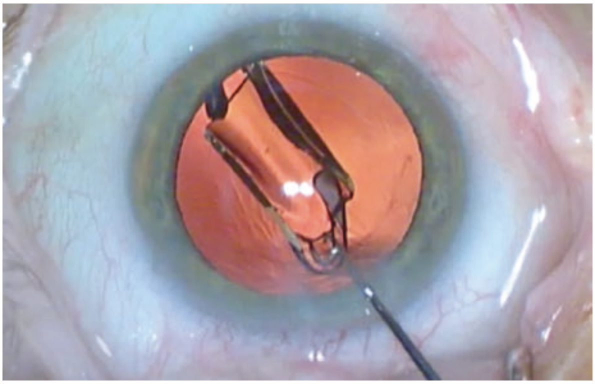

Fig. 3.7 Direct insertion of trailing haptic and shoulder of intraocular lens into capsular bag. Lens is pushed downwards into bag using dialler instrument before haptics have fully unfolded

exists. Unhindered, downward movement of the lens into the bag is possible as the folded haptic only partially rests on the anterior capsule surface. This ideal situation allows the surgeon to quickly apply downward pressure to the trailing optic edge, which will force the IOL shoulder and trailing haptic completely into the bag (Fig. 3.7). A small amount of capsule stretch will be tolerated as the optic edge slips past the capsulorhexis. The surgeon must ensure the edge of the optic and its shoulder are pushed below the plane of the capsulorhexis edge. Once done the haptic will then easily unfold within the bag. See Video 3.1.

3.3.5 Step 5

Once the IOL leading and trailing haptics have been inserted into the capsule bag, the optic and haptics will continue to unfold completely. Depending on the technique chosen to remove the viscoelastic, there is now a good opportunity to access the space under the IOL (see Chap. 2). Before the lens is completely centred with the capsule bag, the potential space between the optic and capsulorhexis edge can be used to gain access and remove any viscoelastic from beneath the IOL (Fig. 3.8). Afterward, the IOL can be centred using the irrigation aspiration probe tip.

Alternatively, the lens can be centred using the dialler instrument. The lens optic should be covered by the edges of the capsulorhexis (Fig. 3.9) to help prevent the risk of lens epithelium cell ingrowth covering the posterior capsule.

3.4 Dialling the Lens Into the Capsule Bag

If the trailing haptic has already started to unfold, it may not be possible to simply push the IOL into the bag via the capsulorhexis opening. In this scenario, the IOL must be *dialled* into the bag.

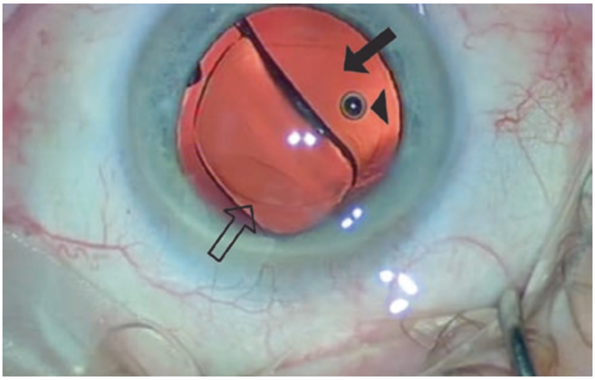

Fig. 3.8 Gap between intraocular lens and capsulorhexis as lens unfolds. Capsulorhexis (*open arrow*), gap (*solid arrow*), air bubble (*arrow head*)

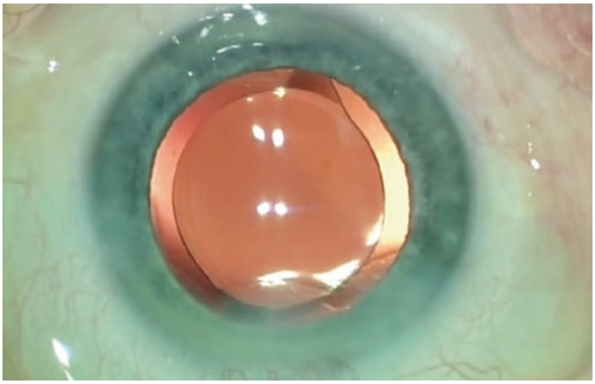

Fig. 3.9 Intraocular lens implant is centred within the capsule bag and over lapped by the edges of the capsulorhexis

Dialling consists of two combined movements: *rotation* combined with *downward pressure*. If only rotation is performed (with one haptic out of the bag), the lens will spin and the haptic and shoulder will remain above the capsulorhexis edge as the lens rotates. Using only downward pressure will result in the lens springing upwards when the force is released, as the haptic and shoulder remain above the anterior capsule. Only the dual movement of rotation and downward pressure will work effectively with minimal dialling effort.

Correct instrument placement is required to perform the dual movement. It is recommended the dialling instrument is placed into the haptic optic junction. This will allow a rotational force to be applied. Furthermore, the dialler needs to tilt, so that part of it *leans* on the optic surface. This will facilitate a downward pressure on the optic. The lens can to be rotated and directed downwards so that the shoulder gets past the capsulorhexis edge, ensuring the IOL is fully inserted into the bag (Figs. 3.10 and 3.11). It is common for novice surgeons to hold the dialling instrument in a completely vertical position. Rotation of the lens is possible, but as a

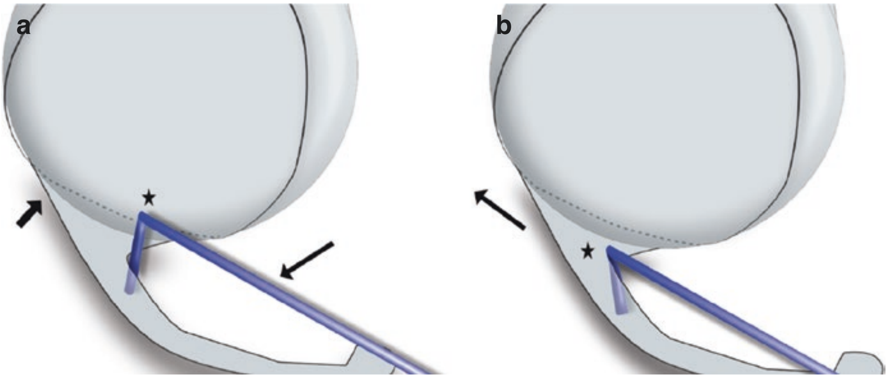

Fig. 3.10 Correct and incorrect placement of the lens-dialling instrument into the haptic optic junction: part 1. (**a**) Correct placement of the lens-dialling instrument into the haptic optic junction. The dialler (*long arrow*) abuts against the haptic optic junction and leans onto the optic (*star*), applied pressure allows the optic shoulder (*short arrow*) to spiral downwards below the capsulorhexis edge (*curvilinear line*). (**b**) Incorrect placement. The dialler abuts against the haptic optic junction (*star*) and only one direction of force (*arrow*) is applied. The lens will rotate but optic shoulder and haptic will remain above the capsulorhexis (*solid curvilinear line*)

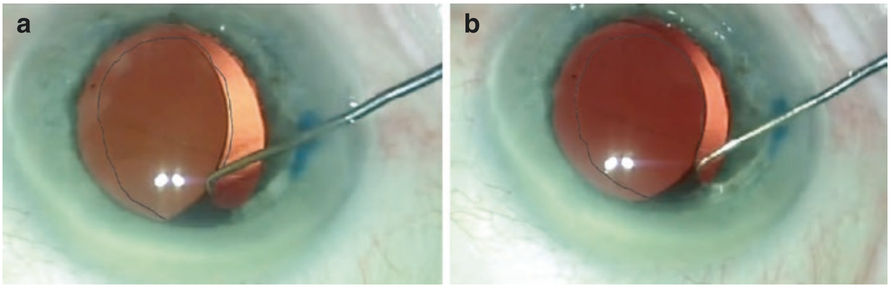

Fig. 3.11 Correct and incorrect placement of the lens-dialling instrument into the haptic optic junction: part 2. Colour image. (**a**) Correct placement of the lens-dialling instrument into the haptic optic junction. The dialler abuts against the haptic optic junction and leans onto the optic. (**b**) Incorrect placement. The dialler abuts against the haptic optic junction but fails to lean on the optic. Capsulorhexis (*solid curvilinear line*)

downward force is applied the instrument will tend to slip under the haptic, thus requiring additional attempts at dialling or pushing the IOL into the bag.

Trainees occasionally will hold the dialling instrument with the shaft against the left hand side of the incision during insertion into the eye. This can make correct placement into the haptic optic junction awkward and the instrument is kept more vertical. By approaching the lens with the shaft of the dialler more towards the right hand side of the incision can help with getting the placement of the dialler tip into the haptic optic junction and allow it to tilt it so it rests it partly on the lens optic. See Video 3.2.

If both haptics are outside of the bag it is recommended that the trailing haptic nearest the incision is initially dialled into the bag. Then, rotational pressure *only* should be applied to spin the lens around in the bag *without* trying to dial the leading haptic and shoulder into the bag. The lens will reach a position where the haptics have switched positions. The second haptic and shoulder can then be dialled into the bag as usual. This will allow a more comfortable surgical hand position for dialling the leading haptic and shoulder of the lens into bag. If the surgeon is more confident, the leading haptic can be pulled centrally using the dialler and the leading shoulder pushed down into the bag. The trailing haptic is subsequently dialled into position.

Before dialling the IOL into the bag, it is sensible to check whether the injected lens appears almost flat or remains obliquely orientated. If tilted obliquely, it is recommended that the optic is pushed down slightly in order to flatten the IOL before attempting to dial the trailing haptic and shoulder into the bag.

Box 3.1 Trainer Teaching Pearls

Once the Trainer has removed the lens and soft lens material, most the cases are suitable for IOL implantation by novice surgeons. Exceptions may include patients with a low endothelial count, or cases where the rhexis is incomplete.

It is good practice for the novice surgeon to continue to perform soft lens material pseudo-removal movements above the lens implant during viscoelastic removal and IOL insertion training.

It is common for novice surgeons to want to watch the IOL unfold after implantation. Consequently, the trailing haptic unfolds and more manipulation and subsequent dialling is needed. Novice surgeons should be warned that they should be ready to use the dialler immediately after IOL injection rather than pausing.

Incorrect instrument placement by the novice during dialling of the lens has the potential for the instrument to slip past the optic and damage the capsule during multiple attempts at lens in-the-bag placement. This may lead to a brief period of Trainer and Trainee anxiety during training. It is common amongst novice surgeons starting this module, to misunderstand how to perform the dual movement required to dial a lens into the bag. It is recommended that novice surgeons perfect instrument placement and dialling technique. Verbal feedback from the Trainer, coupled with watching recorded technique can help gain understanding on how to hold and ideally place the instrument into the haptic optic junction so it partly rests on the surface of the optic.

Dialling technique can be utilised by the Trainee to dial an IOL into the sulcus if in-the-bag placement is not possible.

Novice surgeons may be unaware that the IOL is obliquely positioned and titled within the capsule bag after initial injection. Dialling a more vertically placed IOL into the capsule bag can pose a challenge for the novice compared to a more horizontal initial position. It is advisable that the Trainer actively comments during surgery on whether they wish the novice surgeon to flatten the IOL orientation, by initially pressing down on the lens optic, before dialling the IOL.

Some novice surgeons struggle to grasp how to insert an unfolded trailing haptic *(recognised by the training haptic resting on the anterior capsule with its haptic end either hiding in the iridocorneal angle or under the iris)* and its associated shoulder smoothly into the bag. Often the problem lays in the fact the novice does not quite understand the principle of applying both a downward force and a rotatory movement. This may stem from lack of understanding of where to place the dialling instrument. Consequently, more time and repeated attempts are needed. A more precise downward and a rotatory dialling technique will then be required. To aid technique feedback during a theatre session, the Trainer can visually represent the IOL and dialling position using ones' own hands. The left hand (palm down with the thumb extended) represents the lens. The thumb, the index finger and the web space between the index finger and thumb represent the haptic, optic and optic haptic junction respectively. By placing the right index finger (representing the dialler) into the space, the novice can be shown visually how correct or incorrect dialler placement moves the lens (Fig. 3.12).

The Trainer is advised to intermittently observe the novice surgeon's hands during IOL insertion. It is common for beginners to hold the injecting

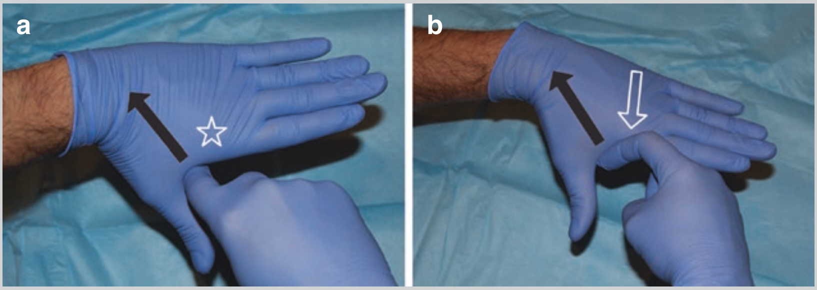

Fig. 3.12 Visual representation of correct dialler placement within optic haptic junction. (**a**) Incorrect placement. *Left* hand, thumb and web space represent the lens optic, haptic and optic haptic junction. *Right* index finger represents the dialling instrument. Lens movement occurs in one direction (*solid arrow*). No applied downward applied pressure on the optic (*star*). (**b**) Correct placement. Dual movement with rotary (*solid arrow*) downward (*open arrow*) component

cartridge awkwardly when trying to inject the lens. This can lead to a tremor, and as the cartridge tip moves within the eye the IOL is not released smoothly. Trainees may find it easier to hold the injector steady with their dominant hand and control the plunger with the non-dominant hand rather than the other way round.

For initial cases, the Trainer is advised to fill the bag with viscoelastic before hand over. For subsequent cases, since the Trainer has performed early steps plenty of viscoelastic is available for the novice to use. When the novice starts capsulorhexis training however, a larger amount of viscoelastic may be used up and thus an insufficient amount available to subsequently completely fill the bag for IOL insertion. The novice may be advised to leave a greater amount of viscoelastic within the tip of the injector before injecting the lens, or additional viscoelastic may be required. If, during injection, the IOL should start to touch the posterior capsule, advising the novice to flatten the angle of insertion (so the lens is directed into the equator of the bag) can help prevent potential zonular or capsule damage.

3.5 Summary

Insertion of the IOL is a relatively easy technique to master. Being able to successfully dial the IOL into the bag is facilitated by having a good understanding of the fundamentals how to correctly place the instrument into the optic haptic junction. Once mastered, novices will be able to complete the remainder of the procedure in most cases, thus promoting modular training.

4 Soft Lens Material Removal

Irrigation/aspiration (IA) of residual soft lens cortical material is required to clean the inner surface of the capsule bag before placement of the intra ocular lens (IOL).

The various movements the surgeon is required to make with the IA probe tip are explained in Chap. 2. It is assumed the novice surgeon is familiar viscoelastic removal and IOL insertion. Furthermore, the novice surgeon is expected perform IA probe movements and manipulate the IA probe in the correct trajectory when instructed by the Trainer. Ability to demonstrate foot pedal control of irrigation only verses irrigation combined with aspiration and ability to reflux the material from the IA tip port is recommended.

The following description is for a right-handed surgeon—transposition of instructions will be required for left-handed surgeons. Fundamental IA principles that describe the most common method (coaxial) are introduced below in a stepwise fashion. Though manual and bimanual techniques are not described, the fundamental principles of aspiration technique remain the same. Recommendations for Trainers are suggested at the end of the chapter.

4.1 Irrigation/Aspiration Fundamentals

4.1.1 Aspiration of Soft Lens Material

The fundamental idea of SLM removal is based on 3 principles:

1. A redundant strip of anterior SLM is aspirated and captured into the IA port (i.e. holding aspiration used).

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2. The SLM attachment to the anterior capsule is loosened by pulling and dragging the SLM away from its capsule. This severs the SLM capsule adhesion anchor points on the anterior aspect of the capsule (i.e. peeling aspiration used).
3. The SLM is completely peeled off the posterior capsule by increasing aspiration, fully removing the strip of captured SLM (i.e. foot down aspiration used).

During SLM removal the following questions need to be considered:

1. "Where is SLM adherent or stuck to the capsule?"
2. "Towards which direction does the SLM need to be dragged in order to free it from its capsular bag anchor points?"

It should be noted that the direction of drag required to maximise the area of SLM removal may change as SLM is peeled or fully aspirated. Experienced surgeons will do this automatically, but for novice surgeons the subtle change in IA tip direction may not be appreciated unless pointed out during training.

4.2 Aspiration Zone Terminology

The capsule bag can be divided into five zones that each contains 2–3 clock-hours of SLM. Although experienced surgeons may tackle the SLM zones in any order, it is recommended that novice surgeons remove the SLM in a set order, beginning with zones 1–3 consecutively and finishing with the choice of either zone 4 or 5. It is further recommended that each zone of SLM is removed by moving the IA tip in a particular trajectory (Fig. 4.1).

For novice surgeons operating under instruction, tackling a fixed order of zones using set IA movements promotes easy identification of each zone, allows a predictable movement pattern within the eye, and ensures the IA tip trajectory is as short as possible. As each case is performed in a repetitive fashion, the controlled movements required for stripping the SLM from each zone is quickly developed. If the

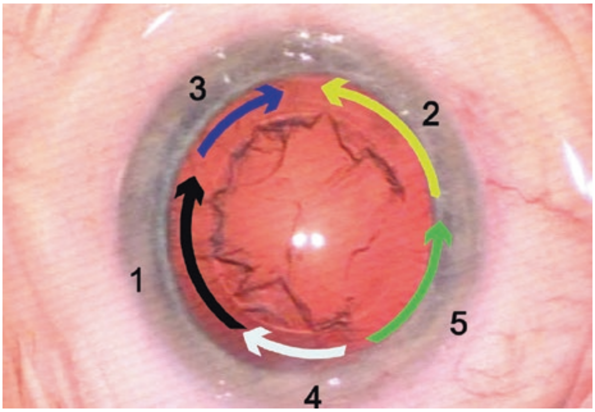

Fig. 4.1 Soft lens material removal zones. Zones are labelled 1–5, direction of irrigation/aspiration probe tip movement (*solid arrows*)

Trainer feels a certain area of SLM needs to be removed out of sequence, the novice surgeon can be instructed to tackle the appropriate zone accordingly.

Box 4.1 SLM Aspiration Training Tip

- When initially learning IA of the SLM, it is recommended that the Trainer remove all sub-incisional SLM in zones 1, 4 and 5. The novice surgeon can take over and continue to remove the residual zones of SLM in zones 2 and 3, followed by lens insertion and viscoelastic removal. As training progresses, more of the SLM in zones 1, 4 and 5 can be left in situ for the novice to remove. Overall, this modular approach reduces the need for the Trainer take over, facilitating the on going practice of IA movements required until the novice surgeon is ready to attempt the remaining zones. See Videos 4.1 and 4.2.

4.3 Step by Step SLM Zone Instruction

4.3.1 Zone 1

Before entering eye check the irrigation fluid flow works, briefly wet the cornea, and enter the eye with the port-up. Aspiration during insertion of the IA tip should not be applied (*listen out for the sound difference generated during irrigation-only compared with that of the aspiration setting*). Once inside, pause for a moment in the safe zone with the port-up to allow anterior chamber to inflate fully (Fig. 4.2).

Rotate the tip anti-clockwise so that the aspiration port almost faces side-on towards the start of zone 1. For novices, it is preferable to initially maintain the instrument within the centre of the safe zone until the rotation movement is complete, before moving the IA tip towards zone 1 (Fig. 4.3). For more experienced surgeons, the tip can be rotated into the side on position as it is moved towards zone 1.

As the port approaches the capsulorhexis border, commence aspiration and increase it so that the redundant SLM overhanging the capsulorhexis edge is *captured* into the IA port (i.e. *holding* aspiration). The SLM will be drawn to the aspiration port in preference to the capsule itself. Movement of the SLM into the IA port should be looked for and recognised (foot down aspiration is avoided as this would allow the port access to unprotected anterior capsule as the redundant SLM is fully removed).

Once a portion of the SLM is captured, the initial aim is to strip the SLM off the anterior portion of the capsule, then the posterior aspect. In order to achieve this, the tip movement should continue in a circular fashion just under the capsule. The IA tip, as it is moved in a circular fashion, will peel off the initial border of zone 1 SLM. It will then continue to peel the remaining wedge of zone 1 SLM as it is moved under the under the capsule and returned to the safe zone. The tip should ideally be port-up by the time it reaches the safe zone. The SLM is peeled off the anterior capsule in a tangential fashion (Fig. 4.4).

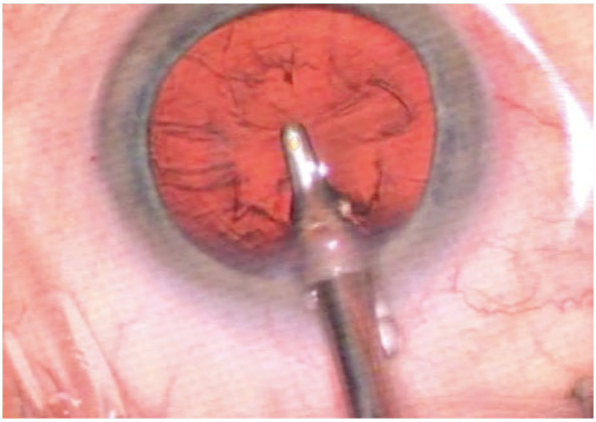

Fig. 4.2 Irrigation/aspiration probe inserted into the eye

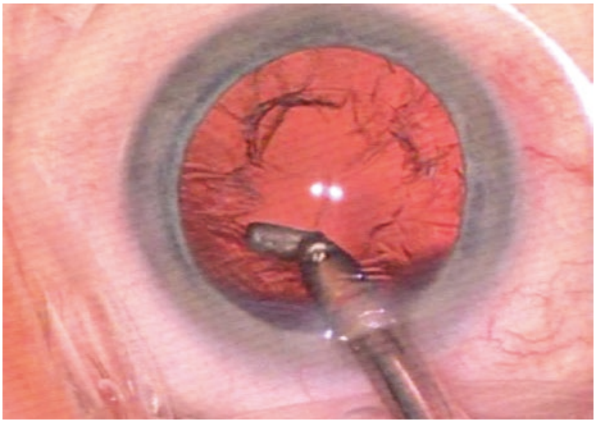

Fig. 4.3 Zone 1 soft lens material removal

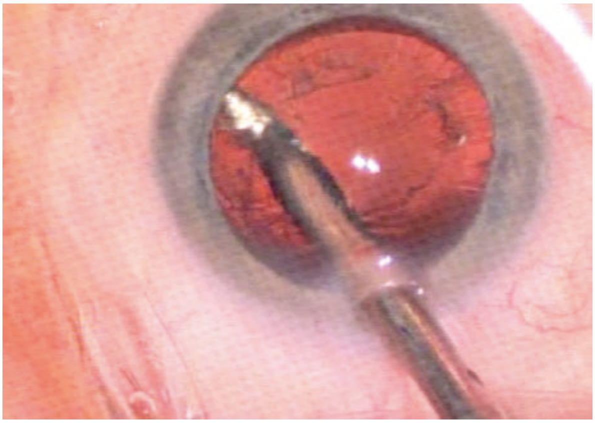

Fig. 4.4 Zone 1 soft lens material removal—clockwise movement

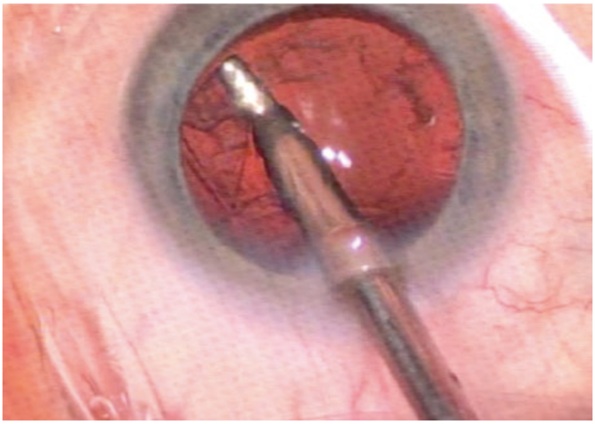

Fig. 4.5 Zone 1 soft lens material removal—triangular wedge. A triangular wedge of soft lens material is peeled off the anterior aspect of the capsule

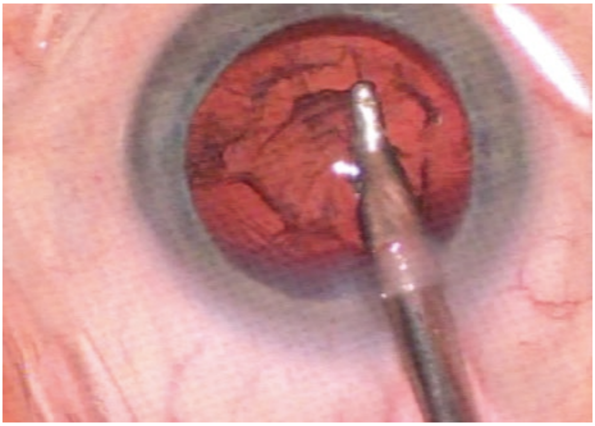

Fig. 4.6 Zone 1 soft lens material removal—lateral movement. Lateral movement maintains the soft lens material hold under tension

A clockwise movement of 2–3 clock-hours is performed as the IA port is rotated back to the port-up position.

During the movement, aspiration is adjusted and increased accordingly (*peeling* aspiration) in order to continue holding the SLM without fully aspirating it. As the tip is returned to the safe zone the SLM will be held under tension. Additional lateral with or without a *wind-on-a-stick* movement will increase the dragging effect and continue to peel the SLM off the anterior and part of the posterior capsule (Figs. 4.5 and 4.6).

If the SLM is not quite peeled off the capsule, then additional dragging movements may be required before engaging maximum aspiration. Additional dragging movements are done by making to-and-fro movements with the tip, attempting to grab a new holding point on the redundant, loose SLM. This new, fixed hold can then be used to drag and peel the remaining wedge of SLM off the capsule.

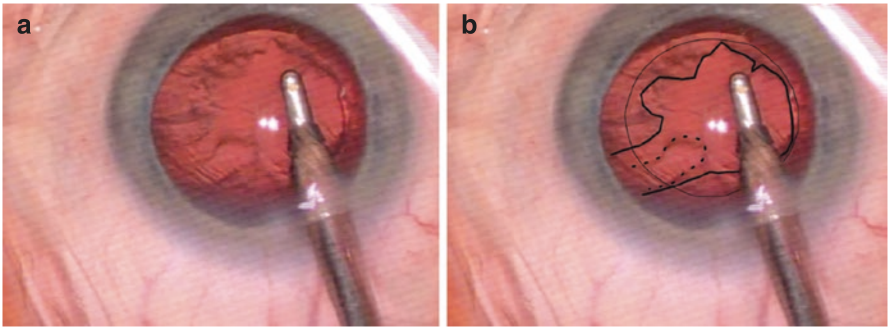

Fig. 4.7 Red-reflex appreciation post soft lens material removal in zone 1. (**a**) Colour image, (**b**) Colour image annotated. Gap (*dotted line*) in posterior portion of soft lens material (*irregular solid line*), capsulorhexis (*circular solid line*)

Once an area of SLM has been peeled sufficiently it is the time to apply f*oot down* aspiration to fully aspirate the strip of loose SLM. As soon as the SLM has been fully aspirated, power can be reduced and the tip positioned for Zone 2.

The borders of the missing sector of removed SLM will be identified by two signs:

1. A gap in the anterior SLM red-reflex contrasted by the reflex of the remaining SLM.
2. A wedge-shaped change in red-reflex on the posterior aspect of the capsule (Fig. 4.7).

4.3.2 Zone 2

The IA port should now be now close to the start of zone 2. The SLM is now removed from this region. Start aspiration just before the capsulorhexis edge as the port approaches the SLM. If required, a slight clockwise rotation of the tip just before commencing aspiration may help to ensure the IA port faces the SLM in zone 2. This facilitates capture of zone 2 SLM (Fig. 4.8).

Increase to *holding* aspiration in order to capture the SLM. Then make an anti-clockwise circular movement (at least 2 clock-hours) under the capsulorhexis, rotating the port up as it passes under the capsule (Fig. 4.9). Increase the aspiration to maintain the grasp on the SLM. The zone 2 SLM will then be seen to start to peel off the anterior then the posterior capsule (Fig. 4.10).

Drag the held SLM to the centre or beyond, so as to peel as much of the SLM from the capsule as possible. Diagonal and lateral drag can be combined with a *wind-on-a-stick* technique to ensure the SLM is peeled off the capsule, and then

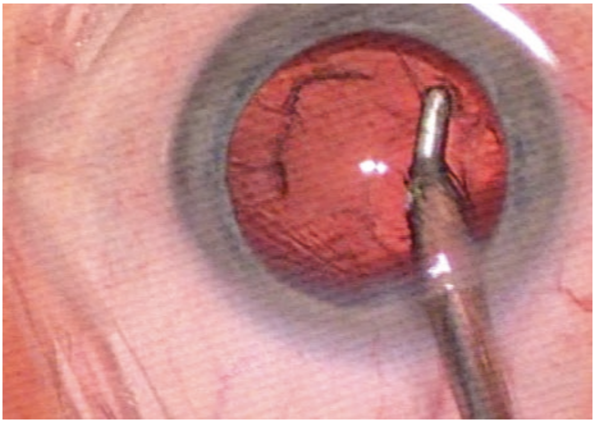

Fig. 4.8 Zone 2 soft lens material removal. Redundant anterior soft lens material over hanging capsulorhexis is captured. The IA port is rotated slightly to face the start of zone 2 soft lens material

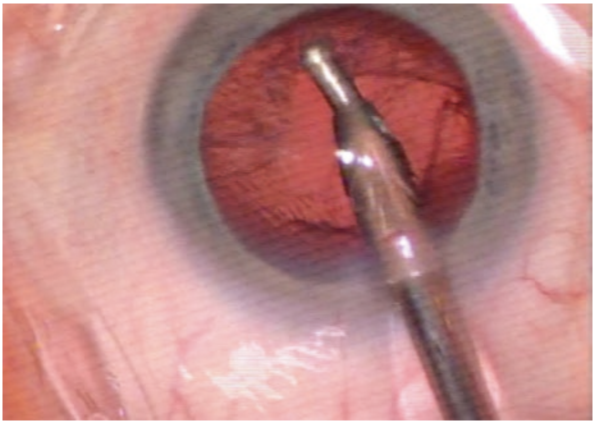

Fig. 4.9 Zone 2 anterior soft lens material is peeled off the capsule

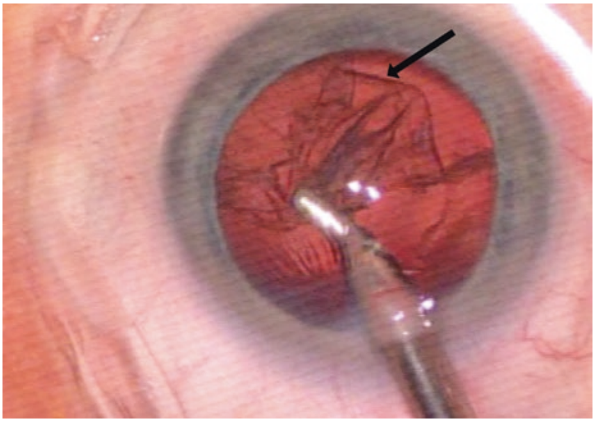

Fig. 4.10 Zone 2 soft lens material is dragged in an opposite direction to its capsule anchor points (*arrow*)

apply *foot down* aspiration to fully remove the wedge of SLM. The borders of the missing removed wedge of SLM will be clearly seen (Fig. 4.11). After Zone 2 SLM is removed, the IA tip is rotated slightly so that the port faces the SLM in Zone 3.

One of the key aspects of SLM peeling is to determine the direction the IA tip should take to ensure the held SLM is kept under tension. This direction may require adjustment during the peeling phase, as the SLM is dragged into the central safe zone, and readjustment during the aspiration phase. The change in direction is determined by deciding which part of the SLM remains attached to the capsule. The wedge of captured SLM forms a triangle, with the apex in the IA port and the base still attached to the capsule. Peeling in one direction usually peels one aspect of the triangle base more than the other (Fig. 4.12). Simply put, the surgeon asks, "Where is the SLM attached to the capsule?" and moves the IA tip accordingly to free that area of attachment.

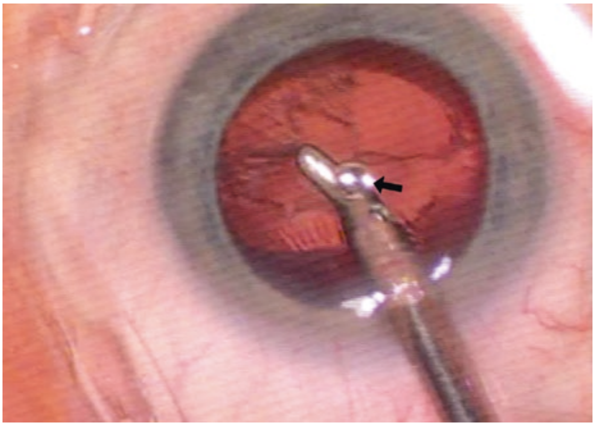

Fig. 4.11 Zone 2 red-reflex appreciation post SLM removal. A clear "V" shaped red-reflex wedge is noted where the SLM has been removed, air bubble within anterior chamber (*small arrow*)

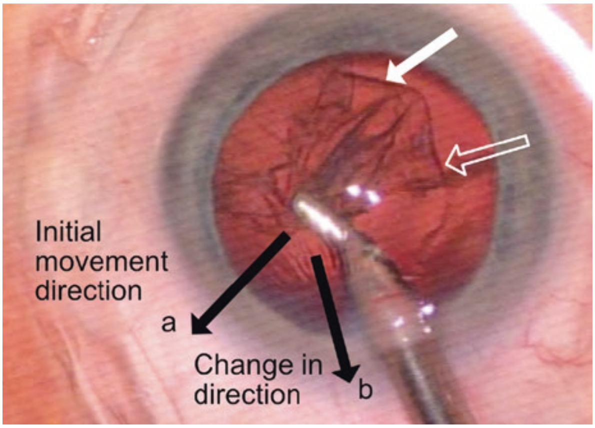

Fig. 4.12 Soft lens material is peeled off the capsule. SLM peeled off the capsule (*open arrow*) by initial movement (*arrow* **a**). A change in movement direction (*arrow* **b**) addresses soft lens material capsule adhesion points shown by solid white arrow

If *foot down* aspiration is applied without peeling the entire base, then a small strip of SLM may be left behind. Part of the SLM area may be fully aspirated whilst part of the targeted SLM area remains firmly attached to the capsule. The SLM should be watched closely during the *peeling* and *foot down* aspiration stages. A change in aspiration power that holds the SLM, rather than fully aspirating it, can provide time for the IA tip movement direction to be altered accordingly. With practice this change in movement will be done automatically during *foot down* aspiration.

4.3.3 Zone 3

Following SLM clearance from zone 2 the IA port should now be in close proximity to zone 3 and the SLM can now removed from this region. Again, it is recommended that aspiration is commenced *just before the capsulorhexis edge is reached*. Early aspiration will encourage the port to *catch* the SLM that extends beyond the capsulorhexis as the tip approaches the start of zone 3. Aspiration should be increased to maintain the SLM hold, before making a circular clockwise movement of at least 2–3 clock-hours. Ensure the IA tip passes under the capsulorhexis edge during this circular motion, and ensure the port is facing upwards towards the capsule. This movement will again pick up more SLM and occlude the port to maintain the SLM hold, allowing peeling of the SLM from the capsule. Drag the held SLM to the centre of the safe zone and/or beyond before *foot down* aspiration (Fig. 4.13).

Lateral movement can be combined with a *wind-on-a-stick* technique to facilitate dragging the SLM. The direction the surgeon takes, peels the SLM off the capsule, can also be adjusted. Once peeled off the anterior capsule, the redundant SLM can be fully aspirated within the safe zone.

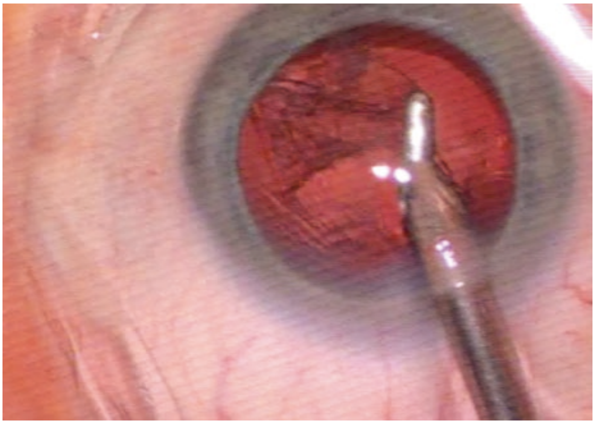

Fig. 4.13 Zone 3 soft lens material removal

4.3.4 Sub-Incisional Zones 4 and 5

Zones 4 and 5 can be done in any order, as the technique is similar. In the case illustrated, SLM in zone 5 was cleared initially. It is recommended that novices practice the manoeuvres required for zone 4 and 5 with the lens implant in situ, before attempting actual SLM removal.

Sub-incisional SLM removal technique has 3 components:

1. Correct irrigation/aspiration probe tip position.
2. Aspiration "fishing".
3. Sub-incisional zone 4 and 5 Soft Lens Material peeling.
   a. Circular drag.
   b. Direct drag.

4.3.5 Correct Irrigation/Aspiration Probe Tip Position

Starting in the safe zone, on irrigation only, rotate the port (anti-clockwise for zone 4, clockwise for zone 5) with the IA tip kept in the central area. Then slowly move the tip with the port facing towards the sub-incisional SLM. The port should be maintained just below the plane of the capsule (Figs. 4.14 and 4.15). The IA shaft may be moved to the right or left within the corneal incision as much as possible to facilitate sub-incisional positioning of the IA port at the start zone 4 or 5 respectively.

The SLM to be captured will overhang the capsulorhexis edge slightly. Aspiration of the overhanging SLM should begin *just before* the capsulorhexis edge is reached. The SLM movement into the port will be visualised as the holding aspiration is achieved.

Whilst the IA port is plugged and occluded with SLM, it is unlikely to inadvertently aspirate capsule. The caught segment of sub-incisional SLM needs to be peeled off the anterior capsular bag and dragged into the central area in preparation for complete removal.

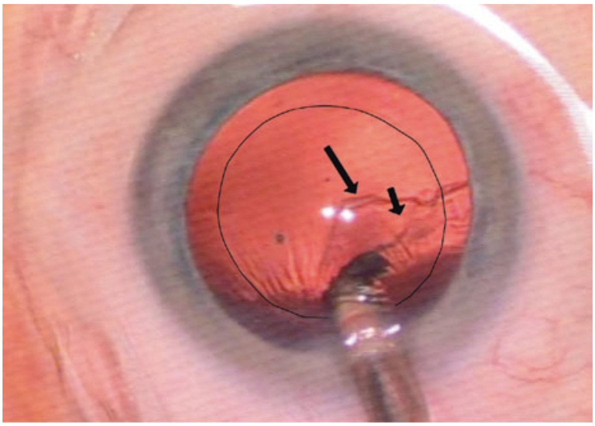

Fig. 4.14 Zone 5 correct placement of IA tip. Capsulorhexis edge (*solid line*). Anterior (*small arrow*) and posterior (*long arrow*) soft lens material

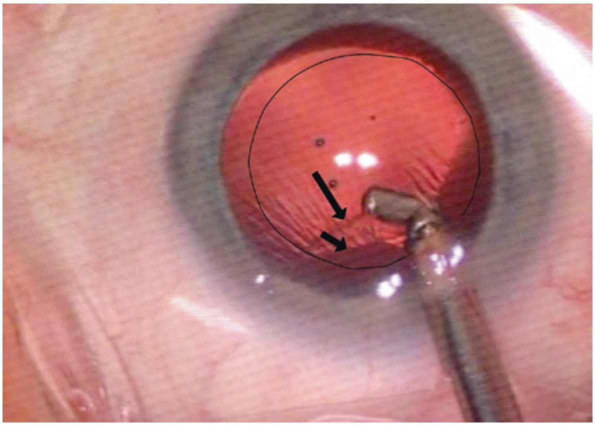

Fig. 4.15 Zone 4 correct placement of IA tip. Aspiration is started before capsulorhexis edge (*solid line*). Anterior (*small arrow*) and posterior (*long arrow*) soft lens material

4.3.6 Aspiration "Fishing"

If no SLM is seen to engage the IA port, a trial of aspiration "fishing" may need to be performed to catch a portion of SLM.

The fishing aspiration technique consists of placing the tip in close proximity to the rhexis (but not underneath) and applying aspiration to try and capture the loose SLM into the port. If no SLM is captured successive attempts are tried but the surgeon increases the aspiration until some SLM is captured into the IA port. During each fishing attempt, the IA tip makes a slight circular clockwise motion under the edge of the capsulorhexis once the aspiration is applied, whilst returning to port-up position in the safe zone. As the aspiration is increased, eventually on one attempt a portion of SLM is picked up and the port is occluded. The SLM caught is held under tension and easily noted by the surgeon as the probe is returned to the safe zone.

It is not advisable to leave the tip for too long in any particular area during the attempt. Prolonged focal aspiration can remove a small area of SLM and will thus allow the IA port access to bare underlying capsule.

If no SLM is caught after a few attempts, the surgeon should re-evaluate if the tip is held in the correct position with the port facing the SLM. The IA tip should be maintained at the correct level to ensure the SLM will engage the port. Too high, and the iris will be caught Too low, and the surgeon will often require higher aspiration power, or may even aspirate the posterior aspect of the capsule. A slow controlled movement during the aspiration attempt is more likely to allow capture SLM.

The aspiration sound emitted may be used to guide whether or not aspiration is increased on each attempt. Furthermore, it is advisable to recall the amount of holding aspiration needed for zones 1–3. This will provide an indication of how much may be required for the sub-incisional material.

Once SLM is engaged, the movement of the tip can be adjusted to drag and peel the SLM.

4.3.7 Sub-Incisional Zone 4 and 5 Soft Lens Material Peeling

Here, the aim is to peel the SLM off the anterior portion of the capsule by dragging it away from its anchor points. Two methods can be used to perform this action:

4.3.7.1 Circular Drag

The port is rotated in a circular fashion with the tip passing under the capsule edge (whilst maintaining aspiration) peeling the SLM in a tangential direction (Fig. 4.16). This circular motion is continued whilst moving the probe back into the safe zone with the port up (Fig. 4.17). In effect, this action is a combination of lateral drag and *wind-on-a-stick* movements. Zone 5 SLM removal is performed in a similar fashion (Fig. 4.18).

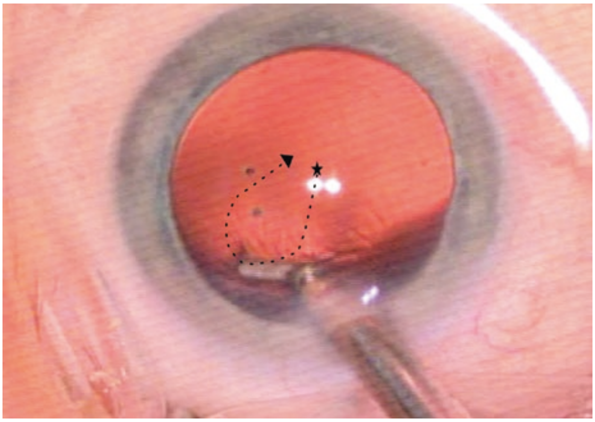

Fig. 4.16 Zone 4 circular drag. Aspiration is started before capsulorhexis edge to capture SLM and then dragged in a circular fashion to peel SLM. Trajectory of IA tip (*dotted line*) from starting point (*star*)

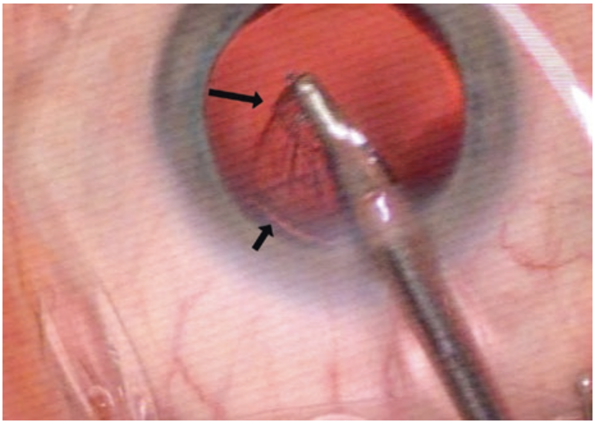

Fig. 4.17 Zone 4 circular drag—peeling. Captured soft lens material (*long arrow*) is peeled off capsule in opposite direction to anchor points (*short arrow*)

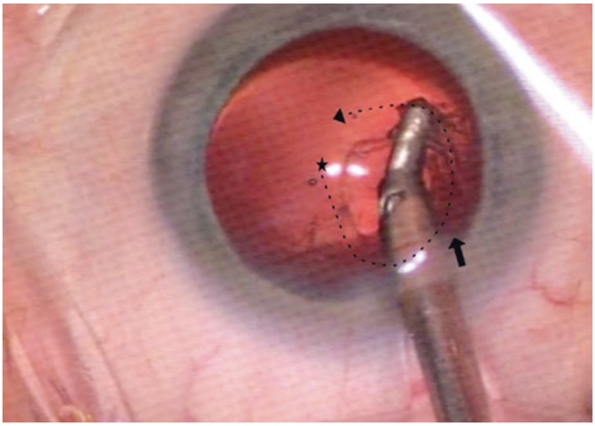

Fig. 4.18 Zone 5 circular drag. Trajectory of IA tip (*dotted line*) from starting point (*star*)

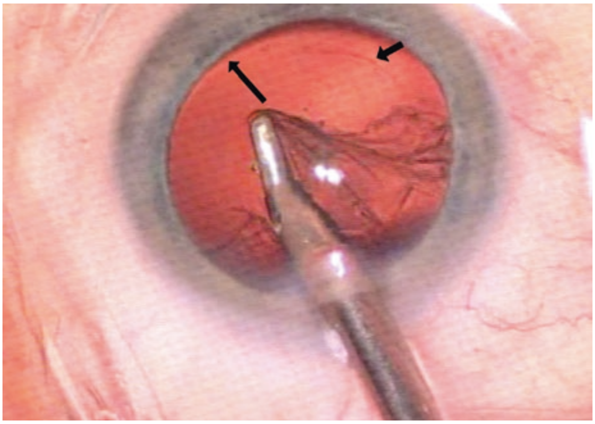

Fig. 4.19 Zone 5 direct drag. Aspiration is started before capsulorhexis edge to capture soft lens material and then dragged in a direct radial fashion in the opposite direction. Direction of drag (*solid line*), Capsulorhexis edge (*short arrow*)

4.3.7.2 Direct Drag

The occluded port is held in its rotated position, with the port held facing the sub-incisional area, and aspiration commenced. Once the IA port is occluded, rather than performing a circular drag to loosen the adhesions, the port is moved directly away in the opposite direction. Thus, the SLM is peeled using a radial-directed drag motion (Fig. 4.19). The tip is maintained in a rotated position, facing the targeted SLM area, as the anterior portion of the SLM is peeled. Since peeling of the SLM is easily visualised as it is pulled away from the sub-incisional area the surgeon can be assured the port is occluded with SLM and that there is little risk of capsule damage. As the port reaches the central area a *wind-on-a-stick* technique can be used to return the port to the port-up position. This increases the tension on the held SLM before it is fully aspirated.

As experience and confidence is gained, applying aspiration near the capsulorhexis edge, performing the aspiration fishing, circular dragging or direct dragging techniques can be applied, even if the view is partially obscured by corneal haze or by a small pupil.

Box 4.2 Technique Tip

- Sub-incisional movements need to be performed methodically. Initially, novice surgeons may try to make combined IA tip movements (which don't quite work) in an attempt to remove the sub-incisional SLM, for example, by rotating the IA tip whilst manoeuvring the tip towards the sub-incisional area. Or alternatively, by pulling back the IA tip and then attempting rotation beneath the sub-incisional capsulorhexis edge to position the IA port. These movements are commonly performed in an attempt to mimic a more experienced surgeon, but the movements are performed more slowly and with less skill and confidence. Subsequently, the corneal section can become distorted, fluid maintaining the chamber is lost, and anterior chamber shallowing occurs. Coupled with inappropriate application of aspiration, the technique becomes ineffective, causing anxiety for both novice surgeon and Trainer.
- A better approach is to split the movement by performing the tip rotation element first with the central area, and then repositioning the tip towards the sub-incisional area. This will keep the tip in the correct plane with the port facing the area of SLM targeted. *Holding* aspiration is applied during the tip movement towards the sub-incisional SLM. The novice should observe where the redundant SLM overhangs the sub-incisional capsulorhexis. This SLM will move towards the IA port as the probe tip is brought closer to the capsulorhexis edge during aspiration. Maintaining the SLM hold and increasing to *peeling aspiration* as the tip is rotated and returned to the safe zone will allow for controlled SLM removal.

4.4 Removal of Lens Epithelial Remnants

Small amounts of residual, wispy SLM on the posterior aspect of the capsule can be gently aspirated using the IA tip or rubbed off using the viscoelastic cannula. If the capsule is *pinched and captured* by the IA port the surgeon should not pull on the capsule but instead simply stop aspirating and reflux the IA port using the foot pedal (usually by pressing on the proximal part of the foot pedal with the heel of the foot).

Lens epithelial remnants can also be noted on the inner anterior aspect of the capsule. These can be removed using gentle IA aspiration before the intraocular lens is inserted (Fig. 4.20). Removal of lens epithelial remnants may help reduce posterior capsule opacification and capsulorhexis phimosis.

It is recommended that the surgeon has good IA foot pedal control and is confident to perform capsule polish before this is done routinely.

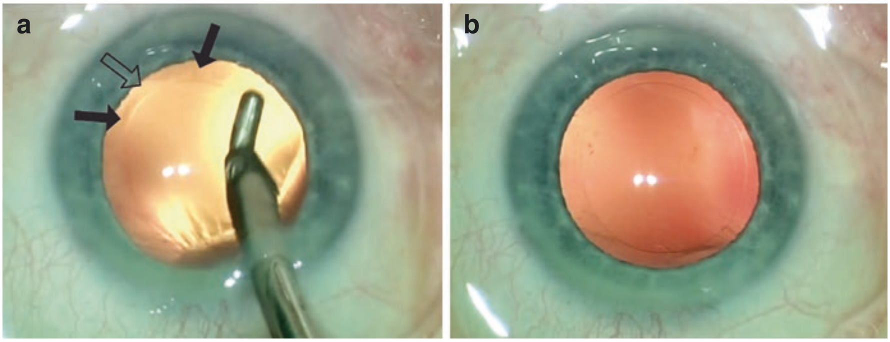

Fig. 4.20 Anterior capsule lens epithelial remnants. (**a**) Before aspiration removal, and (**b**) after. Lens epithelial remnants (*solid arrow*), clean capsule (*open arrow*)

Box 4.3 Trainer Teaching Pearls

With modular training, it is recommended that irrigation/aspiration is the first intraocular technique performed by a novice surgeon on a patient.

Whilst performing surgery under supervision, novice surgeons may suffer from spatial disorientation. Several factors contribute to this problem during initial training: miscommunication between the Trainer and the novice surgeon; not understanding instructions relating to intraocular movements; switching from the right to the left eye in sequential cases; variation of the operating position; and whether or not the novice has a dominant hand which is opposite to that of their Trainer. Each ophthalmic unit should agree on the orientation terminology to be used, the term given for IA movements, and terms for the SLM zones. This text provides useful suggestions in that regard.

It cannot be assumed that the novice surgeon will know what to do simply by observing the Trainer beforehand. Precise instructions, using simple key phrases, need to be expressed so that novice surgeons can easily perform the required steps during surgery. A pre-planned surgical learning plan can identify any terminology differences.

It is important to establish the ability of novice surgeons to follow instructions without making too many unnecessary independent instrument movements within the eye. This is important, as Trainers must be confident that the novice will listen and stop when instructed. Training can then be adapted accordingly and the novice educated to ensure patient safety is maintained.

At the start of training, novices need to appreciate that the Trainer will anticipate potential complications and instruct on how to avoid them, whereas the novice will not have the surgical experience to do this. It is important to explain to novices that independent operating without instruction will only develop over time.

Although surgical lists may comprise cases of varying complexity, as the initial parts of the procedure is performed by the Trainer, once the SLM removal stage has been reached it is likely that some of the remainder of the operation will be suitable for novices. In this fashion, novices may perform the predetermined surgical IA steps on the majority of cases even when they may not have been able to perform any other stage of the procedure.

The Trainer should resist the urge to allow the novice to deviate from the pre-planned SLM removal step.

Novice surgeons often believe that the sub-incisional area of SLM is tricky to remove. This is not necessarily true, and novices need to be reminded that it is a matter of gaining the correct technique, after which the SLM removal will be straightforward. Trainees who struggle with the sub-incisional area do so for several reasons:

1. **Firstly, an epinucleus plate, or layers of SLM, are created during hydrodissection rather than a single residual SLM layer. These layers will require additional instruction and more time to extract.**

   Ideally hydrodissection should aim to create a single layer of residual SLM. If possible the Trainer may avoid hydrodelineation, in order to reduce the risk of a residual plate of epinucleus, or remove any residual plates before handover to a novice surgeon. For more experienced surgeons who find SLM removal difficult, the issue may stem from hydrodissection. It is recommended the chapter the on hydrodissection is reviewed (see Chap. 5).
2. **The Trainee has attempted to deal with the sub-incisional SLM removal before they fully appreciate the IA tip manoeuvres required for zones 4 and 5.**

   When commencing SLM removal training, it is recommended that the area and number of zones of SLM to be removed by the novice surgeon are chosen carefully and increased in stages. At the start, the Trainer is advised to initially remove most of the SLM in the sub-incisional area and instruct the novice to remove the remaining SLM. For example, rather than handing over to the novice with all of the SLM in situ, the Trainer hands over when SLM in zones 1,4 and 5 have been cleared (Fig. 4.21 and Video 4.2). *The novice is then only required to clear zones 2 and 3. As Trainee competency increases, the Trainer can leave more of the SLM in these areas before handing over.*
3. **Lack of confidence resulting in fear when performing movement.**

   The Trainer should avoid the suggestion that any part of the SLM removal is difficult before a Trainee attempts that aspect of surgery. This can lead to a lack of confidence in performing the task. In cases where the Trainer would expect a particular zone of SLM removal to cause a major problem (e.g. sub-incisional zone 4 and 5 in the scenario where the view of the SLM is obscured by corneal oedema) the Trainer should tackle those areas of SLM removal perceived to be difficult before hand over. With time, the novice will be expected to manage these areas completely.

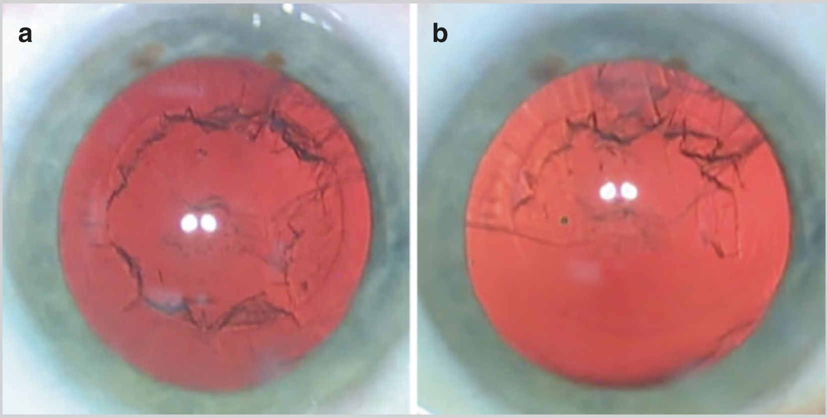

Fig. 4.21 Soft lens material preparation by the Trainer. (**a**) Complete SLM in situ, (**b**) Sub-incisional SLM zones 1, 4 and 5 removed by the Trainer before surgical handover to the Trainee

4. **Lack of understanding when performing required irrigation/aspiration tip movement.**

   By the end of viscoelastic removal and IOL insertion training the novice surgeon should be capable of demonstrating the movements needed for SLM removal above the lens implant. It is recommended that IOL insertion is taught after the start of viscoelastic removal training. Pseudo SLM removal practice should be performed during IOL insertion training and continued during SLM training above the lens implant. This will aid understanding and encourage purposeful movements during actual SLM removal.

4.5 Summary

Removal of SLM is an important step in phacoemulsification surgery. The training can consist of logical, small steps and the novice surgeon instructed to remove purposely left ‘zones’ of SLM and over time expected to strip SLM from all of the zones within the eye. Instruction terms are simplified and key terms can promote clarity between Trainer instructions and Trainee understanding. This rear-ended surgical approach will enhance Trainee confidence, reduce overall stress, and promote better patient outcomes. See Videos 4.3 and 4.4.

Manual Capsulorhexis

5

Continuous curvilinear capsulorhexis (also referred to as the *rhexis*) is performed by creating an aperture in the anterior capsule. The most common manual technique is made by initially puncturing the capsule surface, creating a capsule flap that is then dragged circumferentially to create a central, circular aperture [1]. Experienced surgeons can perform a capsulorhexis quickly, adapting intraocular movements and adjusting the direction of the tearing force to create an ideal rhexis aperture (well centred and of a size that is small enough to just overlap the lens optic). Mimicking the proficient, rapid movements of expert surgeons may be daunting for Trainees who may not appreciate the sequence of movements that are required. However, once the technique broken down into steps, these movements become simple and reproducible. It should be acknowledged that novice surgeons will not always achieve a rhexis that is well centred and of perfect size or shape. Indeed, in everyday practice, capsulorhexis perfection is something all cataract surgeons strive for.

The term *rhexis* in cataract surgery has several interchangeable meanings that require clarification for the novice surgeon. It refers to any part of the cut edge of the incomplete, or completed, continuous curvilinear capsulorhexis aperture. For example, during phacoemulsification, care is taken not to damage the *rhexis*. It also refers to the specific *point* at which the capsule is torn during the creation of the capsulorhexis aperture. Loss of control of the rhexis implies the rhexis *tear* is extending outwards towards, and potentially under, the iris margin.

This chapter will describe the principles involved in creating a manual rhexis. Femtosecond laser capsulorhexis formation is also possible, but is not discussed. Terminology and steps are explained with the aid of diagrams highlighted with a "cartoon" capsule. This will allow the steps to be visualised. Concepts will be introduced in stages throughout the chapter and it will be necessary to read the whole

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chapter for a full understanding. During training, novice surgeons will be shown various modifications of the described technique. The principles underlying basic technique remain the same.

Assumptions for this module are shown in Box 5.1

Box 5.1 Assumptions Made in Relation to this Training Module

- The anterior chamber is pre-filled with viscoelastic.
- Viscoelastic top-up is applied as required.
- The Trainee is right-handed. For left-handed Trainees, an anti-clockwise direction may be applied and the instructions are reversed. The Trainer may prefer to initiate the rhexis at a different position, or even perform the capsulorhexis clockwise. The fundamentals remain applicable.
- The chapter describes the use of a short orange needle to start the rhexis flap, but a cystotome or equivalent can be used if preferred. If using a cystotome, remember to rotate the tip during insertion and removal to prevent "catching" the section.
- Adhering to the rules described facilitates performing rhexis in a routine fashion. The basic rules can be broken as experience is gained. *Breaking the rules too early will lead to a higher rate of take-over by Trainer.*
- The Trainer will provide specific guidance to novice surgeons during each rhexis attempt, slowly withdrawing instruction as technical skills are gained. *It is assumed the novice does not know where to hold the flap nor the direction of movements required.*

5.1 Fundamentals of Capsulorhexis

5.1.1 Anatomical Orientation

To facilitate surgical instruction, a common anatomical surgical orientation between the Trainer and novice surgeon should be used. One method is to consider the eye as a clock face with four *cardinal* reference points, namely the 3, 6, 9, and 12 o'clock positions. To avoid confusion, the corneal incision is always designated the 12 o'clock cardinal position (Fig. 5.1). This ensures that the corneal wound once created acts as a fixed reference point for the surgeon, even when changing the location of the incision or switching from the left to the right eye.

5.1.2 Viscoelastic Fill

Viscoelastic material is needed to protect the internal ocular tissues, maintain the anterior chamber depth and tamponade the capsule surface. It aids visualisation and facilitates controlled rhexis surgery. At the end of intraocular lens training it is a

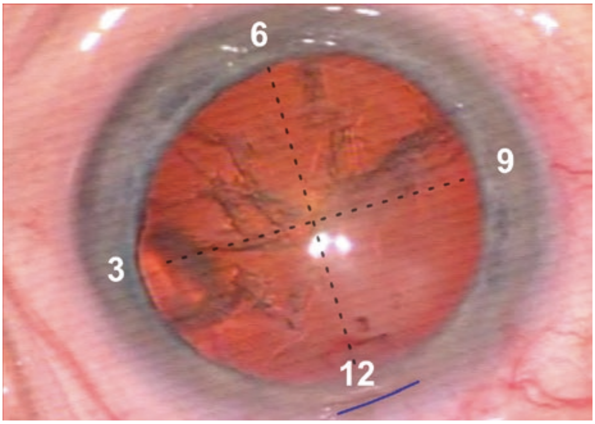

Fig. 5.1 *Cardinal* points of orientation. Corneal incision (*solid line*), cardinal points (3, 6, 9, and 12 o'clock) with joining imaginary cross hairs (*dotted lines*)

simple matter to fill the anterior chamber with viscoelastic. To recap: expel a small amount of viscoelastic before entering the eye to ensure any potential trapped air bubbles in the syringe hub are removed. A side-to-side movement of the cannula during insertion will allow the cannula to navigate the corneal wound. Continue to inject viscoelastic and direct the cannula towards the 6 o'clock position. Noodle-like streams of viscoelastic will start to fill the eye and then coalesce together to form a bow wave. This bow wave of viscoelastic moves towards the cornea incision as the anterior chamber is filled. The cannula can then be slowly withdrawn whilst further viscoelastic is injected. Once the chamber is completely filled the viscoelastic will start to leak from the wound. At this point stop injecting and remove the cannula.

Experienced surgeons are able to complete the rhexis without a top-up of viscoelastic. Novice surgeons are more likely to require a viscoelastic top-up during surgery, as it is common to inadvertently depress the posterior lip of the corneal wound whilst forming the rhexis. This will allow viscoelastic to escape. This is not a major concern during the initial stages of rhexis creation as ample viscoelastic is present. In the later stages, however, as additional viscoelastic escapes, a top-up may be required. This will ensure the viscoelastic tamponade of the capsule is maintained.

5.1.3 Creation of Capsule Flap

Depending on surgeon preference, initial puncture of the capsule surface can be implemented with a variety of instruments. This includes: a keratome tip, a cystotome (pre-formed, or created by the surgeon by bending a needle tip into a cystotome shape), capsulorhexis forceps, or 25-gauge needle tip. Novice surgeons will be guided by the Trainer's teaching preference. The chapter will describe the use of a 25-gauge needle (attached to an empty syringe) to breach the capsule and create a flap. Subsequent rhexis completion is described with capsulorhexis forceps.

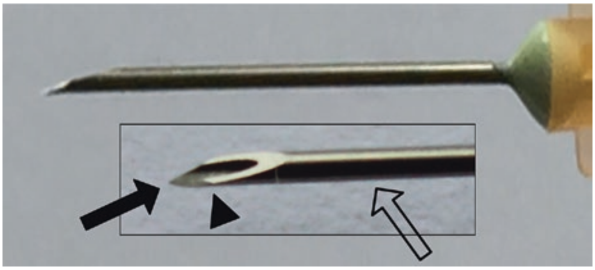

Fig. 5.2 25-gauge needle. Lateral view (*main image*), superior view (*insert*). Needle tip (*arrow*), cutting edge (*arrow head*), non-cutting round bodied shaft (*open arrow*)

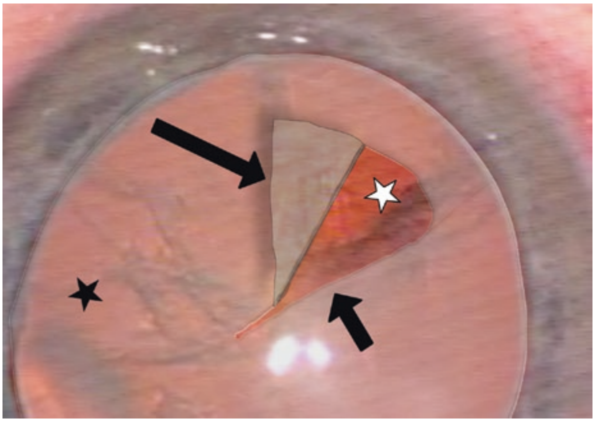

Fig. 5.3 Capsule flap orientation. Flap (*large arrow*), edge of tear (*short arrow*), capsule surface (*black star*), exposed lens surface (*white star*)

A short, 25-gauge needle (Fig. 5.2) in the bevel up position is used to make the capsular flap (Fig. 5.3). The flap is needed for controlled tearing of the rhexis. The needle-tip has sharp edges and a round-bodied shaft attached to the needle hub.

The initial flap creation has three components:

1. The needle-tip is used to *stab* and breach the capsule surface.
2. Its sharp edge used to *slice* the capsule open.
3. The tip is used to *push* and *fold* the capsule over itself to create the initial flap.

Before insertion into the eye, preparation of the needle shaft is required (Fig. 5.4). Keeping the needle bevel facing upwards, the shaft is bent upwards using applied finger pressure. Bending the needle shaft facilitates the angle of entry into the eye.

Insertion of the needle into the eye may initially be met with resistance due to the difficulty of navigating the stepped corneal incision. This can be exacerbated if the needle tip is rotated slightly within the corneal section. It is recommended the tip is held so that the cutting edges remain horizontal. One approach is to place the tip to one side of the corneal section (rather than the centre of the wound) and then perform a side-to-side movement whilst navigating the wound. This encourages the stepped corneal incision to open slightly and allows the needle tip access into the anterior chamber without catching the corneal tissue or creating false passage

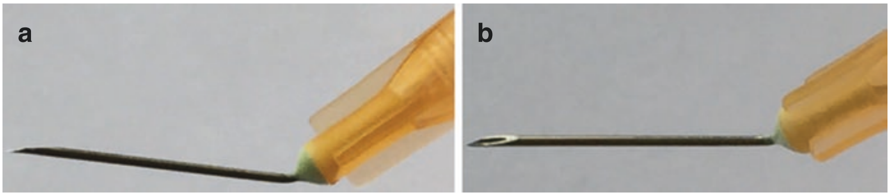

Fig. 5.4 Bent needle. (**a**) Bent needle side profile, (**b**) Bent needle superior view

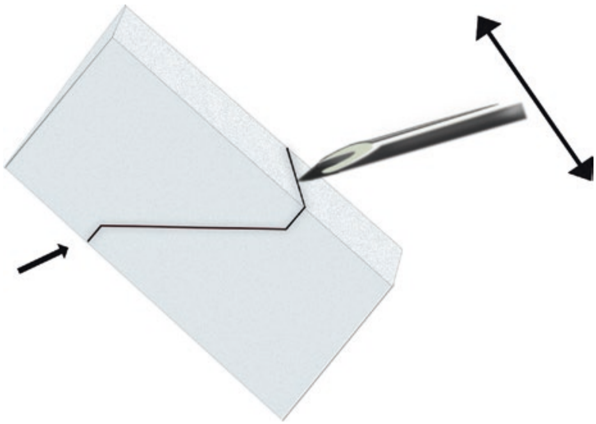

Fig. 5.5 Needle insertion. Corneal incision (*arrow*), horizontal movement of needle (*double headed arrow*)

(Fig. 5.5). Occasionally, novice surgeons may need to lift the upper lip of the corneal wound using forceps, in order to insert the needle. However, with practice this is usually is not required.

5.1.4 Capsule Stab

Once the needle has been inserted into the anterior chamber, it is advisable to pause and determine the ideal centre for the rhexis. Imagining crosshairs connecting the four cardinal points will act as an aid. The preferred point for the initial stab that breaches the capsule surface is just lateral and off-centre (Figs. 5.6 and 5.7). If the stab is made too centrally, the rhexis may extend outwards towards the iris when the flap is created.

Breaching the capsule surface requires a bold stabbing motion, (Fig. 5.8). The needle tip should be aimed obliquely downwards (as if aiming for the posterior pole of the eye) during the stab. Once the capsule is breached, the needle should be lowered closer to the horizontal to avoid disturbing too much cortex material during the next movement. If the stab is done too slowly, then the capsule will stretch under the force, before it is breached. This should be avoided as it results in unnecessary downward force being applied to the lens.

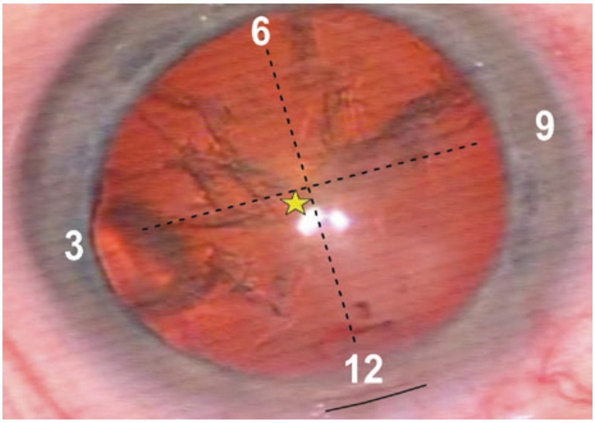

Fig. 5.6 Capsulorhexis initial stab. Incision site (*star*), imaginary cross hairs (*dotted lines*) along cardinal points (12 to 6, and 3 to 9 o'clock), corneal incision (*solid line*)

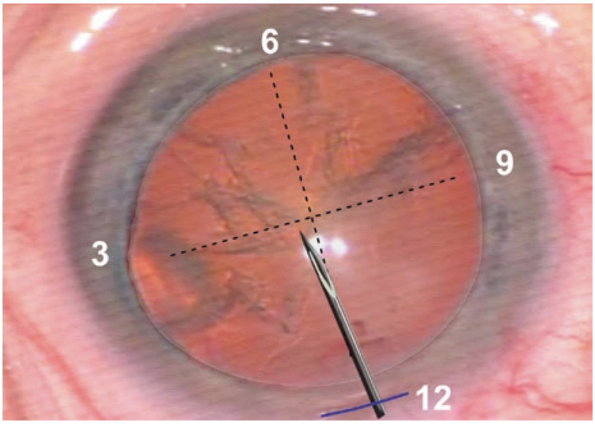

Fig. 5.7 Needle tip poised to stab capsule

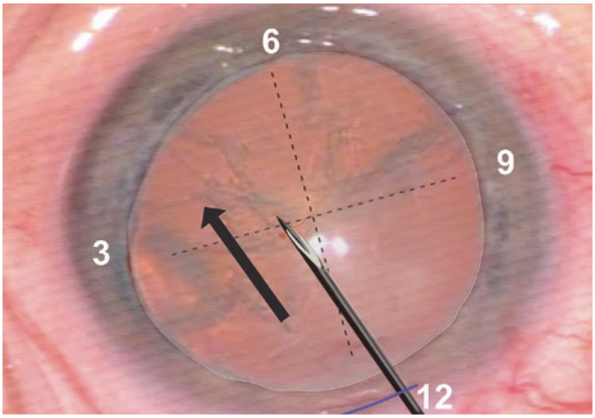

Fig. 5.8 Needle tip stabbing capsule

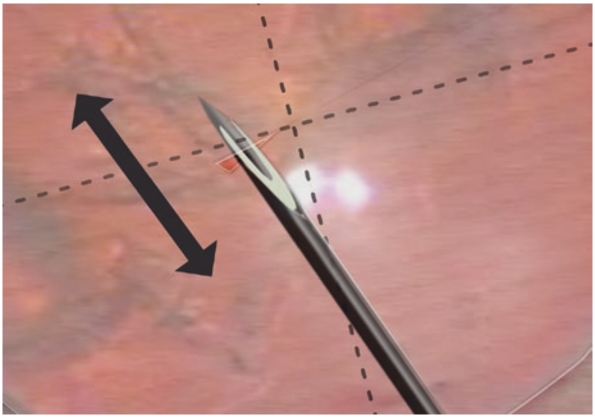

Fig. 5.9 Correct needle tip sharp-edge positioning. After stabbing the capsule the needle tip is pulled back (*arrow*) so cutting edge is ready to slice the capsule

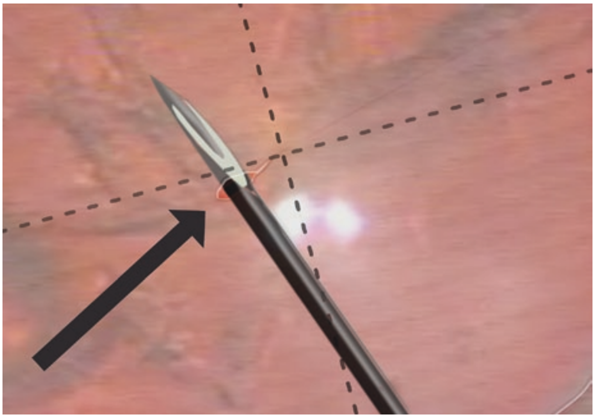

Fig. 5.10 Incorrect needle tip positioning. Here the needle is incorrectly positioned, and the shaft of the needle (*arrow*) will cause an uncontrolled tear

Adjustment of the tip is now required. Pull the tip back so that the sharp *edge* of the tip is used for the next stage (Fig. 5.9). *Pull-back* ensures the round body of needle shaft is not inadvertently used to cut and slice capsule (Fig. 5.10). If the shaft is used it will stretch the capsule and may result in an irregular, uncontrolled tear when the next step is performed (usually towards the 10 o'clock position directly underneath the needle shaft). Should this occur, withdraw the shaft and start to create the capsule flap using the eccentric tear.

5.1.5 Capsule Flap Creation

Once positioned, the cutting-edge of the needle tip is ready to slice open the capsule. Both oblique and horizontal movements may be used, but an oblique direction will result in predictable tearing of the capsule when flap is folded over. An in-and-out sawing action, using the needle tip edge as a blade, will facilitate making the cut. Once proficient in the movement, a sliding action alone will work. The slide should not go right out to the iris, but instead leave a reasonable margin (Fig. 5.11).

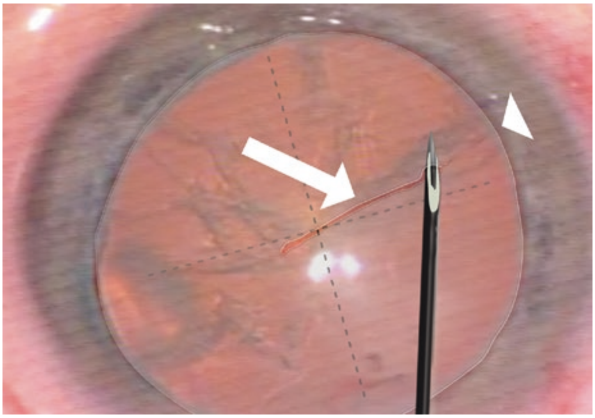

Fig. 5.11 Capsule slice. Capsule slice (*arrow*) ends a reasonable distance from iris margin (*arrow head*)

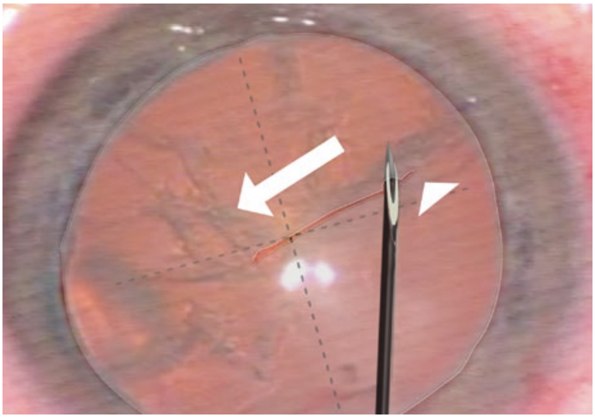

Fig. 5.12 Capsule slice, horizontal movement. Needle is moved horizontally (*arrow*) to ensure outer edge of tear is visualised (*arrow head*)

The capsule now needs to be folded over to create a flap. Novice surgeons can be nervous about the capsule tearing in an uncontrolled fashion. This concern can be reduced with good visualisation and the knowledge that a predictable tearing of the rhexis is possible. To help visualise the flap origin and the direction in which the initial capsule tear will extend, the needle tip needs to retreat a fraction along its original path. This allows visualisation of the outer peripheral edge of the recently made cut (Fig. 5.12).

Lifting the capsule (using the needle tip on the internal surface of the capsule), and folding the capsule over, will result in two successive extensions of the initial capsule tear. Firstly, as the capsule is lifted, the tear extends outwards slightly (to accommodate the lift). Second, as the needle tip pushes the capsule over (to create a flap), the tear will extend and form the initial rhexis boundary. The longer the tip length under the capsule, the bigger the initial tear extension. To avoid excessive extension of the tear towards the iris, only a small amount of the tip should be used to lift the capsule. Therefore, the needle tip should be withdrawn so that only a fraction of the tip remains under capsule.

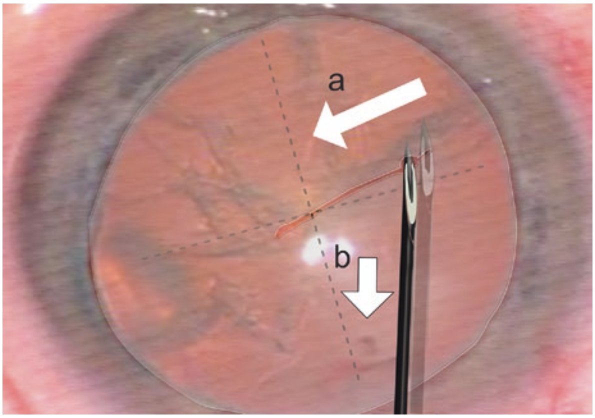

Fig. 5.13 Capsule slice, needle movement. The needle tip is (**a**) moved horizontally (*large arrow*) and (**b**) withdrawn slightly (*short arrow*)

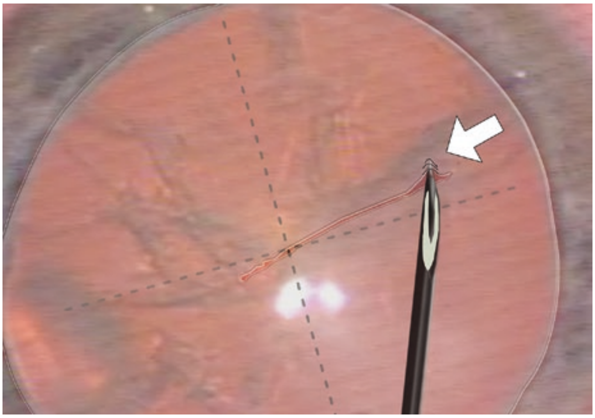

Fig. 5.14 Tenting of the capsule (*arrow*)

The movement to withdraw the needle can be performed simultaneously as the needle is moved horizontally back along the newly created cut (Fig. 5.13).

During the initial capsule lift, the capsule will tent up slightly. This is a useful clinical sign to look for (Fig. 5.14). Occasionally the tip may slip out from underneath the capsule during the lift. This should be expected to happen. The tip is easily re-inserted and the lift attempted again.

Once the capsule is tented slightly, the capsule should be pushed in a *straight* line parallel to the imaginary 12 to 6 o'clock meridian (Fig. 5.15).

The aim of this step is to fold over the capsule and create a flap. It is unnecessary to try and curve the flap at this point and there is no need to try to make a circular shape—this will happen automatically.

Once the folded flap starts to form (Fig. 5.16), it should continue to be pushed to ensure it is folded over completely (Fig. 5.17). The push to achieve the folded-flap should again be in a straight line parallel to the vertical meridian.

At this point, once the flap is folded over, novice surgeons are advised to remove the needle and not use it to extend the rhexis. Instead, the rhexis formation should be continued using forceps.

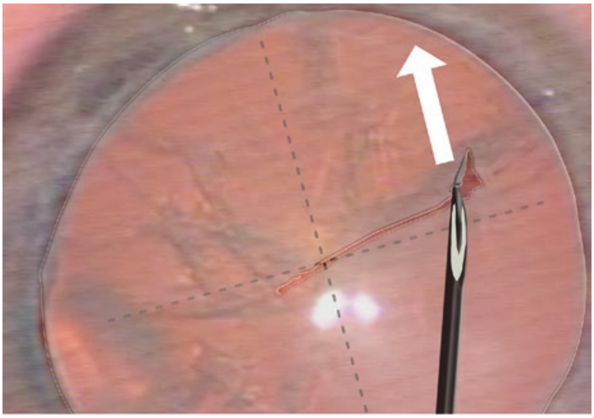

Fig. 5.15 Capsule folding. The capsule is folded over pushing in a direction (*arrow*) parallel to imaginary vertical meridian (*dotted line*)

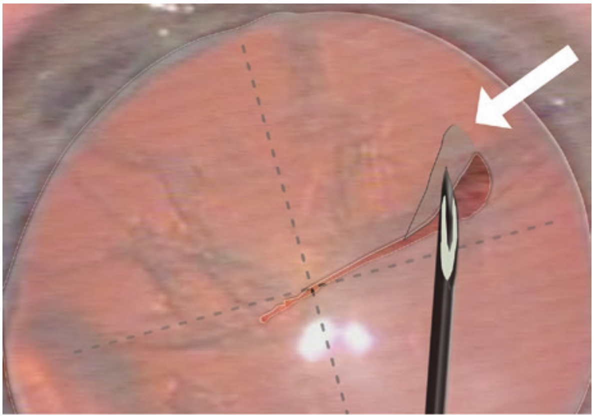

Fig. 5.16 Initial formation of capsule flap (*arrow*)

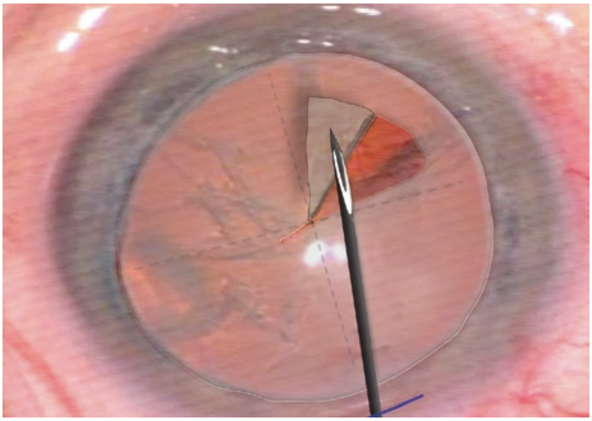

Fig. 5.17 Flap is completely folded over

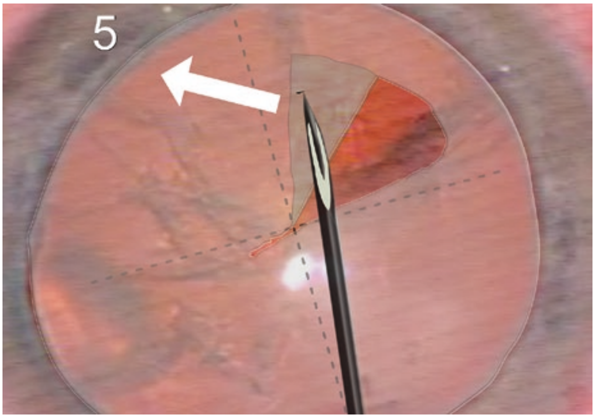

Fig. 5.18 Pushing the flap

However, as training progresses, there may be opportunity to continue the rhexis with the needle. If the needle tip remains in good contact with the underside of capsule (i.e. the newly created flap), then one could try to direct the push towards 5 o'clock to continue tearing the rhexis (Fig. 5.18). The flap should not be pushed down into the lens, but rather skimmed over lens surface when pushing.

If contact between the needle and capsule is lost at any stage during this extra push, it is better not to try and re-engage the flap. Re-engagement attempts can cause the rhexis tear to run out, and the process wastes time as, typically, the rhexis is only enlarged by a small amount. Instead, it is recommended that the rhexis is continued by switching to forceps.

5.2 Creation of Continuous Curvilinear Capsulorhexis

5.2.1 Capsulorhexis Flap Terminology

To facilitate rhexis instruction, a common terminology for the flap anatomy can make surgery easier to understand. Suggested anatomical definitions of the capsulorhexis flap are shown in Fig. 5.19.

5.2.2 Shearing or Ripping

Pulling on the flap causes an extension of the capsule tear and propagates the rhexis. A force when directed on a small focal point on the capsule, sequentially overcomes the individual bonds holding the capsule fibres together. Little effort is needed to extend the rhexis margin as the force separates one capsule bond at a time along the direction of force. This is referred to as a *shearing* force. This situation occurs when the flap is folded over and the flap pulled in a straight line away from the tearing point.

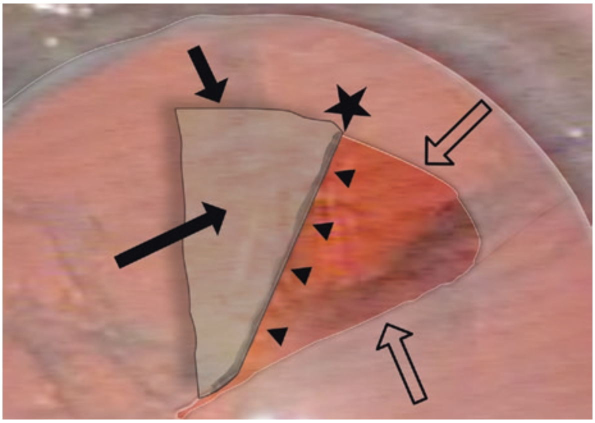

Fig. 5.19 Capsulorhexis flap terminology. Fold (*arrow heads*), flap (*arrow*), capsulorhexis outline (*open arrow*), tearing point of capsule (*star*), outer edge of flap (*short arrow*)

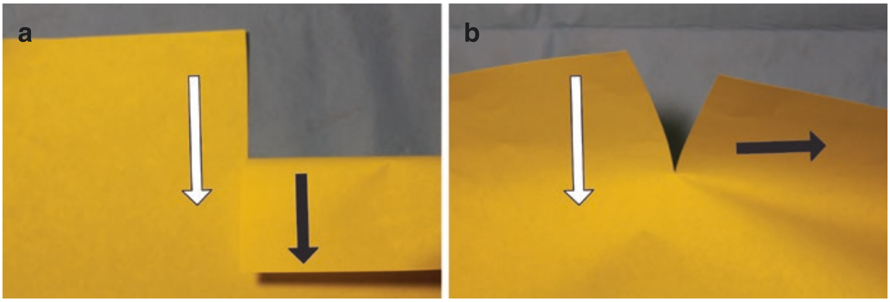

Fig. 5.20 Shearing and ripping force applied to tearing a piece of paper. (**a**) Shearing force. Direction of force (*black arrow*) is in the same direction as the intended tear (*white arrow*). Little effort to tear the paper. (**b**) Ripping force. Direction of force (*black arrow*) is 90° to direction of intended tear (*white arrow*). Force is spread over wider area and additional effort required

If the flap is pulled away from the rhexis edge either upwards or radially towards the centre, the direction of force is at 90° to the direction of the tearing point. In this situation, the force is spread over several capsule fibres and they are stretched as a group until they eventually rip apart. This is a *ripping* force. More effort is required to extend the rhexis. An element of ripping is needed to change the rhexis direction as shearing forces tend to produce a straight line. The Trainee is recommended to try and tear a piece of paper by using a shearing and a ripping force (Fig. 5.20)

The flap needs to be maintained in a folded over position with good opposition of the capsule to the surface to the lens. Simply put, a “flat flap” is recommended (Fig. 5.21). Maintaining this apposition against the surface of lens will promote better tear control during capsulorhexis completion as inadvertent upward pull may cause the tear to run out.

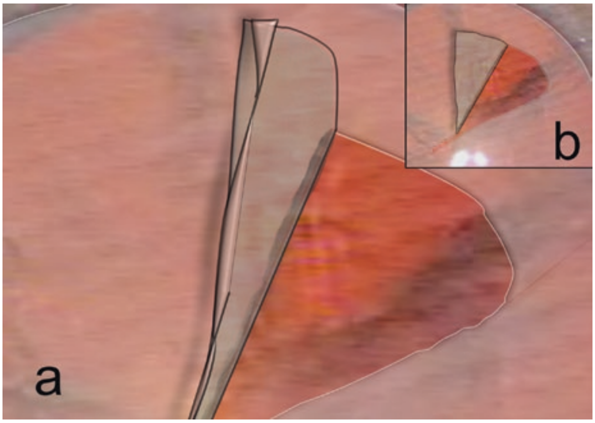

Fig. 5.21 Vertical based flap. (**a**) Vertical flap, (**b**) insert: flat flap

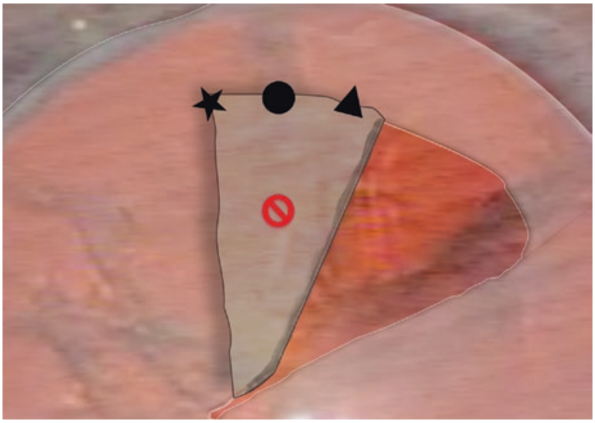

Fig. 5.22 Terminology of holding position of capsulorhexis flap. Long (*star*), mid (*circle*) and short (*triangle*) hold, centre of flap (*barrier sign*)

5.2.3 Where to Grasp the Flap

The capsule tissue can be grasped anywhere on the outer edge, the fold or the central area (away from the outer edge) of the flap. The force applied to try and extend the rhexis can have a different effect (controlled and less controlled tearing) depending at which holding point is used. Needless to say, control of the rhexis tear is preferable. Grasping part of the flap in any location that causes the rhexis tearing point to lift upwards (vertical flap) will result in a ripping force and make the rhexis extension less predictable.

The central, area of the flap is easy to grab, but causes the capsule flap to lift up at the rhexis tearing point as this holding point is pulled. Grabbing the flap in the central area should be avoided. Grabbing any part of the flap fold will also cause the capsule at the tearing point to lift upwards and again this holding point should be avoided.

The outer edge of the flap has three significant points namely; *long-, mid-,* or *short*-hold (Fig. 5.22). Grabbing a very *short* hold, on top of the fold of the flap,

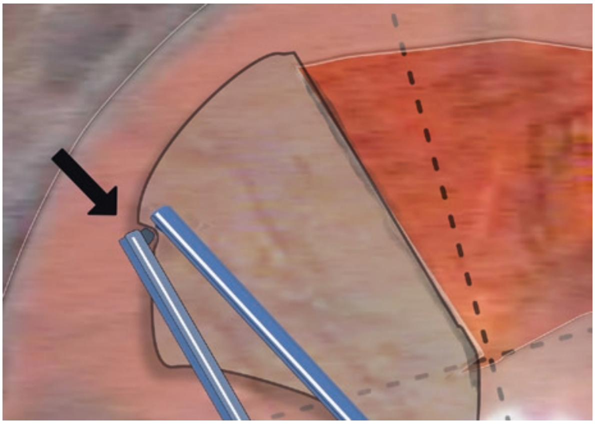

Fig. 5.23 Correct hold of flap edge with forceps. Internal and external capsule surface held with forceps (*arrow*), imaginary cross hairs (*dotted line*)

effectively lifts the capsule upwards and should be avoided. A mid- or long-hold is preferred, and for the novice, initial instruction on which is needed should be directed by the Trainer. Over time novice surgeons will gain experience on exactly where to grab the flap.

The technique described for rhexis completion involves the use of forceps to control the capsular tear after the initial flap has been created. For improved control, it is recommended that, whenever possible, the flap should be grasped by both the inner and outer capsule surface (i.e. the edge of the flap). This ensures the flap is keep flat against the lens surface as much as possible (Fig. 5.23).

5.2.4 Rhexis Propagation

The rhexis opening is created by tearing the capsule and dragging the flap in a controlled fashion. Though a circular shaped rhexis is the aim, in reality the movements used are constructed of straight-line vectors that eventually result in a circular shape on completion of the rhexis tear. For simplicity, these horizontal and vertical vectors are divided into movements needed to cover the rhexis creation between the cardinal points.

The control of the rhexis tear is governed by the following rules:

1. The 6 and 12 o'clock cardinal positions should be passed using a horizontal vector before a change in direction.
2. The 3 and 9 o'clock cardinal positions should be passed using a vertical vector before a change in direction.
3. Once past a cardinal point the grasp on the redundant flap tissue should be released and a new shorter hold obtained.
4. A flat flap should be maintained.
5. The movement refers to the rhexis tearing point and not where the forceps hold the flap.

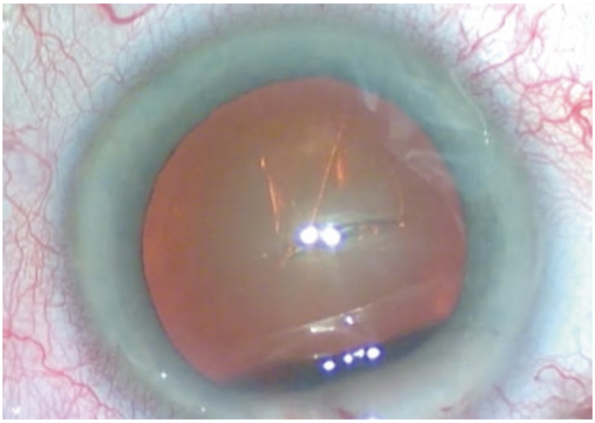

Fig. 5.24 Red reflex highlighting rhexis, the capsule flap and the the flap

6. The radius of the rhexis can be determined by the length of the flap fold.
7. The size of the rhexis is increased by continuing the movement (horizontal or vertical accordingly) past the cardinal point.
8. The rhexis is made smaller by directing the tear centrally.
9. The focus should be on the rhexis tearing point rather than the flap hold. The red reflex causes the flap fold to stand out and this can be used to easily locate the edge of the rhexis tear (Fig. 5.24).

5.2.5 6 o'Clock Cardinal Point

Using forceps, the flap should be held by a mid- or long hold position. The rhexis tear is continued by pulling the flap in a *horizontal* direction until the flap fold has passed the 6 o'clock cardinal point. Once past this point, the temptation to continue pulling the flap should be resisted (even if further extension of the rhexis is possible). As the rhexis is enlarging, the flap also enlarges and thus a very long-hold position develops. The hold on the flap will end up lower than the tearing point (Fig. 5.25). Eventually, if pulled further, the tension direction applied to the tear will alter (from a shearing to a ripping force). The key is to maintain control of the tear at all times, rather than allow problems to develop and then try and correct them.

5.2.6 3 o'Clock Cardinal Point

As the 6 o'clock cardinal has been passed a change in direction is now possible. The flap is grasped in a mid-hold position and pulled down in a straight line, parallel to the vertical meridian (Fig. 5.26). The rhexis will curve automatically. The flap must be maintained in a flat position against the anterior capsule as it is pulled.

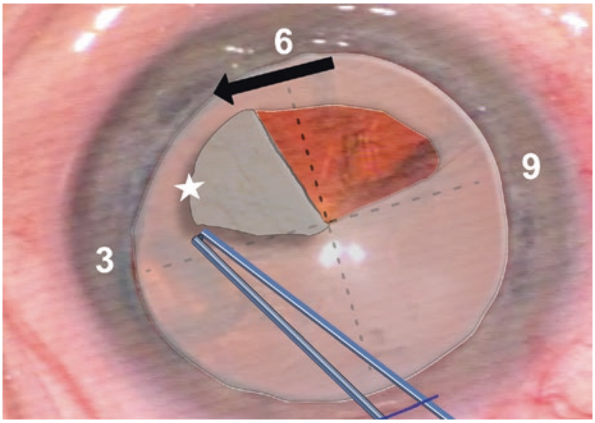

Fig. 5.25 6 o'clock cardinal movement. Direction of movement (*arrow*), point of release (*star*)

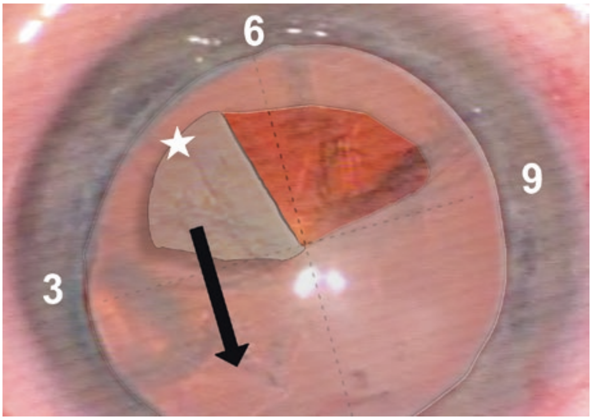

Fig. 5.26 3 o'clock cardinal movement. Direction of movement (*arrow*), holding point (*star*)

As the fold passes the 3 o'clock cardinal position the temptation to continue pulling the flap should again be resisted (Fig. 5.27). Release the flap and acquire a new shorter hold.

5.2.7 12 o'Clock Sub-Incisional Cardinal Point

The sub-incisional 12 o'clock rhexis is straightforward to perform and can be done with confidence. The movement has the following rules:

a. A flat flap is maintained.
b. A continuous grip on the flap is maintained during the movement past the sub-incisional area.
c. The rhexis is extended using three movement vectors (Fig. 5.28).

The first movement consists of a pull almost parallel to the vertical meridian, as if intentionally making the tear extend further past the 3 o'clock cardinal point

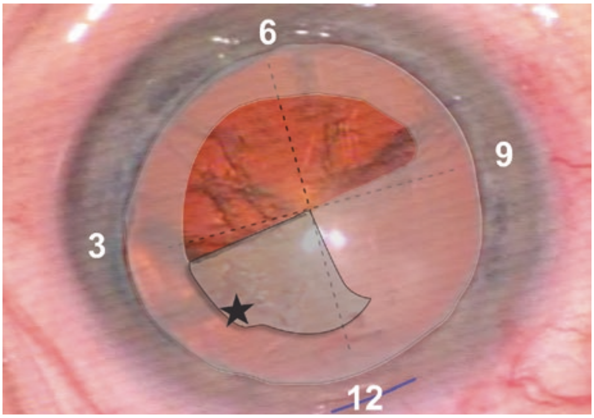

Fig. 5.27 Flap hold is released (*star*) once past the 3 o'clock cardinal point

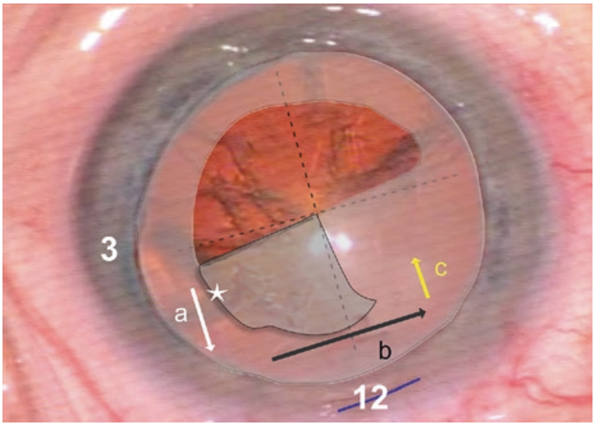

Fig. 5.28 Sub-incisional 12 o'clock rhexis. Three movements (**a**–**c**) are required. Initial short hold (*star*)

towards the iris. The rhexis should not be turned as if making a circle as this results in a small rhexis. A short hold grip is used (Fig. 5.29).

The second movement requires the flap to be pushed rather than pulled. An important aspect of the technique is the correct positioning of the forceps. Pivoting within the corneal section, the forceps are moved to the right side of the corneal section. As this is done the flap is held on tension and the tear extended as the capsule flap is pushed away horizontally (Fig. 5.30).

During this push the tearing rhexis cannot always be fully visualised. The horizontal push will take the rhexis past the 12 o'clock cardinal point provided the surgeon does not let go of the flap.

The third movement requires a small movement to change the direction of the tear, since the cardinal point has been passed. The tension on the rhexis tear is maintained and the flap once again pushed away as if following a parallel line from the 12 to 6 o'clock meridian.

This will start to curve the rhexis (Fig. 5.31). The flap is released and a new hold obtained for the final stage.

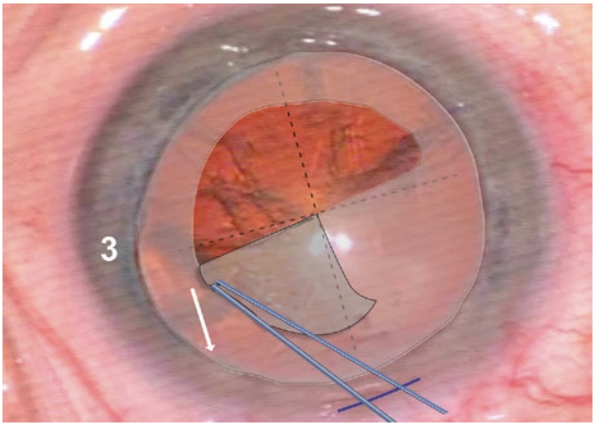

Fig. 5.29 Sub-incisional movement step A

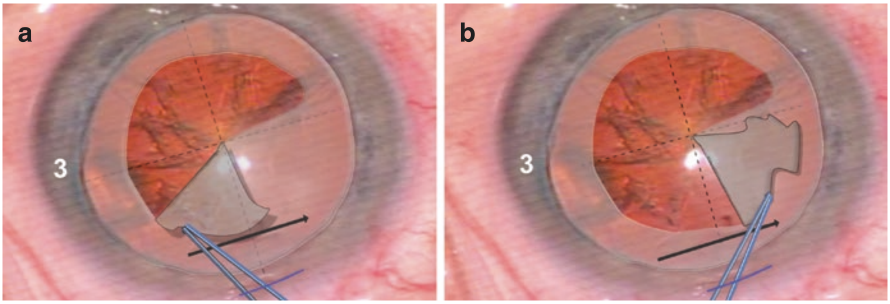

Fig. 5.30 Sub-incisional movement step B. (**a**) Initial forceps position, (**b**) final forceps position

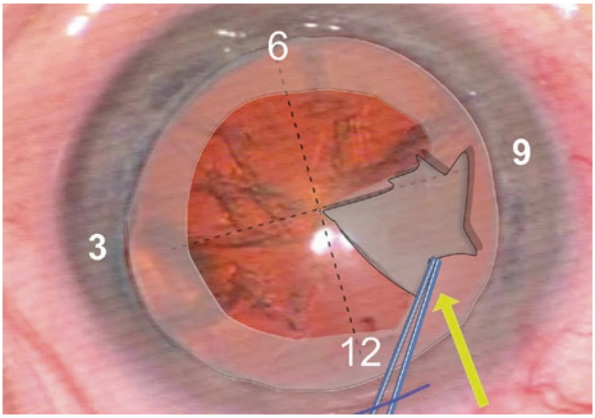

Fig. 5.31 Sub-incisional movement step C

5.2.8 Completion of the Rhexis Past 9 o'Clock Cardinal Point

Completion of the rhexis past the 9 o'clock cardinal is comprised of two movements, namely: a push past the cardinal point, followed by a "C" shaped turn into the centre (Fig. 5.32).

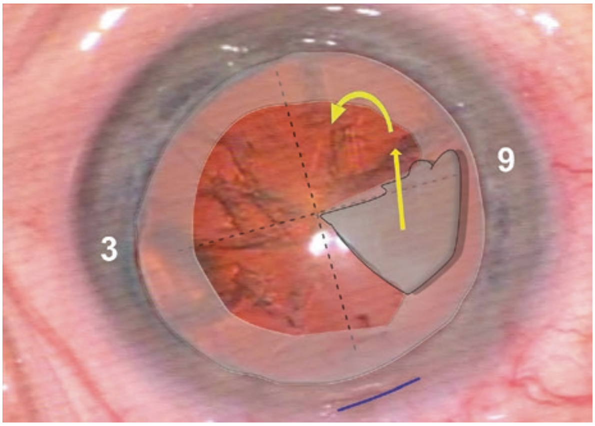

Fig. 5.32 Completion of the rhexis movement. The flap is pushed past the 9 o'clock cardinal point and the rhexis tear completed with a C-shaped moved (*arrows*)

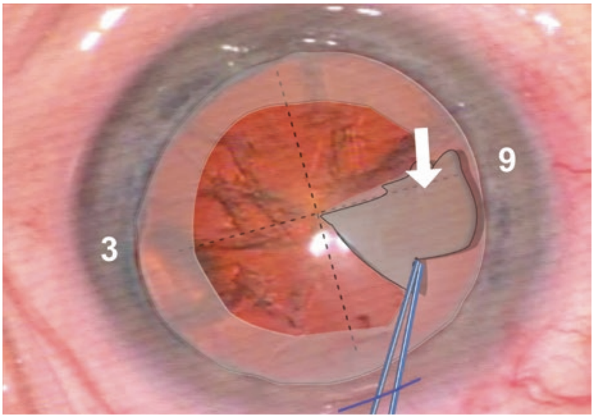

Fig. 5.33 Completion of the rhexis. Position of hold at start of movement. Redundant capsule (*arrow*)

By pulling into the centre, the rhexis tear spirals inwards. Control of the flap is still essential and a *long* hold on the flap should be avoided when starting (or during) the final movement (Fig. 5.33). The flap should be released as necessary and a *short* hold acquired as needed.

As the forceps are pushed away, the forceps tips and redundant capsule flap are moved slightly centrally. This movement allows the more peripheral tearing edge to be visualised once again, giving the surgeon confidence in performing a controlled tear to complete the rhexis (Fig. 5.34).

5.3 Additional Surgical Advice for Capsulorhexis

5.3.1 Ensuring a Circular Rhexis

It should be appreciated that the completed rhexis shown in Fig. 5.34 is not quite circular between the 12 and 9 o'clock position. This is caused by under-performance of the horizontal movement past the cardinal point before changing direction. This

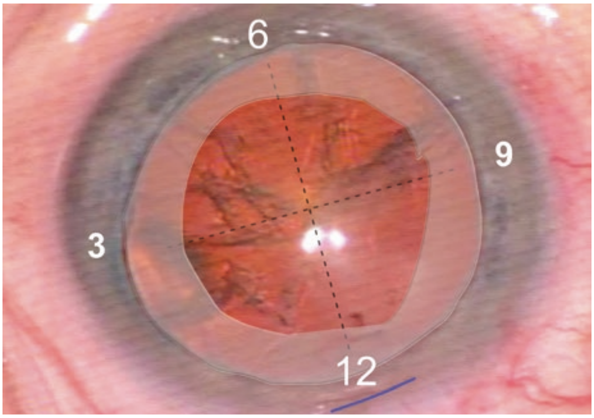

Fig. 5.34 The completed rhexis. Imaginary cross hairs (*dotted lines*) between cardinal points

smaller, irregular shaped rhexis effect can occur in any of the cardinal quadrants. It is easily corrected by performing a further horizontal movement (past the 6 and 12 o'clock cardinal points) or by performing a more vertical movement (after the initial flap is created, or after the 3 o'clock cardinal) before changing direction. It is recommended that the surgeon re-grab the flap after the cardinal has been passed then perform this additional movement.

5.3.2 Repositioning the Flap to Ensuring the Redundant Capsule is Moved Out of the Way

Redundant capsule is created as the rhexis is formed. The surgeon can struggle to re-grasp the edge of the flap once past a cardinal point as this capsule material may obscure the next ideal holding point. Trying to grab the flap with overlying redundant capsule tissue should be avoided. Instead, it is recommended that, after completing a movement, the redundant capsule material is moved out of the way before letting go of the flap.

By pushing the held point towards the centre of the lens the flap can be repositioned before letting go. The loose capsule material of the flap can be moved without applying tension on the tearing edge. This maintains a flat flap and moves redundant loose capsule into centre. Only a small amount of movement is needed, and the residual flap should remain flat against the lens surface. A short-/mid-hold, with a good grasp of the edge of the flap, can then be achieved with ease for the next step once past the 6 and 3 o'clock cardinal positions (Fig. 5.35).

5.3.3 Maintaining a Flat Rhexis Flap

Occasionally, between releasing the rhexis flap hold and the process of re-grabbing a new hold, the resting position of flap gets disturbed. As the flap moves and lifts off

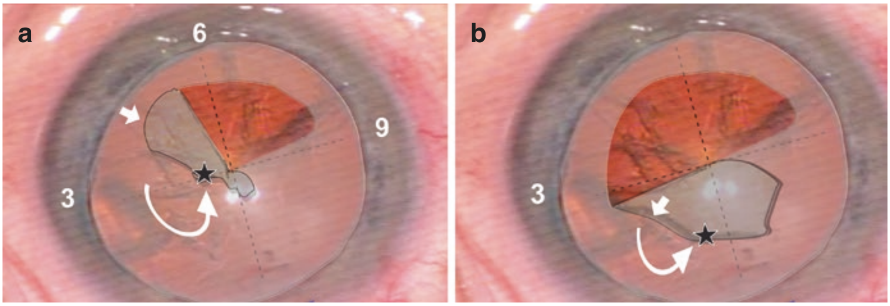

Fig. 5.35 Repositioning of capsule. (**a**) 6 o'clock cardinal. (**b**) 3 o'clock cardinal. Once past the cardinal the redundant flap is pushed centrally slightly (*curvilinear arrow*) before releasing the flap hold (*star*), the flap edge (*arrow*) can be grasped with ease for the next step

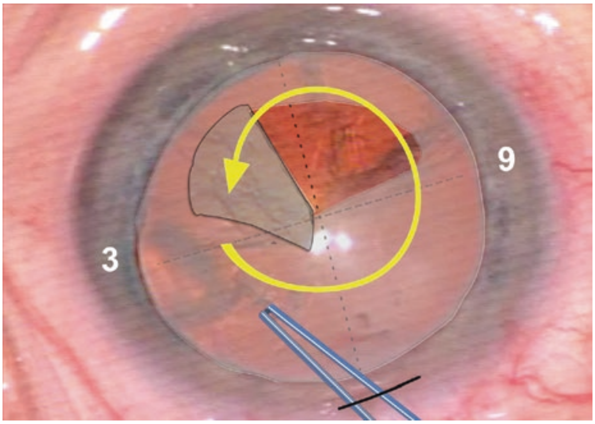

Fig. 5.36 Maintenance of a flat capsule flap. Clockwise forceps movement over the top of the flap is used to keep capsule flap opposed to lens surface

the lens surface, the edge becomes more difficult to grasp. This can be caused by forceps movement inducing viscoelastic disturbance of the flap position. The aim is to maintain the flap in a flat position opposed to the lens surface. Instead of injecting more viscoelastic, the surgeon can flatten the flap by closing the forceps (after the capsule is released) and making a complete clockwise circle with the forceps, traveling over the top of the created flap before grabbing it again, (Fig. 5.36).

Flap disturbance is usually not an issue if the flap is repositioned centrally before letting go.

5.3.4 Capsule Crease: A Clinical Sign Worth Knowing

During creation of the rhexis, it can be tempting to keep pulling or pushing the flap to extend the rhexis tear, especially past the cardinal points if it is tearing effectively. For novice surgeons, this temptation can quickly lead to problems with rhexis control. A good clinical sign to recognise is the "capsular crease" sign. This appears

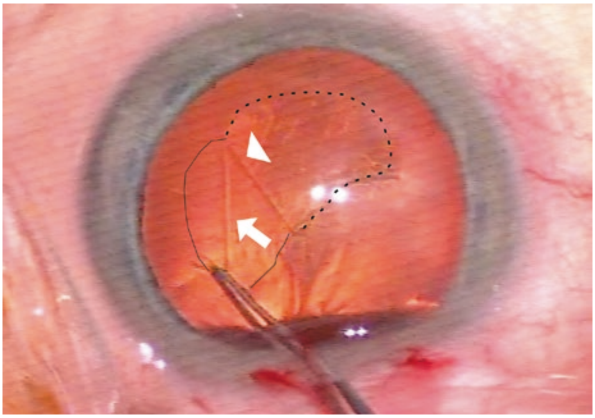

Fig. 5.37 Capsular crease sign. Capsule flap outline (*solid line*), edge of rhexis (*dotted line*), flap fold highlighted against red reflex (*arrow head*), capsular crease highlighted against red reflex (*arrow*)

when the force applied causes the capsule to stretch between the flap holding point and the tearing point in the rhexis margin (Fig. 5.37). This crease implies the hold is too long from the rhexis tearing point. If further tension if applied, an uncontrolled extension of the rhexis tear is likely to occur.

If a capsular crease sign is seen, it is recommended that the flap hold is released and a new flap hold is made (either short- or mid-point). Although is possible to continue pulling the flap even if a capsular crease is noticed—experienced surgeons will alter the direction of force automatically to extend the rhexis—for novice surgeons, it is recommended that a new hold is chosen instead of risking an uncontrolled tear extension.

Box 5.2 Trainer Teaching Pearls

For the first few rhexis attempts, it is recommended the Trainer fill the anterior chamber with viscoelastic and bend the needle for the novice surgeon. This reduces the number of new steps introduced in any one attempt.

Instruction is required throughout rhexis training. Simple encouraging phrases coupled with calm direct instruction can greatly assist novice surgeons appropriately performing a rhexis. The rhexis creation has many small components that are easily forgotten during surgery. Until the steps are automatic it is advised that instruction is given.

The rhexis size and shape will vary during the initial learning phase. This should be accepted. The aim is to promote confidence and skill in the movements with minimal senior take-over. Within modular training, the Trainer is expected to take over at the phacoemulsification stage. Hence, even in the presence of a less than ideal rhexis (for example an amoeboid-shaped, eccentric or small rhexis), safe lens extraction is much more likely to be performed by the experienced Trainer. Of course, should the rhexis veer out, then the Trainer should take over for the sake of patient safety. Likewise, if the rhexis is too small, the Trainer may need to enlarge it.

The natural instinct of novice surgeons is to make exaggerated circular movements in an attempt to make a circular rhexis and avoid the rhexis veering out. This tends to result in a small capsulorhexis. This can be avoided by instructing the Trainee to perform capsule tearing in straight-line vectors where possible. As continued rhexis learning opportunities arise, a circular, correctly sized, central rhexis will be achieved.

Trainees with prior rhexis experience who continue to struggle often verbally or physically express relief when a rhexis (regardless of what it looks like) is completed. Observing this relief of stress can be used to help the Trainer gauge the competency and confidence of the novice and provide additional support accordingly.

Do not hesitate to stop the Trainee and top up the anterior chamber with viscoelastic as needed during the initial attempts.

If drops are applied to a dry cornea during the capsulorhexis, there is a tendency for the eye to move, or for the view to be briefly lost. During drop application advise the novice to relax flap tension, or to wait until the drop has been applied before grasping the flap.

If the Trainee continues to struggle, staining the capsule (e.g. with Vision blue), can aid visualisation and understanding of what is required.

As the Trainee becomes more proficient in rhexis control, if a small rhexis is formed, the Trainee can be instructed to increase the size before the rhexis is finally completed. Instruction to continue directing the flap around the original rhexis opening (changing direction and re-grabbing accordingly) before pulling it centrally to complete the rhexis can be attempted.

5.4 Summary

Capsulorhexis can be easy to learn under instruction, but independent performance is often difficult until the fundamental steps are memorised and executed almost automatically. Following basic fundamental rules will provide the principles of how to perform this task with confidence and achieve a centred, circular, correctly sized rhexis. For the Trainer, precise instruction using a common terminology, will aid the novice surgeon. Surgeons, who have difficulty performing a rhexis, should review their technique and perhaps modify aspects to improve overall rhexis control. See Video 5.1.

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6 Hydrodissection

Most surgeons perform hydrodissection with the intention of injecting fluid into the potential space between the lens capsule and the nucleus. Cortical cleaving hydrodissection is achieved if the fluid separates the cortical material completely from the capsule, leaving a bare surface after lens removal [1]. Although perfect hydrodissection can reduce the need for subsequent soft lens material (SLM) removal, in practice, the injection of fluid results in the separation of the lens endonucleus and epinucleus from the cortex and capsule [2]. With rear-ended training the Trainee will be familiar with removing this thin layer of SLM that remains attached to the capsule.

The aim of this chapter is to provide the fundamental principles of how to perform hydrodissection, and what clinical signs to recognise. In order to simplify this topic, many actions do not appear in sequence. As a result, a full appreciation of the surgical steps will be only gained after reading the whole chapter.

The aims of hydrodissection are two-fold:

1. To separate the adhesions between the lens nucleus and capsule, ensuring the nucleus is freely mobile during phacoemulsification.
   (Poor hydrodissection will result in difficulty when rotating the lens nucleus).
2. To leave a thin, single layer of cortical SLM adherent to the capsule.

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6.1 Fundamental Principles and Clinical Signs

6.1.1 Create Space: The Viscoelastic Burp

Following curvilinear capsulorhexis (CCC), the anterior chamber remains filled with residual viscoelastic (Fig. 6.1).

Thus, there is minimal room for additional fluid to be injected into the eye. Any attempt to inject more fluid requires more force in order to displace some of the existing viscoelastic material. In order to avoid this, it is recommended that space is created above the lens. Gentle pressure on the posterior lip of the corneal incision causes expulsion of a small amount of viscoelastic (Fig. 6.2). The anterior chamber is not allowed to completely empty during the viscoelastic 'burp' (Fig. 6.3).

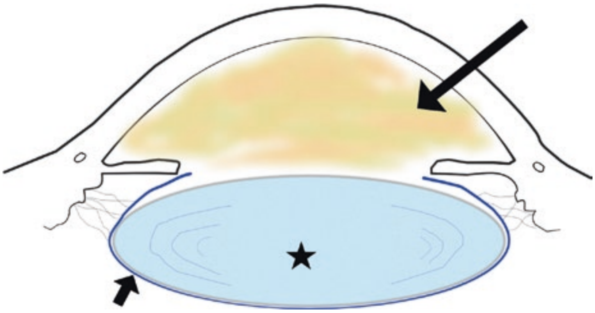

Fig. 6.1 Cross section of anterior chamber. Anterior chamber is filled with viscoelastic (*long arrow*), lens (*star*) and capsule outline (*arrow*) with capsulorhexis performed

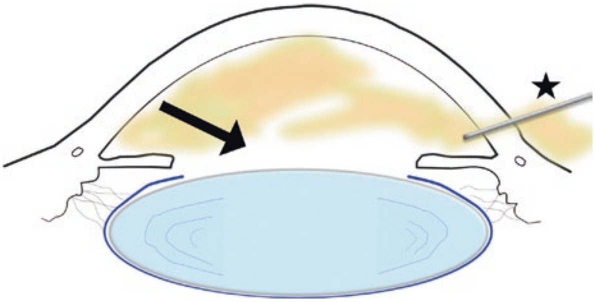

Fig. 6.2 Cross section of anterior chamber—viscoelastic fluid escape. A small amount of viscoelastic is allowed to escape by cannula pressure on the corneal section (*star*). Space is created above the lens (*arrow*)

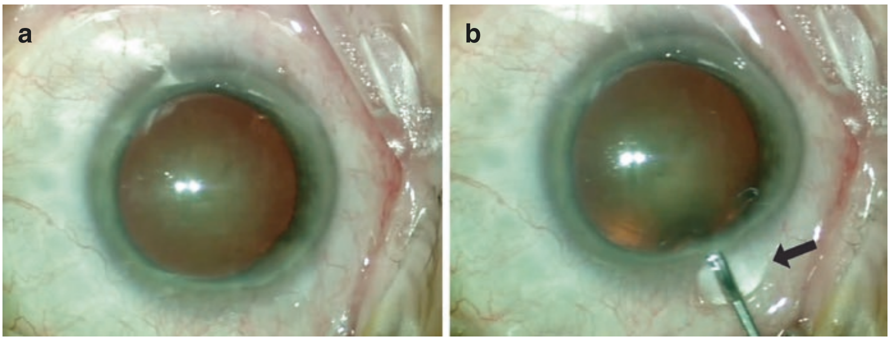

Fig. 6.3 Viscoelastic burp. (**a**) Post capsulorhexis completion, (**b**) posterior corneal incision pressure allows small amount of viscoelastic (*arrow*) to escape

6.1.2 Adequate Posterior Wave Propagation: Lens Prolapse

By burping viscoelastic, space is created for the lens to shift upwards slightly during hydrodissection. The fluid wave can then propagate circumferentially around the nucleus, usually stopping short of the anterior capsule area, opposite the site of injection. For example, if injecting at 5 o'clock the wave halts underneath the corneal section (Fig. 6.4). This is similar to capsular block syndrome and any subsequent fluid injected will then cause the lens to visibly rise upwards and start to bulge through the capsulorhexis opening. This is an important sign to look for (Fig. 6.5). Lens rise can be anticipated by observing the propagation wave and judging when it has travelled from one side of the lens to the other (see Sect. 1.5).

It is advisable to observe a definite small upward rise before stopping further fluid injection. Care is required to abruptly stop injecting, otherwise the lens can rapidly prolapse into the anterior chamber.

6.1.3 Adequate Posterior Wave Propagation: Lens Depression

Withdraw the cannula and depress the lens gently at the apical centre with the cannula. As the lens is gently pushed into the bag the fluid wave will continue to propagate around the capsule anteriorly overcoming any equatorial epinucleus cortical adhesion. The lens should be pressed gently near the capsulorhexis edge in various locations to help further promote the small amount of fluid that is trapped posteriorly to propagate anteriorly under the anterior capsule. The red-reflex under the anterior capsule will alter slightly as this additional step is performed.

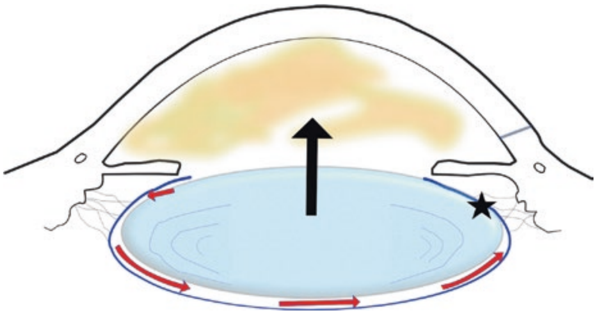

Fig. 6.4 Propagation of fluid wave. The lens move upward slightly (*arrow*) as the propagation of fluid (*curvilinear arrows*) passes beneath it. The wave halts (*star*) opposite the site of injection

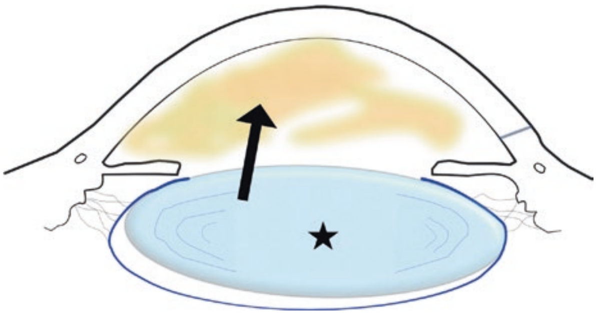

Fig. 6.5 Visible lens prolapse following adequate hydrodissection. Lens (*star*) starts to prolapse upwards (*arrow*) into the anterior chamber

6.1.4 Where Should Fluid be Injected for Maximum Effect?

Incorrect placement of the hydrodissection cannula can result in poor overall technique. The lens is convex in shape with the apex located centrally. Placing the cannula over the central apex of the lens can hinder upward lens shift during hydrodissection and potentially halt the fluid wave from propagating posteriorly (Fig. 6.6). In view of this, avoid cannula tip placement at the 6 o'clock cardinal point, directly opposite the corneal section (Fig. 6.7).

The resistance felt during the injection will increase and require either a more forceful injection of fluid (which could potentially rupture the capsule), or multiple fluid injections at other areas. The latter results in multiple layers of SLM (unintentional hydrodelineation) that will need to be removed, either with the phaco probe or during irrigation aspiration.

Cannula placement between 2 and 5 or 7 and 10 o'clock is ideal as it ensures the shaft is not placed over the apex. The lens will then be free to move upwards during the hydrodissection and the fluid wave can propagate freely (Fig. 6.8).

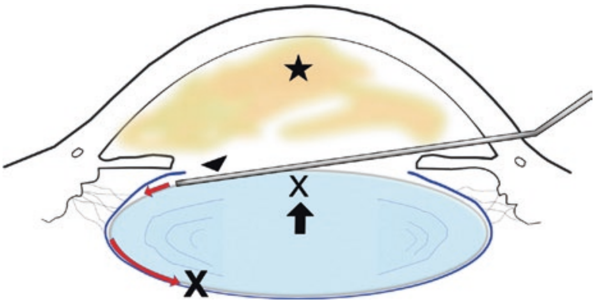

Fig. 6.6 Incorrect hydrodissection cannula placement. Cannula (*arrow head*) is placed with its tip at the 6 o'clock cardinal point with the shaft over the apex of lens. The lens cannot move upwards (*small x hinders movement arrow*) and propagation of fluid wave (*curvilinear arrows*) is hindered (*large X*). Viscoelastic (*star*)

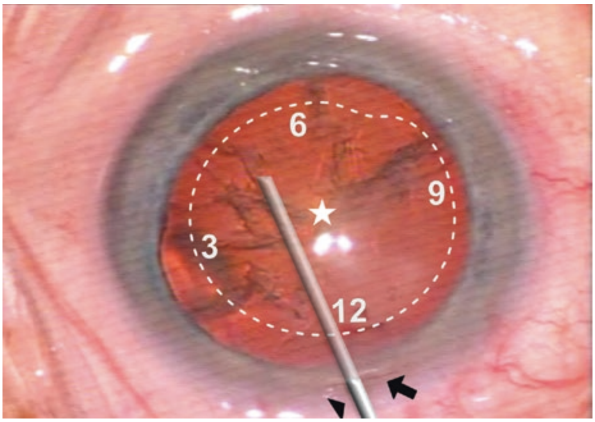

Fig. 6.7 Hydrodissection cannula tip placement. 6 o'clock cardinal point placement avoided to prevent cannula (*arrow head*) resting over the lens (*star*), corneal section (*arrow*), capsulorhexis outline (*dotted line*)

6.1.5 How to Inject

The hydrodissection wave needs to find the plane of least resistance between the lens nucleus and the capsule. To find the ideal plane, advance the hydrodissection cannula towards the capsulorhexis edge. The cannula should ideally rest just on the surface of the lens and start to inject just *before* the capsulorhexis edge is reached (Fig. 6.9).

As the fluid passes between the capsule and the epinucleus a cleavage plane will be seen by a colour change in the red-reflex. This is the fluid wave passing over the anterior of the lens surface and under the capsulorhexis (Fig. 6.10).

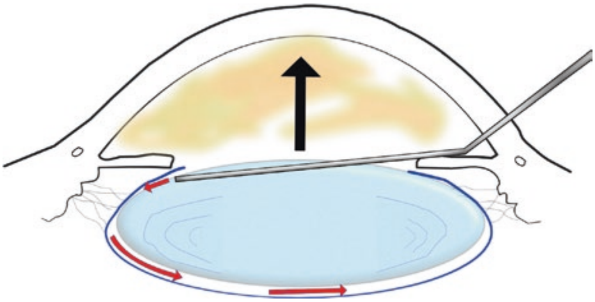

Fig. 6.8 Correct hydrodissection cannula placement. Resting cannula shaft over lens apex avoided. Lens is free to move upwards (*arrow*) and fluid propagation wave (*curvilinear arrows*) takes place

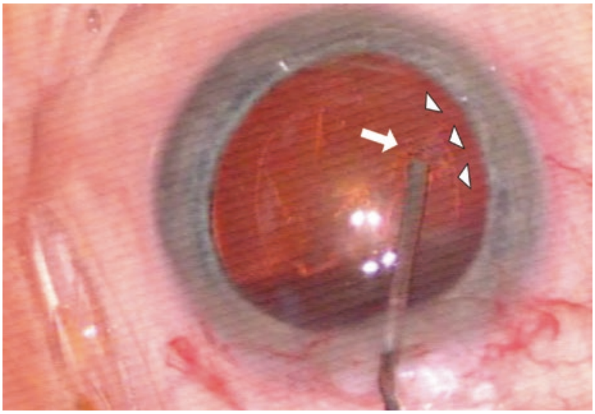

Fig. 6.9 Correct initial placement of cannula tip during hydrodissection. The cannula (*arrow*) is held with the tip slightly away from the capsulorhexis edge (*arrow heads*)

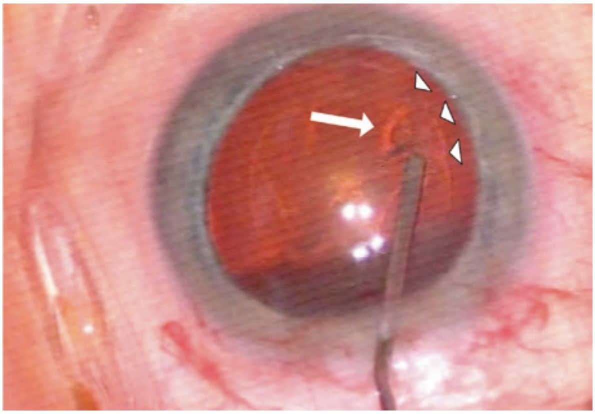

Fig. 6.10 Commencement of hydrodissection fluid wave. The cannula is held with the tip slightly away from the capsulorhexis edge (*arrow heads*). The initial fluid wave causes a colour change in the red reflect (*arrow*)

Advance the cannula tip under the capsulorhexis edge in a continuous motion, *whilst* continuing to inject. There is no requirement to lift or tent the capsule. Tenting the capsule may allow regurgitation of fluid rather than promoting fluid propagation equatorially around the lens. Furthermore, the novice surgeon is often reluctant to try and lift the capsule upwards for fear of damaging it. Too much downward pressure on the lens surface with the cannula shaft is not advised as this will prevent the upward movement of the lens and hinder the wave progression.

As more fluid is injected, the convex bow-wave outline of the fluid wave will be seen, as a change in the red-reflex, as it progresses and travels across the posterior aspect of the lens. This bow wave movement is an important clinical sign to recognise. As the wave is propagating across the posterior aspect, keep injecting until it reaches the opposite side (Fig. 6.11).

The wave may reach the opposite side quickly. Be prepared to inject more gently as wave reaches the opposite side of the bag. As it reaches the opposite side, the wave stops travelling and the lens will start to rise and begin to prolapse through the rhexis anteriorly. This can happen quickly and it is advisable to stop injecting when this is noted. The lens can then be pushed back into the bag using the cannula by depressing the central apical area (Figs. 6.12 and 6.13).

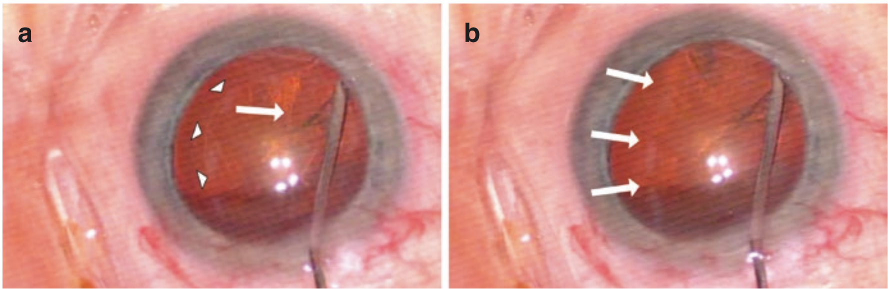

Fig. 6.11 Observation of fluid wave during hydrodissection. (**a**) Commencement of fluid bow wave. (**b**) Bow wave propagation almost completed. Red reflex colour change (*arrows*), capsulorhexis edge (*arrow heads*)

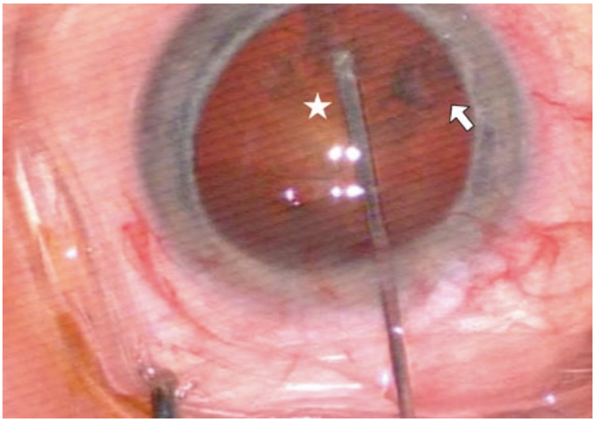

Fig. 6.12 Depression of the lens to complete hydrodissection. The lens is pushed downwards by pressing the lens near the apical centre (*star*) into the capsule bag. The original site of hydrodissection (*arrow*)

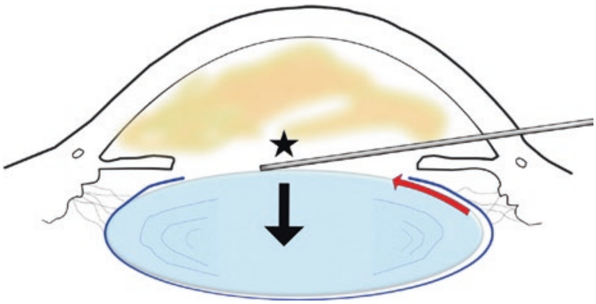

Fig. 6.13 Depression of the lens to complete hydrodissection. The lens is pushed downwards (*arrow*) by pressing near the apical centre (*star*) into the capsule bag. Propagation of the fluid wave around the anterior capsule is encouraged (*curvilinear arrow*)

The lens will return to its usual position within the capsule bag and the wave will move further forward under anterior aspect of capsule. This can be facilitated by gently pressing the lens near the capsulorhexis edge in various locations. Again a change in the red-reflex can be seen under the anterior capsule.

Finally, as the cannula is withdrawn from the eye, a small amount of fluid should be injected to maintain the anterior chamber as the cannula is removed. The Trainee should avoid stroking the globe as the cannula is removed as this may depress the posterior lip of the incision and cause the anterior chamber to shallow as fluid escapes.

Box 6.1 Surgical Tip

- It is recommended that novice surgeons develop the hydrodissection mantra: “burp the viscoelastic, avoid the 6 o’clock position, start to inject before the rhexis edge, watch the bow wave, ease off and let the lens ride up, stop injecting and press the lens back.”
- Whilst advancing the cannula tip into the eye, keep the tip flat and just resting on the surface of the lens.
- If the continuous curvilinear capsulorhexis is eccentric, or not quite centrally placed, it is advisable to place the cannula in the area of eccentricity (Fig. 6.14). This will hold back the lens slightly and prevent the excessive, sudden lens prolapse at the end of hydrodissection through this eccentric area.
- Sometimes the fluid wave propagation beneath the lens is not seen. In such cases it is important to note whether the lens rises upwards as this will indicate the wave has travelled across the posterior aspect of the nucleus.
- If the lens is depressed near the rhexis edge, to try and encourage additional anterior wave propagation, and no change in the appearance is noted, then the surgeon cannot assume anterior wave propagation has fully occurred. In this situation, a useful additional manoeuvre is a *cannula fluid sweep* under the rhexis. Following hydrodissection, and repositioning the prolapsed nucleus, the cannula is placed under the rhexis edge and swept across the surface of the lens (with the tip just under the rhexis edge) whilst

continuing with minimal gentle injection. This can be used for any cataract case, but is particularly useful in cortical cataracts. A cannula fluid sweep motion can be performed, with or without subsequent direct rotation of the lens using the cannula.

- In most cases a single injection is all that is required.

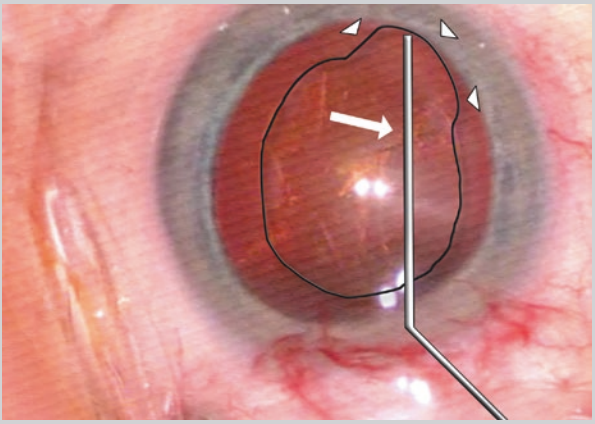

Fig. 6.14 Hydrodissection in the presence of an eccentric curvilinear capsulorhexis. Location of cannula placement (*arrow*) is determined by capsulorhexis (*solid curvilinear line*) eccentricity (*arrow heads*)

Box 6.2 Trainer Teaching Pearls

Incomplete hydrodissection can occur when novice surgeons start to perform this module. There are many tasks to concentrate on: holding the syringe, directing the cannula tip and depressing the plunger. This multitasking can mean certain steps are overlooked or not focused on, for example, burping of viscoelastic or watching the fluid wave propagate. The Trainer needs to remind the novice of the all of the steps and not assume the novice will automatically perform them. The suggested hydrodissection mantra can help the novice remember the steps.

Novice surgeons often try to inject directly opposite the corneal section, preventing the upward rise of the nucleus. For the initial cases it is advised the Trainer constantly remind the novice where the cannula tip should be placed.

After injecting fluid under the capsule, the lens can suddenly prolapse. The Trainer needs to be ready to tell novice to stop injecting when the nucleus starts to bulge forward. Excessive lens prolapse should be avoided. As experience is gained in the wave propagation step less instruction will be needed.

Inadvertent hydrodelineation, in which fluid is injected into the central or peripheral nucleus, creates multiple layers or plates of epinuclear material. Though hydrodelineation is useful in certain instances, for example soft cataracts, the plates created during hydrodelineation are tricky for novice surgeons to remove. It is recommended that hydrodelineation is avoided, if possible, in the early stages of training. Novices will want to inject in multiple locations, mainly to reassure themselves that the hydrodissection is complete. This inevitably leads to hydrodelineation. Multiple attempts can be discouraged if the fluid wave has been seen and the lens has required depression after prolapsing. Novices need to have confidence that they can perform the hydrodissection in the majority of cases with a single well placed injection, with or without a fluid sweep. In the recommended modular training timetable, since the Trainer will take over after hydrodissection it will quickly become apparent if the nucleus is freely mobile and the novice hydrodissection has worked or not.

For surgeons who struggle to manage the irrigation aspiration stage of SLM due to the presence of multiple layers of cortical material, the Trainer is advised to analyse the hydrodissection technique. Making changes to hydrodissection technique can often help sort out the difficulties encountered. Encouraging a viscoelastic burp, avoiding injection at 6 o'clock and encouraging commencement of the fluid injection before rhexis edge will usually induce a single layer of residual SLM for the Trainee to remove.

6.2 Summary

Hydrodissection is a key step in cataract surgery. The technique can be broken down into simple steps, each with well-defined clinical signs. See Videos 6.1, 6.2, 6.3, and 6.4. Hydrodissection can facilitate free rotation of the lens nucleus in preparation for phacoemulsification. It is an essential step in providing a residual single layer of soft lens material, facilitating irrigation aspiration clean up of the capsule. The principles described cover the basic principles, and Trainers can modify the suggested technique accordingly.

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How to Palm an Instrument

7

Palming an instrument is a technique that experienced surgeons use subconsciously. The technique requires the surgeon to reposition and retain an instrument within the grasp of one hand, at the same time freeing up fingers of the same hand to perform other tasks. The reverse technique (i.e. "un-palming" an instrument) is used to reposition and grip the same instrument so that it is ready to use again or hand back to the assistant. Most novice surgeons are not formally taught how to palm, and the skill ends up being self-acquired.

Palming can be used to facilitate smooth transition between certain surgical steps. It cuts down the need to relinquish a pair of forceps and allows the non-dominant hand to act as support for the dominant hand during surgery. It also allows novices to remain focused on certain task and avoid disruption during the process of instrument handling. Finally, reversing the technique allows a palmed instrument to be used again without the requirement to requesting it from the scrub nurse. It is suggested that the surgeon practices this technique in their non-dominant hand before phacoemulsification training. The technique will be referred to in subsequent chapters.

7.1 Palming an Instrument Step-By-Step Instruction

The aim is to manipulate an instrument, for example a pair of forceps, from the primary position of use (Fig. 7.1) to a palmed position (Fig. 7.2).

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Fig. 7.1 Forceps held in primary position

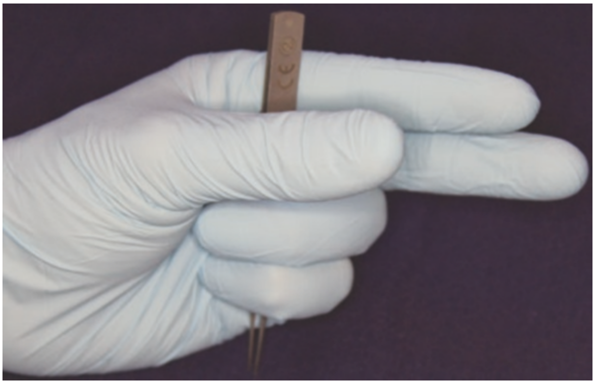

Fig. 7.2 Forceps held in palmed position

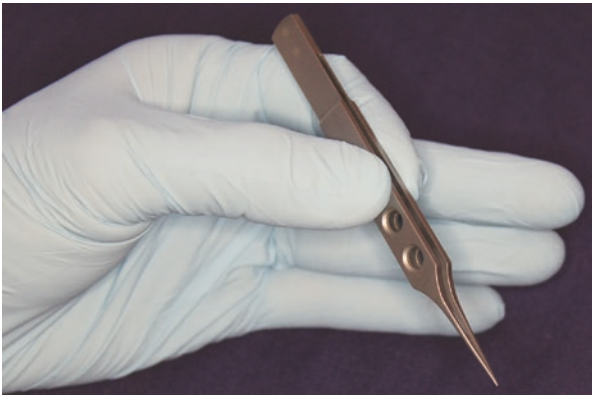

Fig. 7.3 Palming step 1—initial position

7.1.1 Step 1

Release lower finger support of the instrument by straightening the middle, ring and little fingers so that the instrument is held only with the thumb and index finger (Fig. 7.3).

7.1.2 Step 2

Whilst gently holding the instrument between the thumb and index finger, allow the forceps to slip and rotate downwards, as if the instrument is falling out your grip (Fig. 7.4).

7.1.3 Step 3

Fully release the pincer-grip hold, by relaxing the thumb and index finger, and catch the instrument by gripping it quickly with the ring and little fingers. The instrument is then securely held in by the ring and little fingers (Fig. 7.5). The thumb, index and middle fingers are then free to be used for other tasks and the instrument is *palmed* (Fig. 7.2).

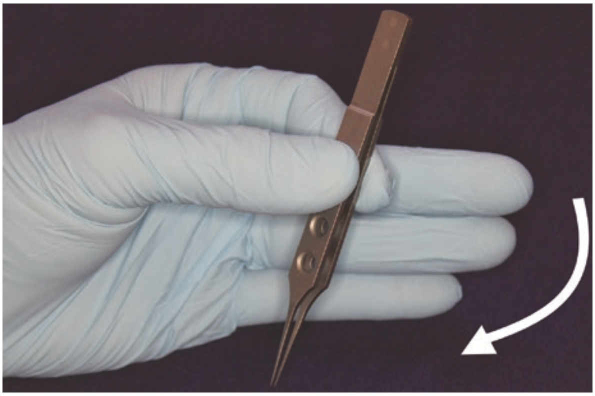

Fig. 7.4 Palming step 2—pivoting. Instrument allowed to pivot within pincer grip downwards (*arrow*)

Fig. 7.5 Palming step 3. Instrument is held only by ring and little finger

7.2 Palming Reversal

In order to reuse the instrument the palming technique must be reversed:

7.2.1 Reverse Step 1

From the palmed position, pincer-grip the instrument using the thumb and index finger (Fig. 7.6) and release lower hold by opening ring and little finger.

7.2.2 Reverse Step 2

After releasing the lower grip, tuck the middle, ring and little fingers beneath the instrument and help it swing upwards, using the thumb index finger pincer-grip as a fulcrum (Fig. 7.7).

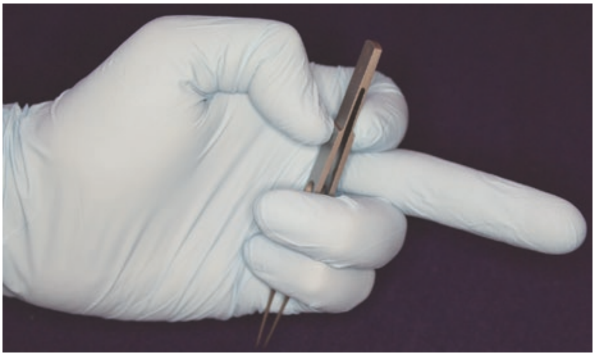

Fig. 7.6 Reverse palming step 1. Instrument is held by thumb and index finger

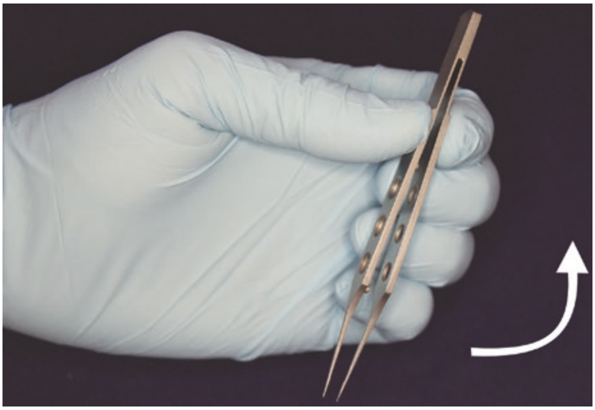

Fig. 7.7 Reverse palming step 2. Instrument is swung upwards (*arrow*) using middle, ring and little fingers

7.2.3 Reverse Step 3

The instrument should then be returned to the working position (Fig. 7.1).

Box 7.1 Surgical Training Tip

Using the non-dominant hand, practice until palming technique can be done with ease. If no spare instruments are available, the technique can be practiced with a pen/pencil instead (Fig. 7.8).

Once the technique is mastered, it is recommended that surgeons practice the following skills:

- Palm a pair of forceps in the non-dominant hand and then accept a new instrument into the *palmed* hand using the free fingers (Fig. 7.9). Pass the second instrument back and forth to the other hand before discarding it. Un-palm the first pair of forceps ready for use.
- Practice palming a pair of forceps and use free fingers to support the other hand (which is holding an imaginary instrument within the anterior chamber).

Fig. 7.8 Palming and reverse palming practice with a pencil

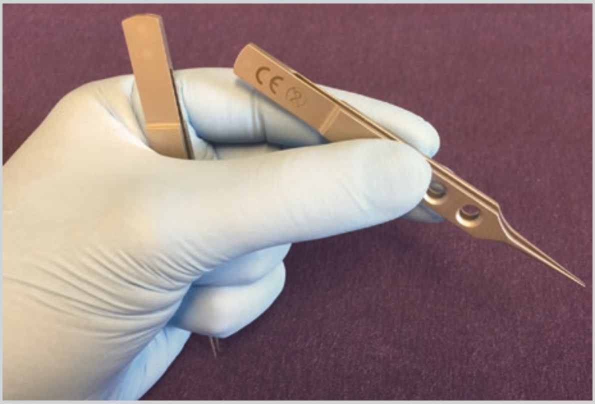

Fig. 7.9 Non-dominant hand has palmed one instrument and is using free fingers to utilise second instrument

Box 7.2 Trainer Teaching Pearls

Novice trainees require additional operating time as they gain the skills needed for efficient surgery. Some of this additional time is taken up by pauses in the surgical flow. The Trainer will often observe a novice looking away from the microscope as they hand back or receive instruments. Palming is very useful skill which will reduce distractions and free up spare fingers needed during certain surgical steps. For example, additional fingers may be needed to steady the phacoemulsification probe after immediate insertion into the eye (Fig. 7.10). Mastery of palming is recommended before Trainers instruct novices in the techniques required for the next module (Chap. 8 Phacoemulsification: small fragments). Initially, during surgery, the Trainer may need to instruct novices as to when to palm or un-palm an instrument. Eventually novices will automatically palm at key moments.

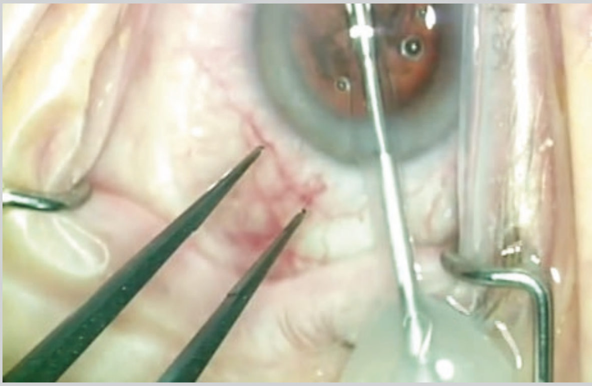

Fig. 7.10 Example of situation in which instrument palming is not performed. Trainee is unaware of palming technique. Forceps hover above globe and phaco probe is inserted using one hand only

7.3 Summary

Competency in palming and un-palming can be quickly mastered. It is recommended that it is practiced before phacoemulsification small fragment removal training. Instruction about when to palm and un-palm is likely to be required from the Trainer so that novices become accustomed as to when it is needed to help surgical flow. See Video 7.1.

8 Phacoemulsification: Small Fragments

After hydrodissection, the lens nucleus is ready for removal. The whole lens, however, is too large to be expressed through the capsulorhexis opening. To avoid overstretching and tearing the capsulorhexis, the lens must be divided into smaller sized pieces. Each fragment must be sized for safe extraction from the bag in preparation for subsequent phacoemulsification. Dexterity, of both hands and feet, is required during phacoemulsification of the lens nucleus. And continuous decision-making is necessary to decide how best to achieve lens disassembly. Although there are a plethora of phacoemulsification techniques described, the aim, simply put, is to develop the skills of the 'lazy phaco surgeon'—that is, to learn how to do as little as possible to achieve lens extraction from the eye.

Learning how to phaco is dependent on the Trainer's ability to instruct and the ability of the Trainee to follow instruction. Since only one person can perform surgery at any given time, it is necessary to make the learning process proceed smoothly, so that the stress of operating is minimised for all involved. Surgery needs to remain controlled and performed within the limits of the novice surgeon. The rate of progression will depend on what the Trainer feels is safe and at which point they feel intervention is needed.

Traditionally, the sequence of phaco surgery is taught starting with a whole lens in situ, with step-by-step techniques acquired to manipulate, split and remove the lens fragments. However, to improve the rate of learning a rear-ended approach to this phaco sequence can be applied, namely:

1. Small fragment removal
2. De-bulking of larger fragments (see Chap. 9)
3. Make a space (see Chap. 10)

Electronic Supplementary Material The online version of this chapter (doi:10.1007/978-3-319-59924-3_8) contains supplementary material, which is available to authorized users.

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4. Cracking and grooving (see Chap. 11)
5. A simple stop, chop and crack technique (see Chap. 12)

The fundamentals for each step have been broken down, starting with the small fragment removal module. In order to commence training at the small fragment removal stage of surgery, the Trainer is required to perform lens nucleus disassembly before handover to the novice.

The primary aim at this stage is for novices to gain essential phaco, fragment rotation and foot pedal skills without having to deal with whole lens disassembly or the debulking of large fragments.

Those already familiar with phaco may prefer to focus on any of the individual phaco module chapters. It is recommended, however, that all the chapters are used in conjunction with each other, so that all the principles described are understood. The principles can be applied when performing surgery, or recognised and appreciated if acting as an observer.

Assumptions made in relation to this phacoemulsification training module are shown in Box 8.1.

Box 8.1 Assumptions Made in Relation to This Training Module

1. Case selected for initial phacoemulsification will be chosen by the Trainer.
2. The Trainee can perform irrigation/aspiration, lens insertion, capsulorhexis, hydrodissection and can 'palm' an instrument.
3. For the first few cases of small fragment phacoemulsification training, the Trainer will perform the initial preparation up to the fragment extraction stage.
4. The Trainee may continue to perform modular aspects of capsulorhexis and hydrodissection on separate or the same case and eventually be able to perform all steps learnt in sequence.

Note: although the images chosen for this chapter are intended to aid understanding of various surgical principles, they may not have been performed during the small fragment removal stage of surgery.

8.1 Terminology

8.1.1 The Phaco Probe

A plastic sleeve covers the metal phaco probe. The sleeve has two irrigation apertures and is rotated to ensure both irrigation fluid jets exit the holes horizontally. The 'mouth' is the exposed phaco tip aperture that engages and removes lens material. The probe maintains this 'primary' position when held as described within the eye (Fig. 8.1).

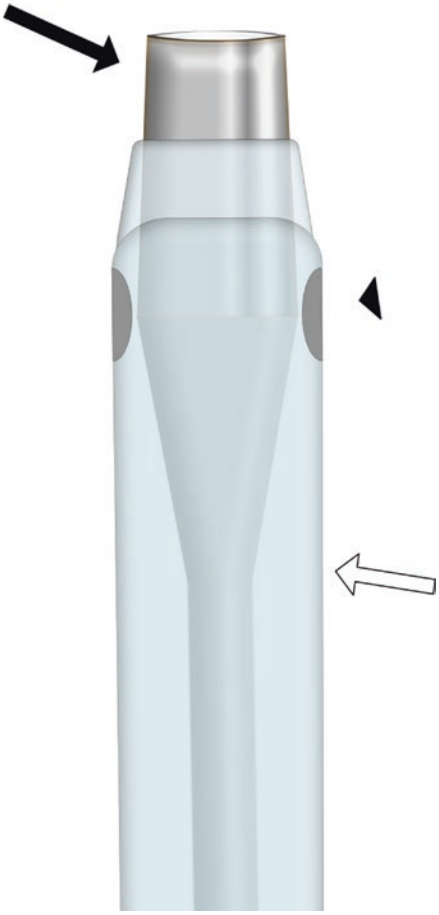

Fig. 8.1 Phaco probe in primary position. Phaco tip and mouth (*solid arrow*), irrigation aperture (*arrow head*), phaco sleeve (*open arrow*)

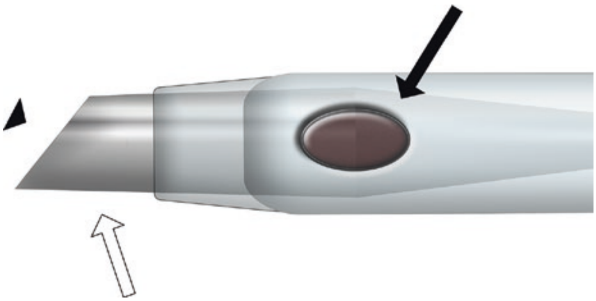

Fig. 8.2 Phaco tip—side profile in primary position. Mouth of phaco tip (*arrow head*), inferior length of tip (*open arrow*) is longer than superior aspect, sleeve irrigation aperture (*solid arrow*)

In side profile, the exposed phaco tip shape is shorter in length superiorly (Fig. 8.2).

In the descriptions below the term *phaco on* refers to the application of ultrasonic phacoemulsification. *Phaco off* implies the ultrasonic phacoemulsification should be turned off.

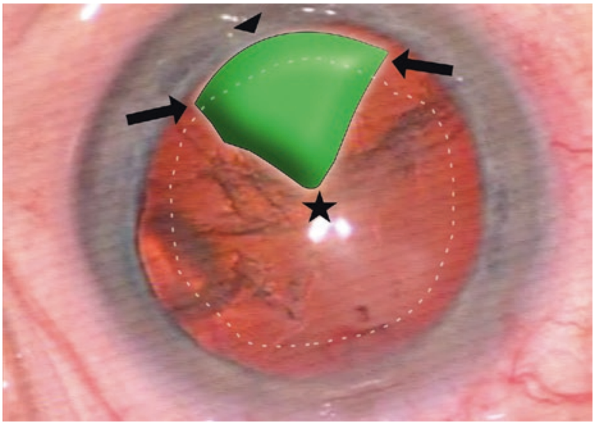

Fig. 8.3 Lens segment. Apex (*star*), shoulder (*arrow*), base of segment (*arrow head*), capsulorhexis outline (*dotted line*)

8.1.2 Lens Fragment Anatomy

After division of the nucleus, lens fragments are pyramid shaped with an apex and a curvilinear base. At the widest point of the base the fragment has two shoulders (Fig. 8.3).

When a fragment lies within the capsule bag, the base and shoulders remain under the rhexis edge and will need to be freed before phacoemulsification can occur.

If the lens is divided into two halves, each hemi-nucleus will have a curved base, two shoulders but no apex. If a hemi-nucleus is chosen for phacoemulsification, it will be necessary to extract one shoulder from the capsule bag and then the other, otherwise the hemi-nucleus may not fit through the rhexis opening.

8.1.3 Lens Fragment Capture

Fragment capture refers to the situation where a fragment is firmly held by the phaco tip ready for manipulation or phacoemulsification.

8.1.4 The Safe Zone

The *safe zone* is the central area within the anterior chamber (Fig. 8.4). It is recommended lens fragments are manoeuvred into, and phacoemulsified within, the safe zone.

Pulling the phaco tip back (towards the corneal section), and keeping the fragment in the centre of the safe zone, maximises the free space surrounding the captured fragment in preparation for phacoemulsification removal. It reduces the likelihood of accidental phaco damage to the rhexis edge, iris or the endothelium.

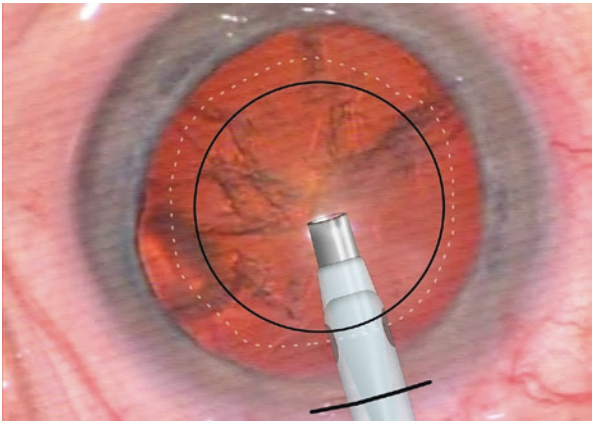

Fig. 8.4 Phacoemulsification safe zone. Capsulorhexis outline (*dotted line*), safe zone (*solid circle*), corneal section (*solid line*)

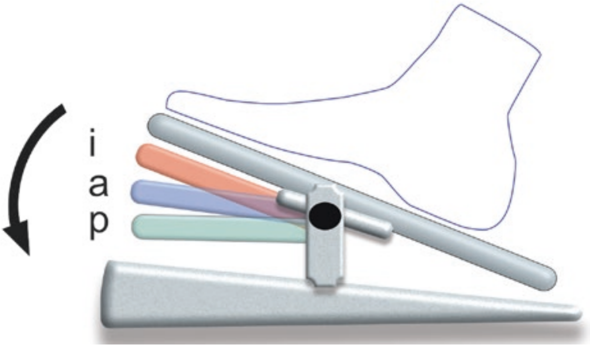

Fig. 8.5 Linear foot pedal control. (i) Irrigation, (a) aspiration plus irrigation, (p) phacoemulsification plus irrigation and aspiration

8.2 Foot Pedal Control

Two foot pedal modes are available to control the amount of aspiration and phacoemulsification: linear and dual-linear. Linear control, akin to a car accelerator pedal, allows the surgeon to control the three variables needed to remove the nucleus; irrigation, aspiration and phacoemulsification. The programmed progressive change automatically occurs as the foot pedal is depressed (Fig. 8.5). Common preprogrammed machine settings, referred to as 'phaco 1' and 'phaco 2', are set up by the surgeon according to their aspiration and phaco power preference. Commonly, phaco 1 is used for nucleus grooving and cracking, whilst phaco 2 is for fragment capture and phacoemulsification. It is necessary to actively pause during surgery and switch from phaco 1 to phaco 2 as required.

In dual-linear mode, both the vertical and the horizontal yaw foot pedal moment is used to control the three variables. One direction is set up to control phacoemulsification whilst the other direction controls irrigation and aspiration. This allows the surgeon to toggle between the maximum aspiration and the maximum phacoemulsification, applied independently of each other. There is a learning curve when using dual-linear mode, but it is more flexible when applying aspiration and phacoemulsification. Novice surgeons usually start training on a linear setting, but this will depend on their Trainer.

The phaco machine can be set to allow continuous irrigation. This is a useful setting that ensures the anterior chamber is maintained once irrigation has been initiated. Irrigation will continue to flow and has to be consciously stopped, using the foot pedal, whenever the phaco probe is removed from the eye. Failure to remember this will result in a very wet operating area.

It is recommended that novice surgeons become familiar with the phaco machine sounds (for irrigation, aspiration and phaco) emitted by the brand of phaco machine used in their facility.

8.3 Insertion of the Phaco Probe

Insertion of the phaco tip into the eye is the first step in phacoemulsification surgery. A proficient, smooth technique is required. Technical barriers to overcome include: initial resistance of the corneal wound, accidentally catching the curved edge of the phaco sleeve irrigation ports on the lip of the corneal section, and potential anterior chamber collapse. The probe insertion technique can be broken down into steps:

8.3.1 Step 1

Ensure the irrigation is working by briefly wetting the cornea and then stop irrigating. Position the phaco probe so that it is held near the corneal incision in anticipation of the next step (Fig. 8.6).

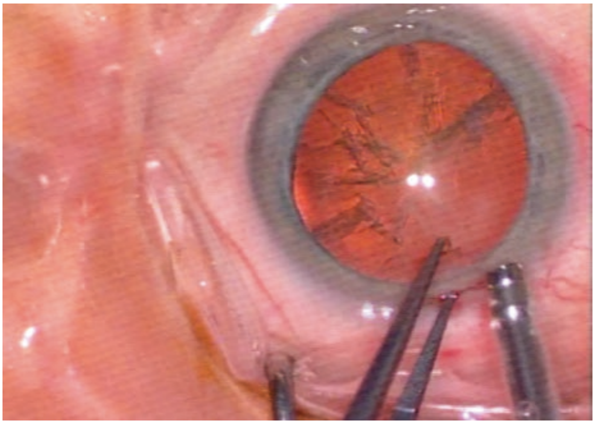

Fig. 8.6 Phaco probe insertion step 1

8.3.2 Step 2

Hold the forceps in the non-dominant hand. Approach the corneal incision from a slight angle (so as to not obscure the view) and use one side of the forceps to gently *lift* the anterior lip of the corneal section. This will cause the wound to gape, ready for the next step (Fig. 8.7). If possible, avoid gripping the corneal section with the teeth of the forceps as this will induce micro-trauma.

8.3.3 Step 3

Immediately place the phaco tip into the wound. The corneal wound has a stepped corneal incision. To help traverse this, depress the posterior lip slightly with the phaco tip as it is inserted (Fig. 8.8).

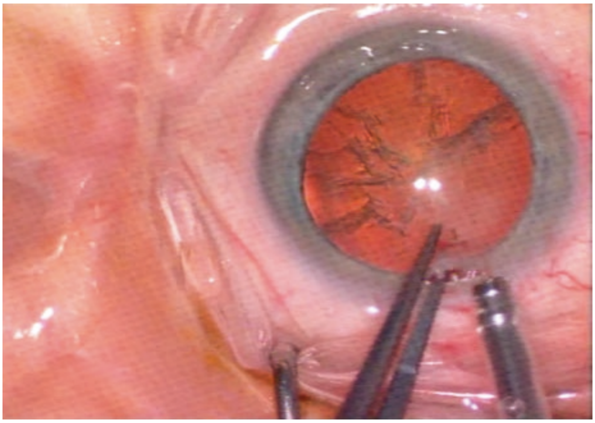

Fig. 8.7 Phaco probe insertion step 2

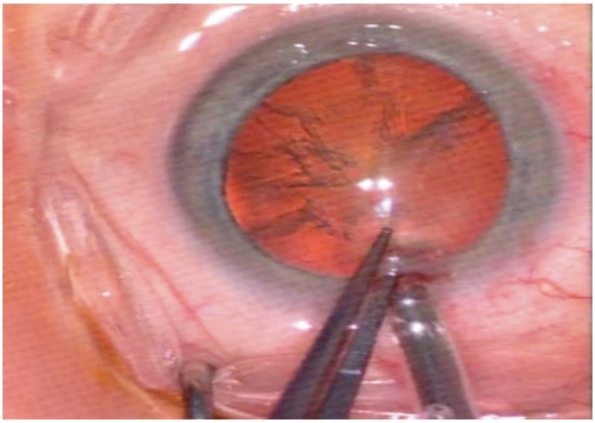

Fig. 8.8 Phaco probe insertion step 3

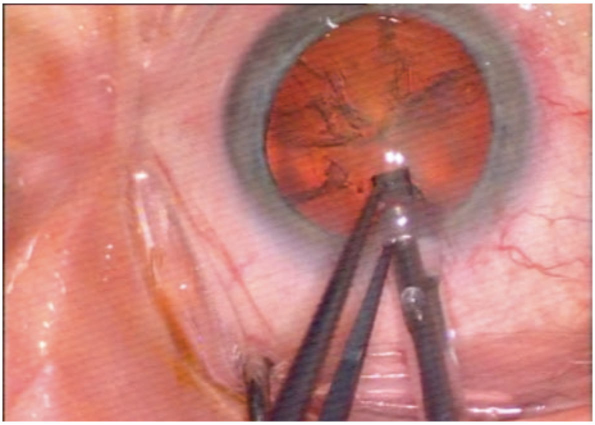

Fig. 8.9 Phaco probe insertion step 4

8.3.4 Step 4

Commence irrigation as the phaco tip starts to enter the anterior chamber. This inflates the anterior chamber and allows the iris to fall back away from the phaco tip (Fig. 8.9). Aspiration should not be used (listen to the emitted sound). Palm the forceps and steady the phaco tip with both hands.

8.3.5 Step 5

If the phaco sleeve starts to catch on the wound, oscillating the phaco using a screwing/unscrewing motion should help the sleeve to navigate the corneal wound and enter the eye.

It is important to proceed with caution if the probe does not smoothly enter the eye. Applying excessive force when inserting the probe can cause the phaco tip to suddenly enter the eye in an uncontrolled inward movement. Be prepared to halt any such sudden movement.

8.3.6 Step 6

Once the probe is inserted, ensure the anterior chamber is fully inflated and perform a *pseudo-groove. This involves* moving the probe backwards and forwards on irrigation setting only, without touching the lens. The *pseudo-groove* enables the surgeon to gauge any probe movement resistance created by the wound before commencing phacoemulsification of the lens.

8.4 Second Instrument Insertion into the Eye

The phaco probe is always the primary instrument—any additional instrument inserted into eye is termed the second instrument. Second instruments (for example a "chopper" or "mushroom") have tips with 90-degree angles. Insert the instrument by holding the shaft perpendicular to the wound. This way, the tip enters the paracentesis incision directly and avoids catching the corneal stroma (Fig. 8.10).

Care is needed when inserting a second instrument into the eye. Well-made, clear, corneal side-port incisions can be hard to subsequently visualise and locate. Localised micro-trauma may easily result in a conjunctival haemorrhage or a corneal epithelium abrasion. To help identify an invisible side port opening, novice surgeons should look for clues such as the presence of a small adjacent haemorrhage or fluid escaping the side port as the limbus is prodded. Although not ideal, *limbal prodding* may be required if the exact location cannot be recalled or visualised. Limbal prodding involves gently pressing the limbus in the general area of the side-port location until the opening is found.

Once the tip has passed the internal corneal opening, the instrument can be rotated so that the shaft can also enter the eye. This allows the tip to navigate the length of the incision.

If second instrument insertion is awkward due to a lack of periocular manoeuvring space, for example if the nose, lid or speculum are in the way, additional space can be briefly created. It is possible to horizontally rotate the globe, in an opposite direction to the side port, by using the phaco probe to apply lateral pressure to the main corneal incision. Once the second instrument has been inserted the lateral movement can be relaxed, returning it to the primary position.

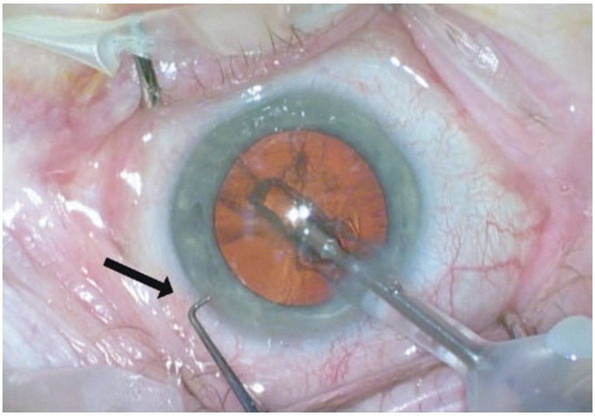

Fig. 8.10 Second instrument insertion into the side port incision

Whilst concentrating on second instrument insertion, the phaco probe can be neglected allowing unintentional drift of the tip. It is recommended that the phaco tip is not resting on the lens surface during the second instrument insertion.

8.5 Fundamental Concepts for Phacoemulsification of Fragments

8.5.1 Fragment Engagement

When trying to extract a fragment from the capsular bag, a common mistake is to initiate aspiration whilst a large gap exists between the fragment apex and the phaco mouth (Fig. 8.11). The expectation being that the fragment will successfully jump the distance and be captured by the phaco tip. The phaco tip should ideally be positioned close to the apex of the fragment *before* trying to engage aspiration.

In practice, aspiration may be sufficient to achieve fragment capture if there is sufficient space surrounding the fragment, allowing it to move freely. If not, the fragment may resist moving towards the phaco tip and apical lens material may crumble, making successive attempts to grab the ‘shrinking’ fragment more difficult.

A better method of fragment capture is to apply phacoemulsification so that the fragment embeds in the phaco tip, securing a firm hold. Care is required to ensure only a small amount of phacoemulsification is applied. The phaco tip mouth should be occluded with a ‘tongue’ of lens material that remains attached to the surrounding fragment. This way the fragment can be manipulated as an extension of the phaco probe and pulled into the safe zone.

A jerky technique should be avoided. There is less control if the phaco probe and captured fragment are quickly pulled back with *phaco on*. Jerky movement with *phaco on* will cause the apex to crumble and the fragment to fall back into the bag. Deliberate fragment capture is preferred, with a short burst of phaco applied during forward movement into the fragment. Fragment extraction should only be attempted once the tip is embedded and with *phaco off*. Maintaining aspiration will aid the extraction.

Additional surgical suggestions on fragment extraction are described later in the chapter.

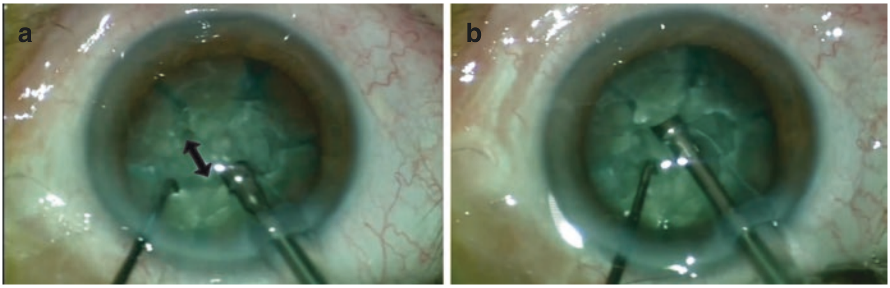

Fig. 8.11 Fragment engagement. (**a**) A potential gap exists between fragment apex and phaco tip (*double headed arrow*), (**b**) recommended phaco tip position with no potential gap

8.5.2 Fragment Wobble

During phacoemulsification removal, the captured fragment needs to be free to move and spin slightly. This freedom for fragment *wobble* is an important concept to grasp. Fragment oscillation allows the phaco tip to continually maintain contact with a solid portion of nucleus material (phaco tip occlusion). As the fragment is eaten away it is observed to wobble and then steady itself as a better phaco tip hold is acquired (Fig. 8.12). The process repeats until the fragment is completely removed.

If a fragment cannot wobble sufficiently, the phaco tip will try to continue to emulsify any lens material in its path. Thus the tip enters one side of the captured fragment and tries to pass through to the other side. The phaco sleeve will prevent complete passage and a *donut* effect occurs (Fig. 8.13). In this situation, no further lens material ahead of the phaco tip exists and there is a risk that the posterior capsule, or other available mobile fragments behind the donut, that may be blocked from surgeon's view, may try to occlude the phaco tip. The risk of capsule rupture is low when removing the first fragment, but as more fragments are removed, creating a donut risks capsule damage. If it seems likely that a donut fragment has been created, the fragment can be nudged off the phaco tip with *phaco off,* and a new phaco tip hold acquired.

Fragment wobble during phacoemulsification can be hindered by: the second instrument, adjacent fragments, the rhexis edge, or anterior chamber shallowing. The second instrument should be pulled back and kept out of the way unless it is

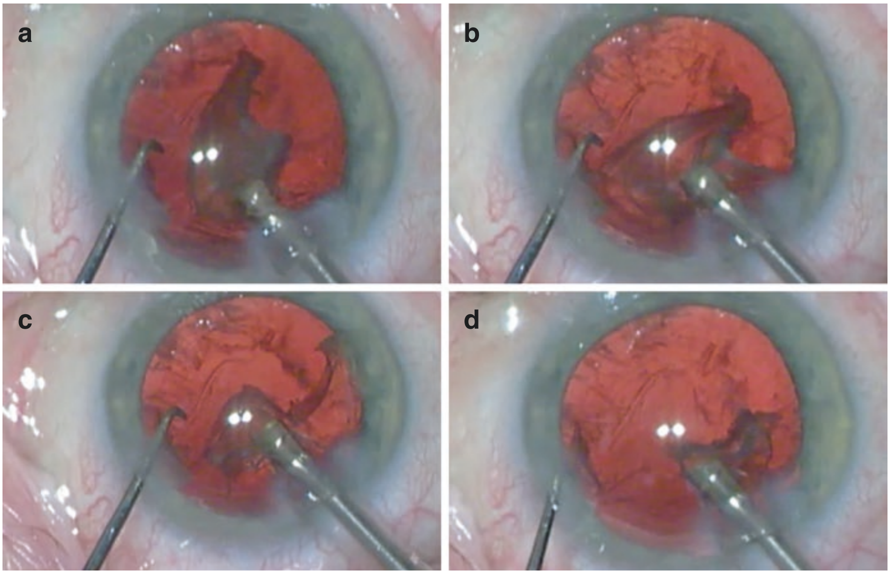

Fig. 8.12 Fragment oscillation (*wobble*) during phacoemulsification (**a–d**)

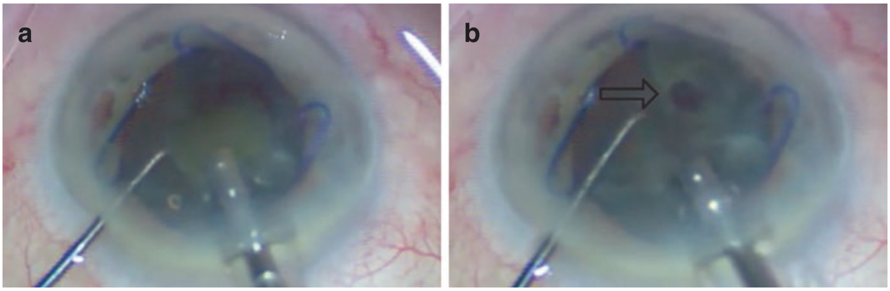

Fig. 8.13 Fragment 'donut' example effect. (**a**) Continuous phacoemulsification applied and probe tip is embeds into fragment. (**b**) Fragment disengaged from phaco tip. Cylindrical, full thickness passage (*arrow*) within fragment created by phaco tip (donut effect)

actively debulking or rotating other fragments to one side. With several lens fragments in situ, wobble space may be limited. In this situation, intermittent tiny nudges help the captured fragment change position thus allowing a better phaco hold. Ideally, novice surgeons should create space around the captured fragment so that the second instrument does *not* have to nudge or feed material into the phaco mouth too often.

Box 8.2 Technique Tip

- If a lens fragment is free to move, but no movement towards the tip occurs, it is possible that the phaco remains occluded with a remnant of lens material. A quick burst of phaco is required to clear the tip. If this does not work then it is necessary to determine the reason why fragments fail to move toward the phaco tip. Fragments will move in the direction of fluid flow—this is towards the phaco tip during aspiration. The flow of fluid and lens material will move towards the side port incision if it is inadvertently depressed by the second instrument. Side port corneal distortion and excessive fluid leakage should be looked for. Correcting any downward pressure will change the fluid dynamics and allows lens material to move towards the phaco tip.
- The phaco tip should be pulled back as far as possible during fragment emulsification, to maximise the available central space. However, the phaco tip should not be accidentally withdrawn from the eye, or pulled back so far that the irrigation ports hydrate the corneal stroma.
- Novices should be record, review and reflect on surgery, taking note of new skills and Trainer feedback.

8.6 Phacoemulsification Control

A lens nucleus fragment needs to be emulsified to the point where pieces are small enough to be aspirated up the phaco probe and tubing. Novice surgeons often perform long bursts of continuous phaco to emulsify the captured fragment. However, as novices are less likely to create space for the fragment to wobble (unlike more experienced surgeons) fragments are more likely to donut. Additional manipulation with the second instrument will be required, resulting in longer overall operating times. This can be improved by using the phaco in short, staccato bursts, with brief pauses in-between to allow the fragment to oscillate during removal. This approach will allow: reduced overall phaco energy; controlled fragment removal in which the phaco probe is held in one position; better visualisation of the disappearing fragment; less donut creation and fragment manipulation.

8.7 Important Movements for Fragment Removal

Knowledge of key phaco tip movements can make surgery easier and allow improved decision making about which fragments are best placed to be captured and removed.

8.7.1 Phaco Tip Movement

The primary movement with the phaco probe is a simple forwards or backwards movement. Fragments within a straight line, directly opposite the phaco tip, are readily available for capture by a simple forward movement (Fig. 8.14, position a).

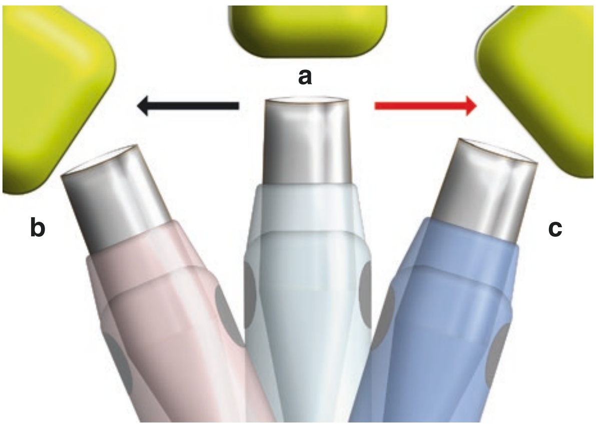

Fig. 8.14 Phaco probe movements. (**a**) Straight ahead, (**b**, **c**) oblique

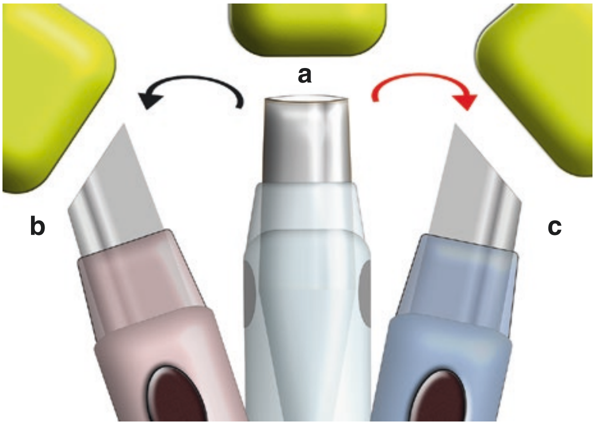

Fig. 8.15 Phaco probe rotation. (**a**) Primary position, (**b**) clockwise rotation, (**c**) counter clockwise rotation

To capture a fragment on either side of this line requires fragment repositioning for direct movement capture. Alternatively, the phaco probe must be aimed towards the fragment (Fig. 8.14, positions B and C).

Lateral capture of these fragments more effective if the phaco tip is rotated in a clockwise or counter-clockwise direction before engagement of the fragment (Fig. 8.15).

This rotary movement has several advantages. Firstly, it increases the potential surface area with which to engage the lens fragment with the phaco tip is. This facilitates fragment capture during aspiration or emulsification. Secondly, once the fragment is embedded on the tip, the subsequent manoeuvre to return the phaco probe back to a primary position will help extract the segment from the bag by rotating the fragment. This will help release the fragment shoulder as it is pulled out from beneath the capsulorhexis.

8.8 Within-the-Bag Fragment Rotation

The second instrument is used to sequentially rotate fragments into a potential position for easy phaco capture. Fragments can be pushed or pulled clockwise or counter-clockwise as individual pieces, or shunted as a group (Fig. 8.16). The second instrument may also be used to sequentially pull and then push (Fig. 8.17). This combination of movements may move fragments into an ideal position, or move fragments away from the targeted fragment, facilitating phaco tip access.

Care must be taken to avoid any downward pressure on the lens fragments during rotation as this can lead to capsule and zonular stress.

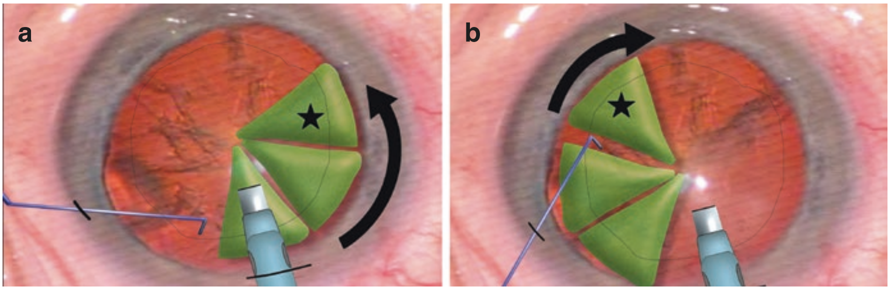

Fig. 8.16 Fragment rotation. (**a**) Anticlockwise shunt (**b**), clockwise individual rotation. Targeted fragment for eventual capture (*star*)

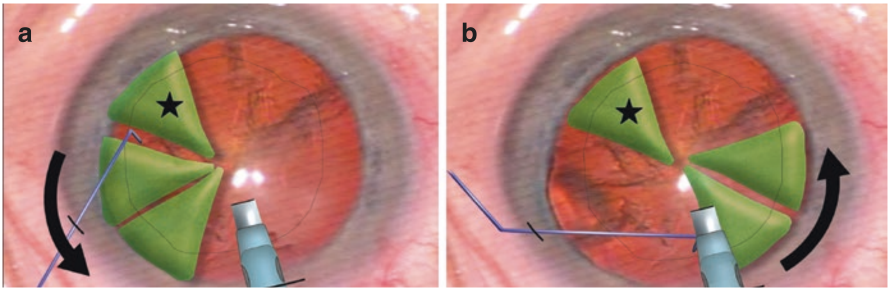

Fig. 8.17 Fragment rotation 2. (**a**) Anticlockwise pull with subsequent (**b**) anticlockwise push to facilitate access to target fragment (*star*)

Box 8.3 Trainer Teaching Pearls

A curriculum of phaco training for the novice surgeon should be agreed. A suggested sequence for phacoemulsification training steps is shown in Box 8.4. Ultimately, the Trainer is responsible for the patient's welfare. Ophthalmologists-in-training, however, clearly need to be taught. A compromise is needed in which good, safe training takes place with minimal stress for the patient, the Trainer, and the novice surgeon. Silent surgery [1] is not recommended. Instead, Trainers are advised to provide novices with regular, calm, reassuring verbal instructions throughout the phaco module. Over time the amount of instruction can be reduced.

Trainees need time and sufficient learning opportunities to acquire the many skills needed for efficient whole lens removal. Starting training with a whole lens in situ can cause unnecessary tissue trauma, higher phaco energy usage times (mainly due to prolonged grooving and cracking secondary to inadequate phaco and second instrument control) and, a prolonged operation. Instead, it is recommended that novice trainee perform small fragment removal first. This will require lens preparation by the Trainer first. For the Trainer this has the advantage of allowing them to use their own preferred technique to rapidly chop or divide the lens nucleus into appropriately sized fragments for the novice to operate on (Fig. 8.18). Subsequent fragment size can be varied according to the Trainer's assessment of the Trainee's ability. Trainers will need to resist the temptation to automatically extract fragments.

For the novice, starting with small fragment phacoemulsification allows many of the stepwise introduction of the phaco skills required for subsequent independent surgery.

It is recommended the Trainer consider the following:

1. **At the start of phaco training, during the first few cases, the initial fragment chosen for phacoemulsification is be extracted from the bag by the Trainer (Fig. 8.19).**

   This avoids any possibility of extraction difficulty. The novice simply begins by inserting the phaco probe and second instrument, and concentrates on removing small lens fragments.
2. **In subsequent cases, the initial fragment is left in the bag for the novice to extract.**

   Trainees are often surprised that initial fragment extraction is not straightforward. It is recommended they read Chap. 8
3. **As training progresses, fragment size and number can be varied by the Trainer. In the early stages, it is recommended that the nucleus is broken up into at least 6 fragments. Later, the number of fragments can decreased from 6 to 5 to 4. This has the effect of intentionally increasing the fragment sizes and therefore fragment-debulking skills can be introduced (see Chap. 8).**
4. **Novice surgeons need advice on which fragment to target and which fragment to rotate (and in which direction). Though apparent to the Trainer, novices will not have the required experience to make such judgements in the early stages of surgery.**

   Instruction is needed. Surgery will proceed more smoothly as the novice can concentrate on movements rather than decision-making.
5. **Trainers may wish to perform all the surgical steps leading up to small fragment removal in the initial few cases.**

   This reduces overall operating time and ensures a well centred, appropriately sized capsulorhexis is present for the novice to start phaco training.
6. **It is common for novice surgeons to press on the paracentesis incision with the second instrument during fragment removal.**

This may cause tiny lens fragments to lodge in the iridocorneal angle. If adjusting or moving the second instrument slightly fails to dislodge the fragment, rather than instructing the Trainee to try and direct the phaco tip towards the fragment and increase the aspiration to dislodge it the following can be tried:

Remove the second instrument and keep the phaco tip within the safe central zone. The blunt end of the second instrument is then used to gently press on the limbus or the peripheral part of the cornea near the lodged fragment. This changes the dynamics within the eye and coupled with gentle probe aspiration is enough to dislodge the fragment. The second instrument can then be reinserted and the fragment removed.

7. **The Trainer is recommended to instruct the Trainee on the duration of applied phacoemulsification when removing a fragment.**

   Using simple phrases for example "buzz, buzz, buzz", "long buzz' or indeed "phaco off" to indicate the duration of the phaco applied can help the Trainee appreciate and learn foot phaco control.

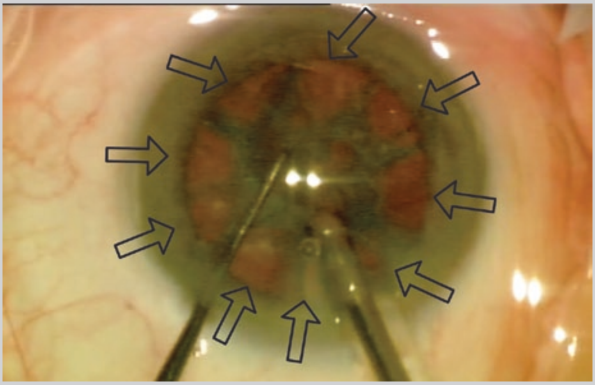

Fig. 8.18 Lens nucleus small fragment preparation. Nucleus divided into small multiple fragments (*open arrows*) before hand over to a novice surgeon. Minimal fragment manipulation expected for phacoemulsification removal.

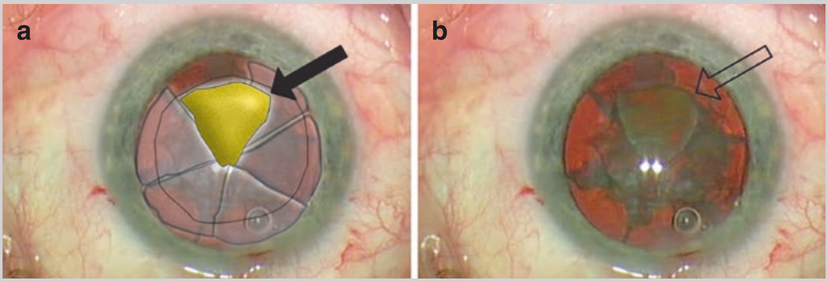

Fig. 8.19 Recommended lens preparation before hand over to novice surgeon. (**a**) Diagram. (**b**) Image. Multiple small fragments in situ with target fragment (*arrow*) extracted from bag.

Box 8.4 Recommended Modular Phaco Training

1. Check the length of exposed phaco tip and ensure sleeve irrigation ports are horizontal
2. Insertion of the phaco tip into the anterior chamber
3. Perform a pseudo-groove stroke to judge the resistance of the feel of the phaco movement within the corneal wound
4. Removal of small fragments (initial segment removed from capsule bag)
5. Removal of small fragments (initial segment not removed from capsule bag)
6. Removal of large fragments (debulk large lens segments into smaller pieces)
7. Nucleus cracking
8. Grooving
9. Intermediate technique
10. Advanced techniques (not covered in this book), for example small pupil management devices, capsule tension rings, vertical and horizontal chop

When placing the second instrument it is recommended the tip is placed peripherally (as visibly possible under the capsulorhexis but not hidden by the overlying iris) to apply as much torque as possible around the central axis.

8.9 Summary

Initial phacoemulsification training can proceed smoothly with a rear-ended modular approach. Multiple, pre-prepared small fragments allow the novice to concentrate on the phacoemulsification removal aspect of the nucleus rather than on debulking of large fragments or the difficulty of nucleus disassembly. This facilitates phaco foot pedal control training and minimises the amount of manipulation needed with a second instrument. Trainees are more likely to complete nucleus extraction and the remaining surgical steps, promoting confidence and training continuity. See Videos 8.1, 8.2, and 8.3.

Reference

1. McAlister C. Breaking the silence of the switch—increasing transparency about trainee participation in surgery. N Engl J Med. 2015;372:2477–9.

9 Debulking of Lens Fragments

When novice surgeons perform nucleus disassembly, the lens fragments are often of an irregular size and shape. It is more technically demanding to remove larger sized fragments, as it requires additional bimanual manipulation and the surgeon must exert better phaco probe control. This chapter will introduce a technique of breaking down large fragments (or even medium sized fragments) into smaller pieces. This is a fundamental skill and it is recommended that novice surgeons gain experience in performing it before taking on whole lens removal.

9.1 Skills to Be Gained

1. Use of the second instrument to debulk fragment.
2. Ability to maintain phaco tip hold on a fragment, whilst the second instrument is used to debulk that fragment.
3. Ability to vary phaco foot pedal control between irrigation only, aspiration and phacoemulsification settings.

The module requires the Trainer to disassemble the whole lens into suitable sized fragments, ensuring that some of which are sized such that debulking is required.

Electronic Supplementary Material The online version of this chapter (doi:10.1007/978-3-319-59924-3_9) contains supplementary material, which is available to authorized users.

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9.2 Debulking of Lens Fragment: Step by Step Instruction

9.2.1 Step 1

The lens fragment is pulled into safe zone (Fig. 9.1). The second instrument (chopper or equivalent) is kept out of the way so that it does not hinder fragment movement or inadvertently knock the fragment off the phaco tip.

9.2.2 Step 2

As the fragment enters safe zone, ensure the phaco retains its hold on the fragment by maintaining aspiration. The second instrument tip is positioned behind the fragment base as the fragment is pulled forward (Fig. 9.2).

9.2.3 Step 3

The second instrument is pulled through the fragment towards phaco tip but slightly to the left hand side. This ensures the tip remains buried in the undisturbed nucleus (Fig. 9.3). The hold on the fragment is maintained with aspiration as needed.

9.2.4 Step 4

Commence phacoemulsification to start removing the lens portion that remains impaled on the phaco tip (Fig. 9.4). The second instrument should hold back the other fraction (*fragment trapping*), pulling it slightly toward the side port. It does not matter if the two smaller fragments are not completely separated.

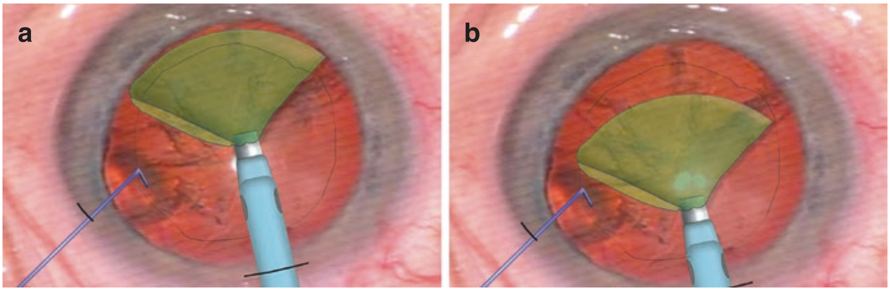

Fig. 9.1 Fragment debulking—step 1. (**a**) Fragment captured and (**b**) pulled into safe zone

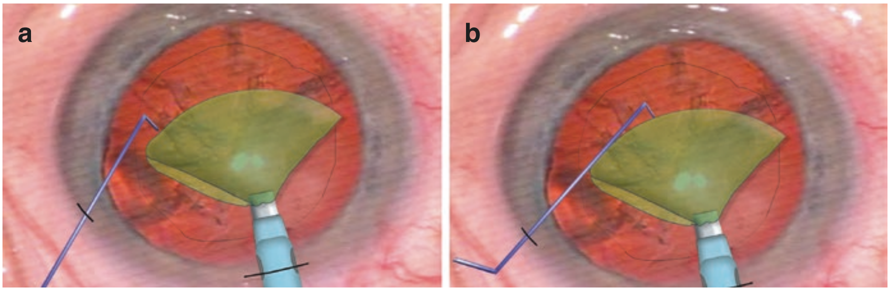

Fig. 9.2 Fragment debulking—step 2. (**a**, **b**) Second instrument positioned behind fragment base

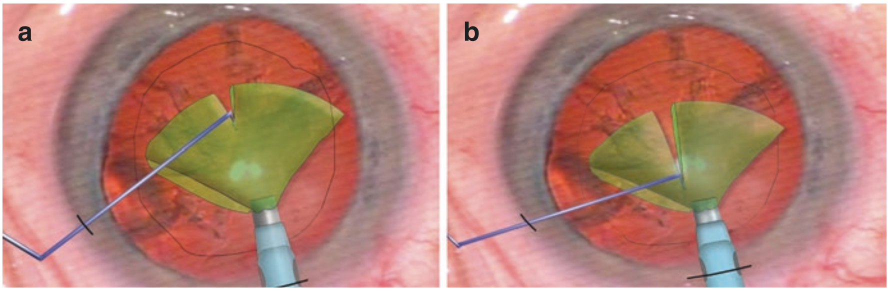

Fig. 9.3 Fragment debulking—step 3. (**a**, **b**) Second instrument is pulled through left hand side of fragment without disturbing the phaco probe hold

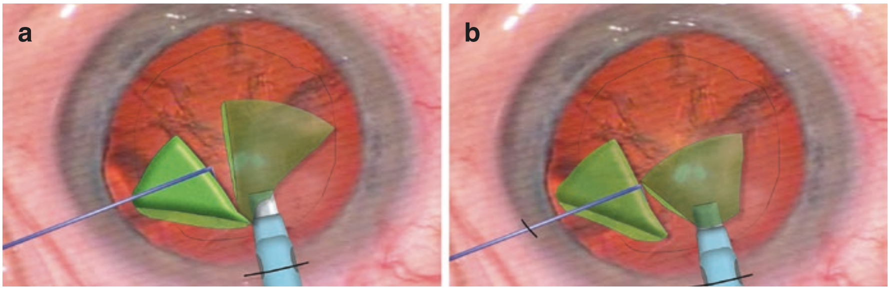

Fig. 9.4 Fragment debulking—step 4. (**a**) Second instrument hold back one half of split fragment, (**b**) Impaled portion is phacoemulsified

Box 9.1 Debulking Training Tip

- Extract the fragment and pull it into the safe zone before placing second instrument. Try rotating the phaco probe (with attached captured fragment) slightly counter clockwise to allow second instrument more space to be correctly positioned behind fragment base.
- Use short bursts of phaco to help emulsify lens.

9.2.5 Steps 5 and 6

Continue to emulsify the fragment (Fig. 9.5). The held back portion will want to move and shudder towards the phaco tip as controlled bursts of phacoemulsification and aspiration are continued.

The *trapping* of the residual portion by the second instrument is continued until the first chunk of lens nucleus is almost gone (Fig. 9.6).

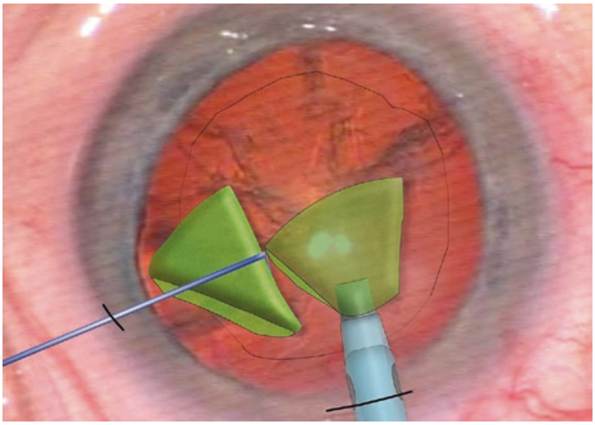

Fig. 9.5 Fragment debulking—step 5

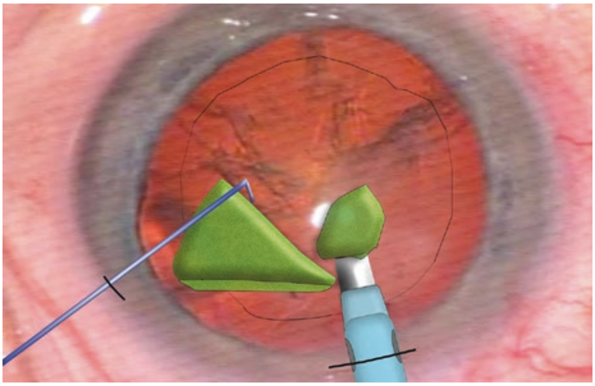

Fig. 9.6 Fragment debulking—step 6

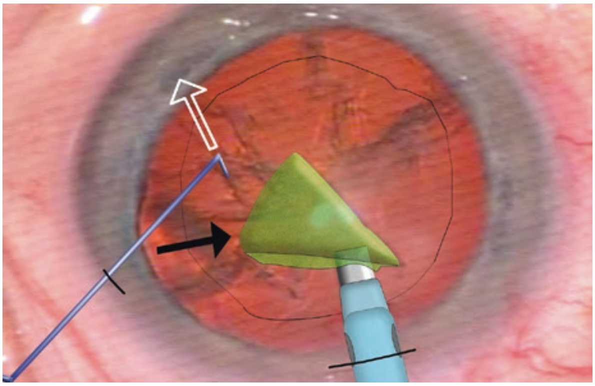

Fig. 9.7 Fragment debulking—step 7. Phaco probe capture of trapped fragment (*solid arrow*) as it is released by moving second instrument aside (*open arrow*)

9.2.6 Step 7

As the phaco tip mouth becomes empty, ease off the amount of applied phacoemulsification and maintain aspiration. The second instrument is moved distally, releasing the trapped fragment. As it is no longer held back, the fragment is aspirated towards the mouth of the phaco tip ready for capture and subsequent removal (Fig. 9.7).

Fragment release by moving the second instrument towards the phaco is not routinely recommended. This causes the instrument to hinder free movement of the fragment towards the phaco tip. Furthermore, additional second instrument manipulation would then be needed for step 8.

9.2.7 Step 8

The debulking technique can be applied again. The second instrument will be positioned distal to newly captured fragment base and can be easily used to split the hemi-fragment piece held by the phaco tip.

Box 9.2 Debulking Training Tip

- If the surgeon notices that the fragment remains quite large, then debulking can be repeated as often as needed on the residual portion of lens material held by the phaco tip. This decision can be made as the fragment shifts position during phacoemulsification making its size more obvious.
- During the manoeuvre the limbus should not be depressed too hard with the second instrument. This will promote excess fluid escape from the side-port and encourage tiny lens pieces to lodge in the iridocorneal angle near the side-port. Too much pressure on the side-port is noted by cornea distortion and excessive fluid leakage.

- The fragment should be pulled into the safe zone and then the second instrument placed behind the base of the fragment. Try to avoid the second instrument going near the capsulorhexis margin.
- Note that the phaco probe stays relatively still whilst intermittently applying phaco to remove the lens material.
- If the metal tip of the second instrument touches the phaco tip during actual applied phacoemulsification a high pitched 'tinkle' sound is emitted. Instrument touch should be avoided to prevent potential damage to the instruments.

Box 9.3 Trainer Teaching Pearls

With rear-ended modular training, it is expected that the Trainer will prepare and disassemble the lens nucleus for the novice Trainee. This can be done according to the Trainer's own personal surgical technique.

As training progresses and small fragment phaco removal confidence is achieved, the Trainer can start to introduce larger fragments (in amongst the smaller ones) for the novice surgeon to debulk. This will prepare the novice for the time when they will have to manage each of the 4 quadrants created as part of 'divide and conquer' training. This method of dividing the lens by sculpting a cross shaped groove into the lens nucleus and then sequentially splitting the lens along each groove will create four large equally sized fragments. For the novice however, the fragment sizes are often vary in size as the sculpting technique has yet to be perfected. Debulking will help deal with the larger fragments.

It is recommended that novice surgeons are encouraged to debulk a fragment (if suitable lens density permits) routinely after extracting each piece from the capsule bag.

The aim is to encourage novice surgeons to be aware of the second instrument position, keeping it out of the pathway of the phaco probe during lens fragment extraction; and also to introduce a technique of splitting the lens within the safe zone.

Novices may not automatically think of performing the debulking action. They may be more likely to try and phacoemulsify a fragment (regardless of size) with prolonged bursts of phaco, using the second instrument purely to try and manipulate the fragment. This leads to higher phaco energy usage and risks capsule damage by creating donut pieces. It is better to advise Trainees when to debulk a captured fragment and encourage short intermittent bursts of phaco to remove the captured fragment.

Useful instructions include: 'debulk the captured fragment' and 'release'. The Trainee will immediately understand what is surgically required and can make a debulking attempt.

9.3 Summary

Debulking of fragments can be learnt fairly rapidly after small fragment phacoemulsification training has commenced. The Trainer is required to disassembly a nucleus into various sized fragments. The Trainee is expected to easily extract and emulsify the small pieces with little manipulation requirement, whilst debulking can be performed for the larger but still manageable fragments. See Video 9.1.

10 Make-a-Space Technique

Even when lens nucleus fragments kept within-the-bag may be adequately separated, individual fragments may resist extraction and subsequent phacoemulsification removal. A variety of factors may be responsible, including: fragment removal that is hindered by adjacent fragments interlocking together; the second instrument inadvertently knocking the fragment off the phaco tip as it is extracted; or the target-fragment colliding with another fragment along the line of movement. The make-a-space principles explained here will aid the surgeon when removing fragments, helping them to avoid the pitfalls listed above.

10.1 Fundamentals: The Lens Fragment

The term 'target-fragment' refers to the selected lens fragment the surgeon intends to extract and phacoemulsify.

A lens fragment is a pyramidal shaped, with an apex and a curvilinear base. At the widest point of the base, each fragment has two shoulders (Fig. 10.1). The base and shoulders remain hidden under the rhexis edge. Once the fragment is embedded on the phaco tip it can be repositioned, rotated and moved about as if it were an extension of the phaco probe.

10.2 Make-a-Space Principles

10.2.1 Initial Fragment Choice

Once the nucleus has been grooved and spilt into four pieces, it is time to pause for a moment so that the size of all the available fragments may be analysed. In spite of the temptation to try and extract the fragment immediately opposite the phaco probe, it is recommended that the smallest sized fragment is identified instead.

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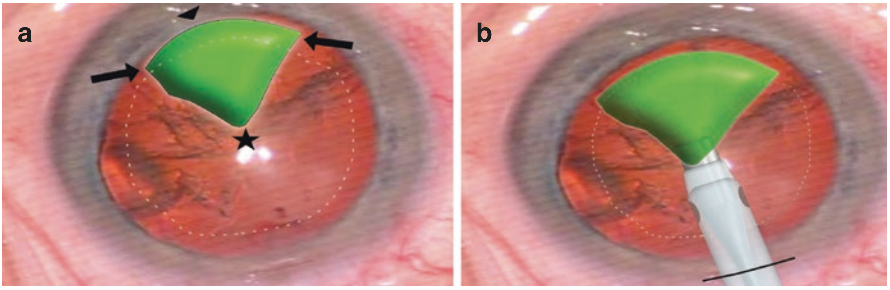

Fig. 10.1 The lens fragment. (**a**) Apex (*star*), shoulder (*arrow*), base of segment (*arrowhead*), capsulorhexis outline (*dotted line*). (**b**) Embedded fragment can be moved as an extension of phaco probe

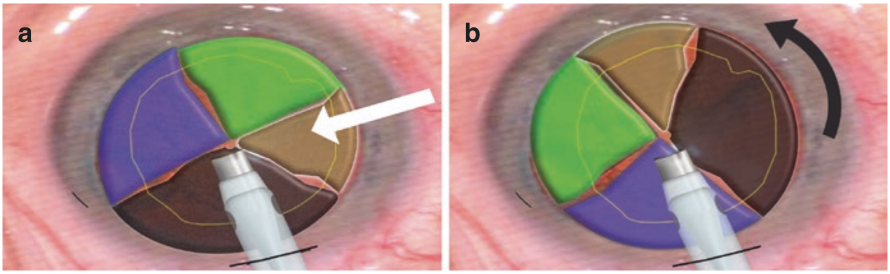

Fig. 10.2 Initial fragment choice. (**a**) Smallest fragment (*arrow*) is not ideally positioned opposite phaco probe. (**b**) Smallest fragment is repositioned opposite the phaco probe by rotating fragments (*curvilinear arrow*)

Ideally the smallest fragment should be repositioned into the *starting position* space (directly opposite and in line with the phaco tip). If the smallest fragment is not directly opposite the phaco probe, an attempt should be made to rotate the pieces until it is (Fig. 10.2). The smallest fragment will exhibit the least resistance to extraction. Once the smallest fragment is removed, additional manoeuvring space for the other fragments is created.

10.2.2 Fragment Extraction from the Capsule Bag: Unlocking Fragments

Separated nuclear fragment pieces may have sidewalls with irregular contours. When this happens, neighbouring fragments can interlock like pieces of a jigsaw, preventing the free movement of one fragment as it tries to slide past another. Interlocking may occur as separated fragments are pushed into each other, for example during fragment rotation, or whilst cracking the lens nucleus.

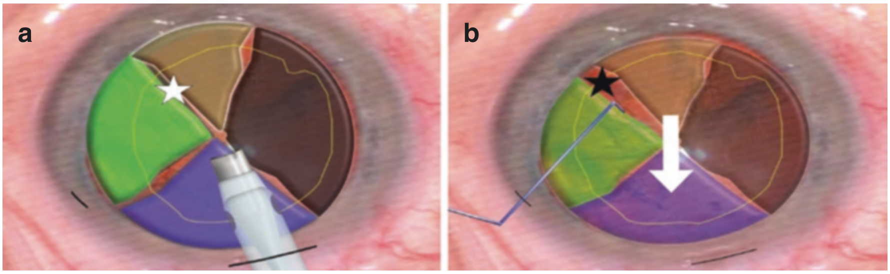

Fig. 10.3 Unlocking interlocked fragments—1. (**a**) Walls of adjacent fragment are interlocked (*white star*). (**b**) Potential space (*black star*) for fragment extraction (*arrow*) created by unlocking pieces using second instrument to retract proximal fragment

Unlocking may therefore be required to facilitate the unhindered movement of fragments.

Fragment unlocking is easily performed by placing a second instrument into the gap between fragments and then using that instrument to pull at the proximal the fragment (i.e. pulling it away from the target-fragment to "make-a-space") (Fig. 10.3). This is a useful technique that can help extract the initial fragment from the capsular bag, whilst at the same time ensuring that the second instrument is kept out of the target-fragment's intended line of extraction.

10.2.3 Fragment Extraction from the Capsule Bag: Unlocking Fragments and Moving the Target-Fragment into a Created Lateral Space Before Pulling into a Central Location

In the previous principle, despite unlocking the left hand side of the target-fragment from it neighbour to "make-a- space" the right hand side of the target-fragment can still be interlocked with its neighbouring segment on the opposite side This can potentially hinder its movement during extraction. It is recommended that a space is created using the second instrument as described in principle 2 'u*nlocking fragments'*. However, instead of pulling the target-fragment directly into the central area, the trajectory should follow a reverse number seven direction (Fig. 10.4a). If the potential space is to the right hand side of the target-fragment, the then target-fragment manipulation should follow a "normal" number seven direction (Fig. 10.4b). Only a small lateral movement is needed before the fragment should be pulled centrally.

As less resistance to fragment movement is encountered, this *make-a-space* technique reduces the likelihood of the phaco tip losing its hold on the target-fragment. It is also less likely that the fragment apex will crumble in the process of extraction.

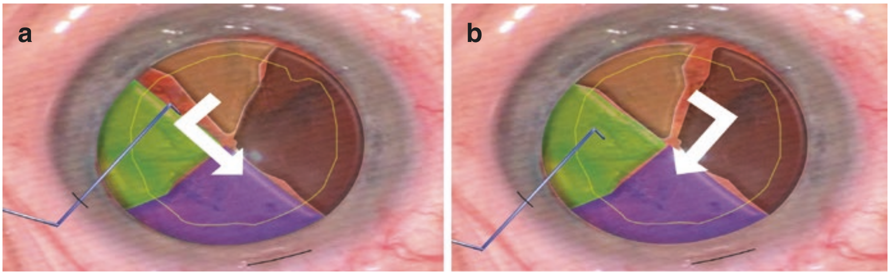

Fig. 10.4 Unlocking interlocked fragments—2. (**a**) Fragment is moved laterally towards potential space and then pulled into central area using a reverse number seven movement (*arrow*). (**b**) Fragment is moved laterally into potential space and then pulled into central area using a number seven movement (*arrow*)

10.2.4 Fragment Extraction from the Capsule Bag: Freeing a Fragment Shoulder

Where a fragment has a broad base, the associated fragment shoulders can become wedged between neighbouring segments during extraction. This may occur despite creating a lateral space and ensuring both edges of the target-fragment are unlocked. This fragment wedging may hinder movement of the target-fragment. By using the adjacent space created by the second instrument, as well as the potential space above the capsulorhexis, one of the fragment shoulders may be freed up as the fragment is extracted.

Rotate one shoulder by performing a slight clockwise movement of the phaco tip whilst extracting the fragment. The fragment shoulder will escape the capsulorhexis edge as it is pulled into the centre using a reverse number seven movement (Fig. 10.5). As one shoulder is freed, the phaco probe can be rotated back to the primary position. This additional rotation will encourage the second shoulder to come forward, thus freeing the whole fragment from the capsule bag.

As the fragment is pulled into the safe zone, the second instrument is keep out of the way and can subsequently be positioned behind the fragment base. This helps prevent the fragment from falling back into the capsule bag if the phaco hold is released. Furthermore, using the second instrument this way means that it is positioned ready to perform segment debulking if needed (see Chap. 8).

10.2.5 Improving the Available Space for Target: Fragment Phacoemulsification

During the phacoemulsification of lens material, space surrounding the fragment within the anterior chamber is required for the fragment to move and tumble. This allows the phaco probe tip to continually re-acquire the best aspiration grip as lens material is 'eaten' away. In Fig. 10.6 the initial aim of removing and emulsifying the first target-fragment has been achieved. A gap now exists in the space where the first

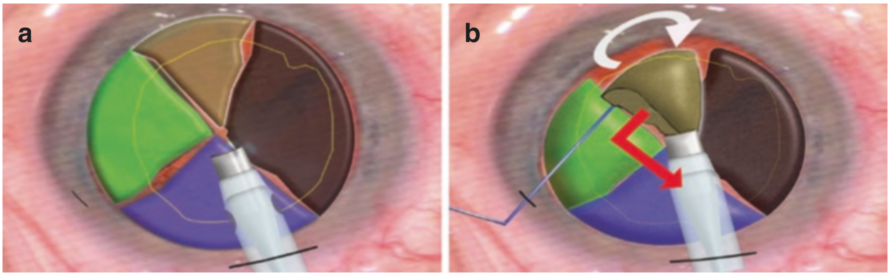

Fig. 10.5 Freeing a fragment shoulder. (**a**) Fragment before any *make-a-space* principles applied. (**b**) Combination of *make-a-space* principles with lens fragment partly rotated using phaco probe (*curved arrow*) and extracted using reverse number seven movement

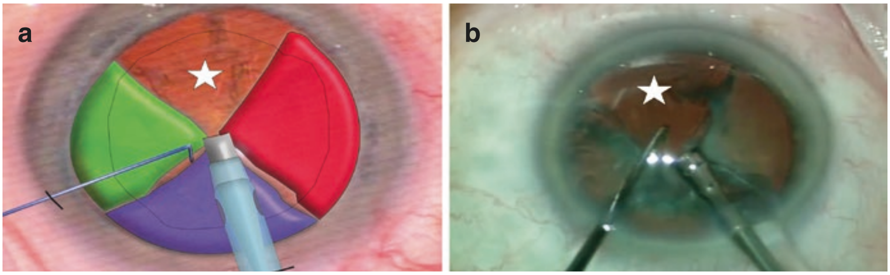

Fig. 10.6 The starting position space. Initial fragment removed leaving a wedge-shaped empty space (*star*) in the capsule bag. (**a**) Schematic drawing, (**b**) Image

target-fragment was previously located. The subsequent aim for a novice surgeon is to move a new target-fragment into this *starting position* space, ready for extraction and emulsification. This starting position ensures the apex of the next segment is ready to be engaged with minimal lateral movement of the phaco tip. With experience, the surgeon will be able to extract fragments from more lateral positions by pivoting the phaco tip, but initially during training it is recommended the '*improving the available space'* suggestion is followed.

10.3 The Next Fragment

Assuming the operator is right handed, and that the next fragment extraction will occur from the *starting position,* on reviewing Fig. 10.6 the surgeon needs to ask, 'Which fragment should be removed next?'

It is possible to rotate and remove any of the remaining three fragments. However, the aim is to use *make-a-space* principles and create an area in which segments can be removed with ease, maximising the available room at the level of (or just above) the capsulorhexis so that fragments can tumble and move during phacoemulsification removal. Various potential fragment positions are discussed:

10.3.1 Potential Position 1

In Fig. 10.7, the targeted green segment has been rotated clockwise into the *starting position*. The fragment apex is close to the phaco tip and *make-a-space* principles 3 and 4 can be used to extract the fragment into the available space. However, it should be noted that target-fragment movement may be hindered by the adjacent fragment (purple fragment) which occupies some of the space into which the target-fragment will move towards as the phaco probe is withdrawn when pulling the target-fragment in the central area. The green fragment will thus require additional manipulation with the second instrument to overcome the lack of space.

10.3.2 Potential Position 2

In Fig. 10.8, the targeted red segment has been rotated counter clockwise. Space has been created to the right-hand side of the target-fragment. For right-handed surgeons, wrist pronation will be required to manipulate the phaco probe during the segment extraction. This makes the extraction more technically demanding and uncomfortable. Furthermore, as in potential position 1, the red target-fragment movement during emulsification will be hindered by the fragment positioned under

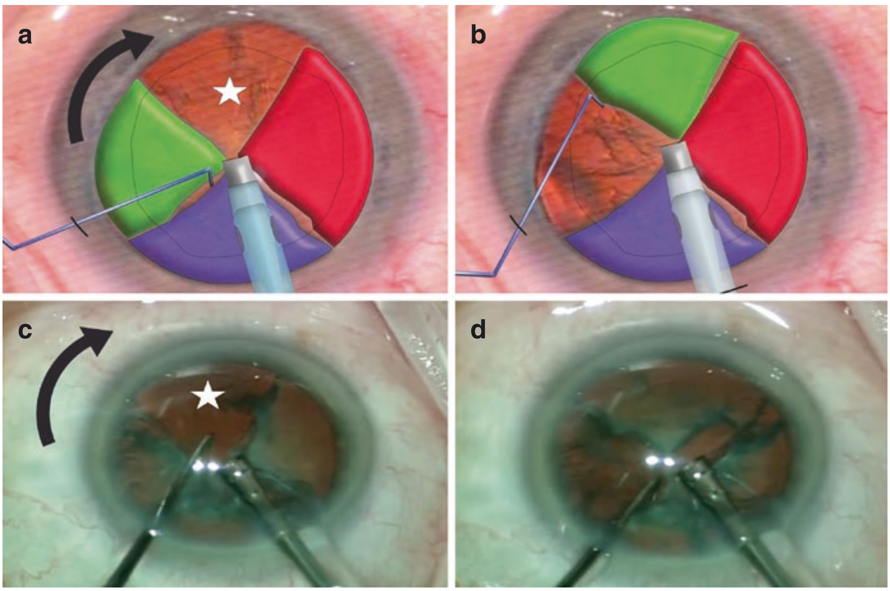

Fig. 10.7 Improving space for fragment phacoemulsification: Potential position 1. (**a**) Targeted fragment (*green*) is rotated clockwise (*arrow*) into starting space (*star*). (**b**) Post rotation. (**c**, **d**) Colour images

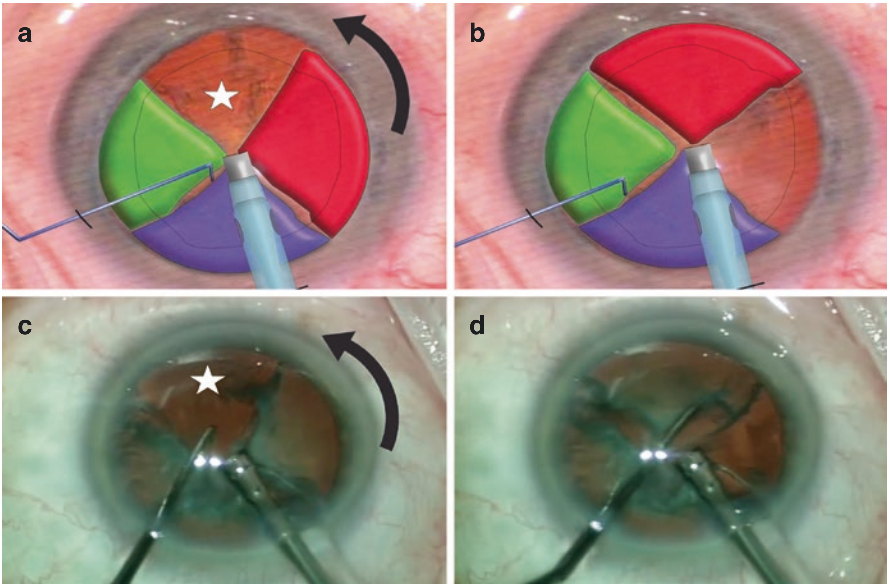

Fig. 10.8 Improving space for fragment phacoemulsification: Potential position 2. (**a**) Red fragment is rotated counter clockwise (*arrow*). (**b**) Red fragment occupies starting position space (*star*). (**c**, **d**) Colour images

the phaco probe (purple fragment). Novice surgeons are more likely to require additional manipulation of the target-fragment is in this situation.

10.3.3 Potential Position 3

In Fig. 10.9, all of the fragments have been rotated in a clockwise direction with the second instrument. The red target-fragment is positioned further clockwise than in Fig. 10.8 and the green fragment has used to shunt the sub-incisional (purple) fragment clockwise. Following rotation, the final position of the red target-fragment, in relation to the remaining fragments, allows a clear path for its extraction and subsequent phacoemulsification. Target-fragment extraction, using the *make-a-space* principles 3 and 4, should now be simple to perform, and space is available for fragment debulking.

10.3.4 Potential Position 4

In Fig. 10.10, the green target-fragment has been rotated clockwise, but not as much as in Fig. 10.7. Furthermore, the purple segment has also been pushed and rotated counter-clockwise. This has shunted the red fragment further around (using the second instrument to rotate fragments under the phaco probe). This maximises potential space for the green target-fragment.

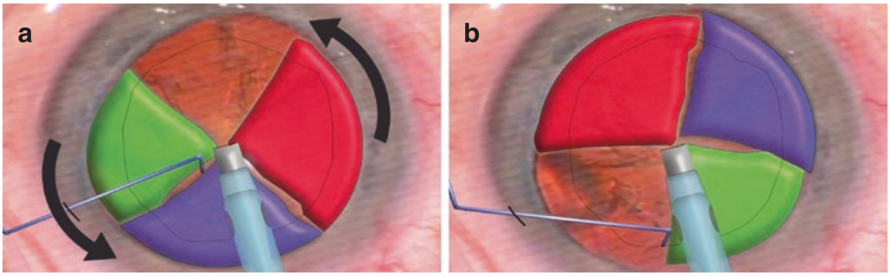

Fig. 10.9 Improving space for fragment phacoemulsification: Potential position 3. (**a**) Red target-fragment and other two fragments are rotated anticlockwise (*arrows*). (**b**) Red target-fragment occupies an oblique position

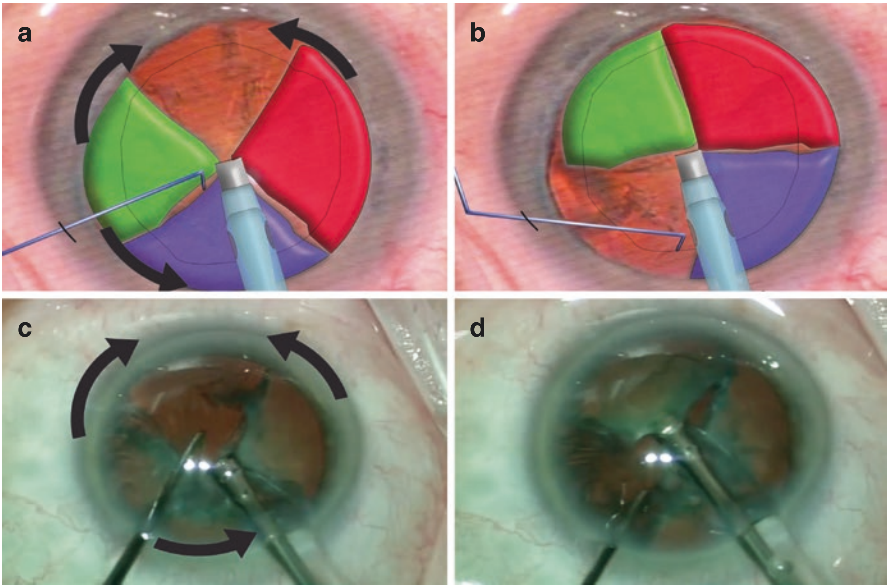

Fig. 10.10 Improving space for fragment phacoemulsification: Potential position 4. (**a**) Green target-fragment rotated clockwise and other two fragments counter clockwise (*arrows*). (**b**) Green target-fragment occupies an oblique position with plenty of space for extraction. (**c**, **d**) Images

10.4 The Final Two Fragments

Once the second fragment has been removed, the remaining sub-incisional fragment is in a good position to be rotated further, thus forcing the next piece into the *starting position* (Fig. 10.11). The remaining fragments can now be sequentially removed.

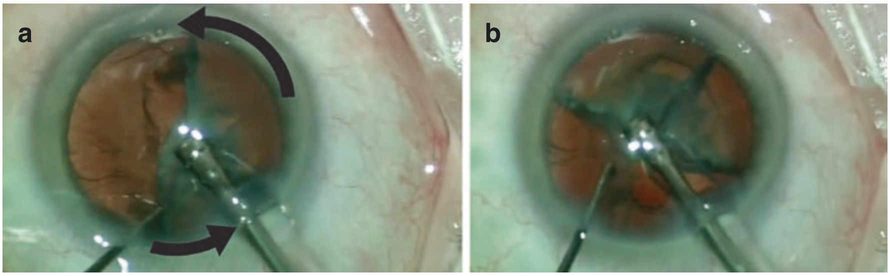

Fig. 10.11 Improving space for fragment phacoemulsification: final two fragments

Box 10.1 Trainer Teaching Pearls

The phacoemulsification technique of novice Trainees will not be as good as that of the Trainer. Trainees will need additional space for fragment extraction and complete removal. They will need instruction as to which fragment to target, which fragment to rotate, and in which direction rotation is required. This will promote good decision making and allow the novice to focus on key dexterity tasks: nucleus fragment extraction, bimanual intraocular movement, foot pedal phacoemulsification control and manipulation of the microscope. Once the Trainee has become more proficient, less instruction and less space and manipulation will be needed.

It is important that verbal instructions by the Trainer are fully understood by the Trainee and translated into applied surgical movements. Regular review of recorded surgery is recommended. Not only can it help the novice reflect on how fragment extraction and phacoemulsification technique could be improved, it provides an opportunity to reiterate the meaning of any misunderstood instructions.

It is recommended that novice surgeons realise that phacoemulsification training requires patience. Novice surgeons are likely to exhibit frustration if cataract surgery does not proceed smoothly. Reassurance is likely to be required in order to maintain their confidence.

Trainers are advised not to promote speed, but rather the development of good technique.

10.5 Summary

Experienced surgeons are able to manipulate and remove fragments with ease using the space available within the capsule bag and anterior chamber. Novice surgeons, however, often need more space to facilitate the phacoemulsification of lens pieces. *Make-a-space* principles allow the novice to apply key fundamentals needed to facilitate lens fragment removal. This will help develop the intra-operative decision making necessary for eventual independent operating.

Phacoemulsification: Grooving and Cracking

11

Two key surgical phacoemulsification skills to acquire are the ability to form a trench in the lens nucleus (referred to as *grooving or sculpting*), and the ability to apply pressure to the walls of the trench, dividing the lens nucleus into two smaller segments (*cracking*). Lens *grooving* and lens *cracking* form the basis for one method of disassembling the lens nucleus.

For simplicity, this chapter describes the true surgical sequence: *grooving* followed by *cracking*. However, when a rear-ended modular approach is followed, training in *cracking* should take place first. This will require the Trainer to prepare the lens nucleus before handing over to the Trainee.

The description is for a right-handed surgeon and transposition is required for left-handed surgeons. The terms *trench* and *groove* are used interchangeably.

The overall technique can be broken down several steps:

1. Check the tip sleeve length and ensure irrigation ports are horizontal to the tip.
2. Ensure irrigation and phaco probe is working.
3. Insert the phaco probe into the anterior chamber.
4. Check the sleeve is not caught on the corneal section and performing a *pseudo-groove*.
5. Perform an initial *true groove* with correct 'foot control' sequence during phaco-sculpture of the lens.

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6. Perform a minor rotation in preparation for next step*.
7. Prepare for and then *crack* the lens.
8. Perform a major rotation in preparation for next step.
9. Continue *grooving* and *cracking* all the remaining segments.

*Surgeons may prefer to perform a major rotation to pre-*groove* (sculpt) the lens into two halves and split the lens (Fig. 11.1), before additional *grooving* and *cracking* to create quadrants. Alternatively, some surgeons prefer to rotate and sculpt trenches consecutively in order to create a 'cross' appearance in the lens nucleus (Fig. 11.2). Each *grooving* trench can then be '*cracked*' to form four

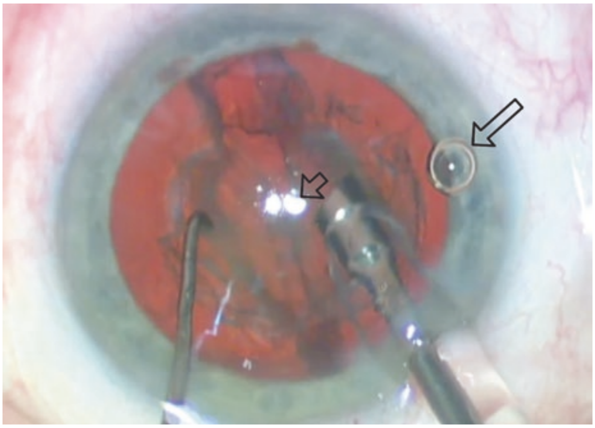

Fig. 11.1 Grooving and Cracking—hemi nucleus. Lens nucleus sculpted and cracked into two halves. Corneal light reflex artefact (*short arrow*), air bubble (*long arrow*)

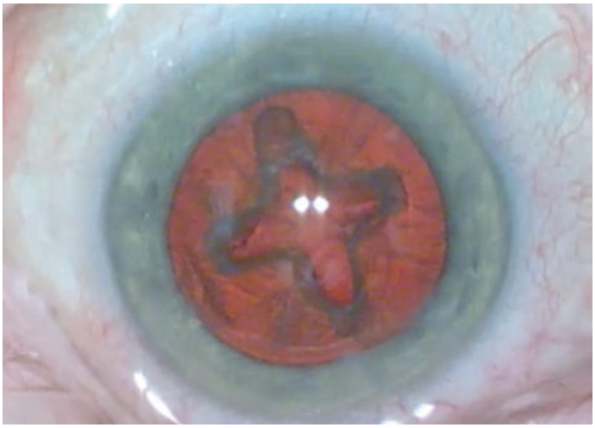

Fig. 11.2 Grooving and Cracking—sculpted cross. Lens nucleus sequentially sculpted to form trenches which intersect to form a 'cross' shape. Cracking to disassemble the lens is required

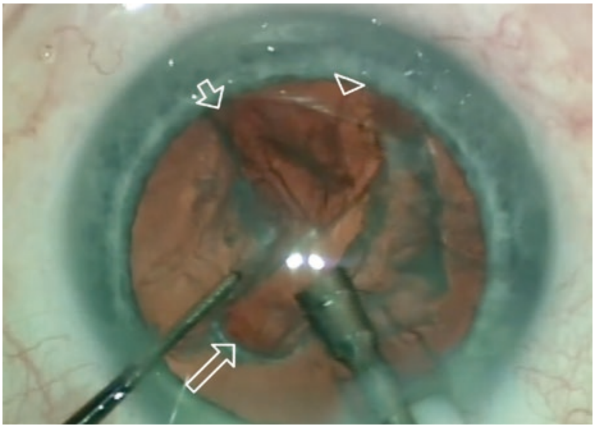

Fig. 11.3 Grooving and Cracking—fragment creation and immediate removal. Lens nucleus sculpted (*short arrow*) at 90 degrees to initial trench (*long arrow*). Cracking has taken place and the created fragment immediately removed. Residual quadrant of cortical soft lens material highlighted by the red reflex is noted (*arrow head*)

fragments. This is referred to as '*divide-and-conquer*', [1]. The principles for divide-and-conquer remain similar, but minor rotation and *cracking* will be omitted until all *grooving* is complete. The Trainer will instruct on which method will be used for any individual nucleus, and the novice must accept that the method may be altered intra-operatively depending on circumstances; if the trench looks good enough to *crack* why not split that area of the nucleus straight away? For Trainees who have developed phaco technique using dual linear control, the Trainer may request immediate removal of a fragment as it is created and separated from the main body of the nucleus (Fig. 11.3).

11.1 Fundamentals

11.1.1 Phaco Probe

The phaco probe uses ultrasonic vibration to emulsify any lens material in close proximity to its metal tip. The "soup" of tiny lens particles is then removed from the eye as it is aspirated up the hollow phaco probe. A plastic sleeve that contains two irrigation apertures covers most of the phaco tip. This sleeve is adjusted according to the surgeon's preference to ensure the exposed phaco tip is a suitable length (Fig. 11.4). During assembly, the phaco probe tip can inadvertently be passed through one of the sleeve irrigation apertures, or the sleeve may not be correctly rotated to allow horizontal flow of fluid from the probe. In view of this, the phaco probe tip must be examined before insertion into the eye to ensure it is adequately prepared. Commonly, the superior part of the exposed phaco tip is shorter than the inferior edge (Fig. 11.5).

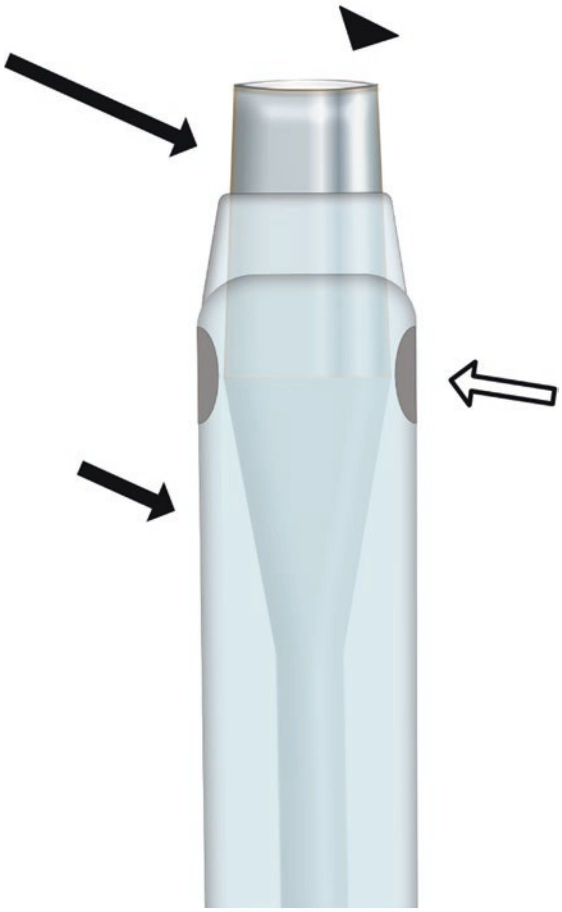

Fig. 11.4 Phaco probe sleeve. Phaco tip (*long solid arrow*), mouth (*arrow head*), irrigation aperture (*open arrow*), phaco sleeve (*short solid arrow*)

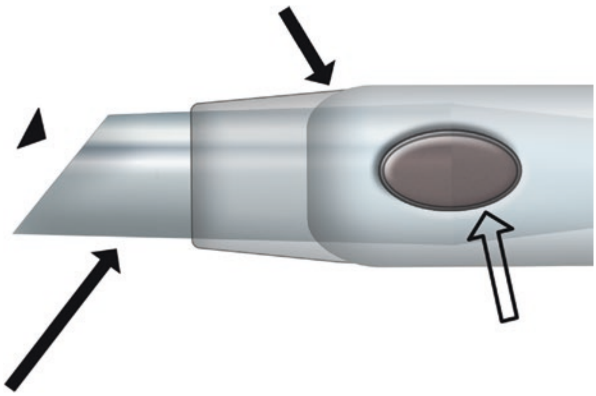

Fig. 11.5 Phaco tip primary position in side profile. Aperture or 'mouth' (*arrow head*), exposed tip (*long solid arrow*), sleeve (*short solid arrow*), sleeve irrigation aperture (*open arrow*)

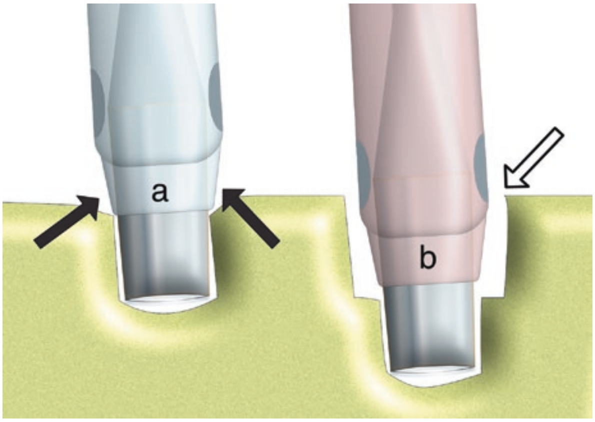

Fig. 11.6 Phaco probe sleeve. (**a**) Edges of narrow *groove* can catch phaco probe sleeve (*solid arrows*) and prevent removal of lens material at the base of the *groove*. (**b**) Widened *groove* (*open arrow*) allows access to the lens material

The sleeve adds a small amount of extra girth to the overall phaco probe width. Appreciating this fact can help novices understand why phaco *groove* strokes are occasionally ineffective at removing lens material. As the phaco tip is used to emulsify lens material, the sleeve may catch the walls of a narrow trench and prevent lens material being removed from the base of the *groove*. *Groove* widening may be required if this occurs, (Fig. 11.6).

11.1.2 Insertion of Phaco Into the Anterior Chamber

The very first insertion of the phaco probe into the newly made corneal incision will feel snug (Figs. 11.7, 11.8, 11.9, 11.10, 11.11, and 11.12). If the phaco probe is removed from the eye, further attempts at insertion will be comparatively more straightforward.

Insertion of the phaco into the anterior chamber has been described in Chapter 8. It is worthwhile reviewing the fundamentals to ensure a smooth, efficient insertion technique develops.

The Trainee should expect small amounts of fluid to escape from the anterior chamber on initial attempts. Wash any surface blood away from the vicinity of the corneal incision. Avoid tightly gripping the corneal incision with the forceps as this will cause micro trauma.

The posterior lip can be lightly pressed with the phaco tip to open up the wound during the insertion. Ensure the angle of approach allows the tip to pass through the corneal section and not pushed into the corneal stroma. The metal portion will start to enter the eye.

If the sleeve irrigation ports catch the wound, oscillate the tip in a screwing motion as the probe is inserted. This will help navigate the section. The anterior chamber will inflate accordingly.

Use the available fingers of left hand to support phaco probe during pseudo-*groove* movements.

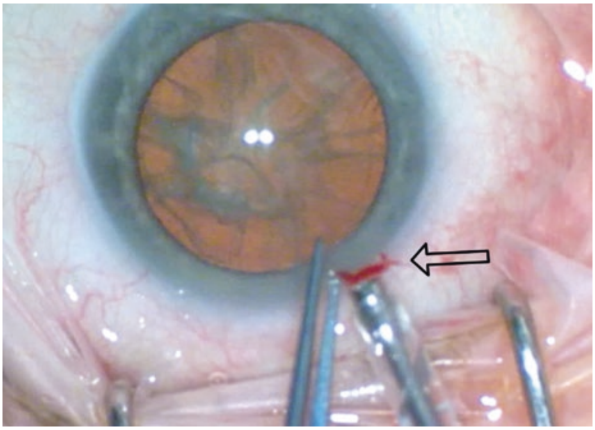

Fig. 11.7 The phaco tip and forceps are poised ready for insertion adjacent to corneal wound. Small amount of blood noted near wound (*open arrow*)

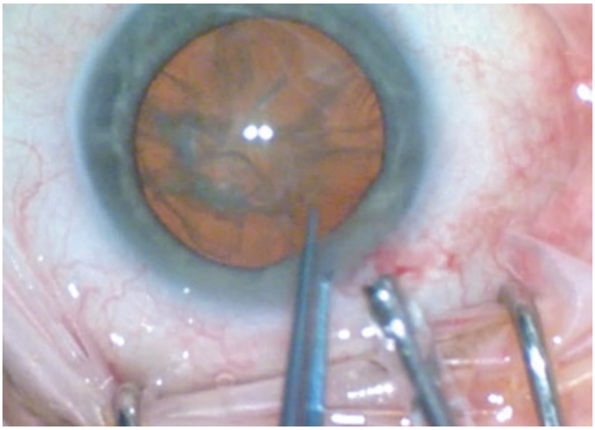

Fig. 11.8 Forceps used to lift upper lip of the corneal section slightly

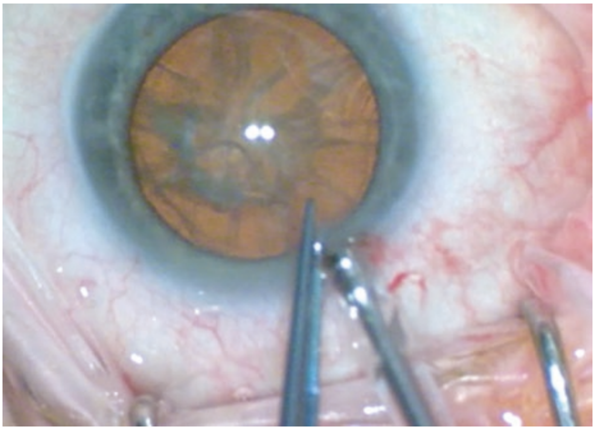

Fig. 11.9 As anterior corneal wound lip is lifted insert the phaco tip

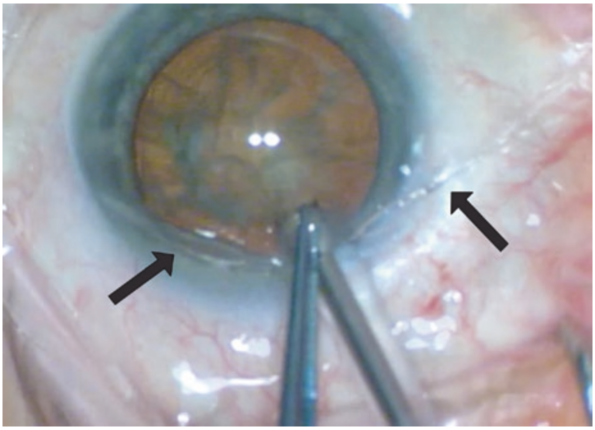

Fig. 11.10 Irrigation is started after insertion of the probe has commenced. The ports are still outside of the eye and fluid jets can be seen (*arrows*)

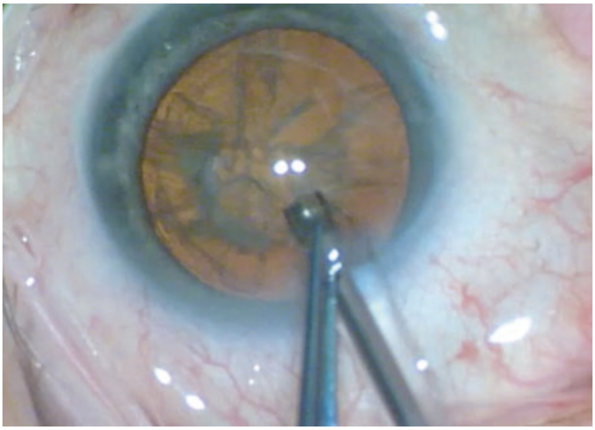

Fig. 11.11 Attempt to navigate the sleeve past the corneal wound

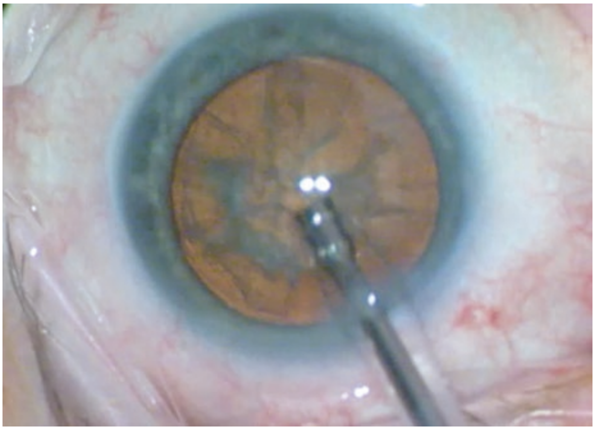

Fig. 11.12 The forceps can be withdrawn and palmed

Box 11.1 Phaco Probe Insertion Tip

The following insertion tips can be of benefit to novice surgeons:

- Ensure that the phaco tip is held close to the corneal wound before any manipulation of the wound occurs. This will decrease the distance travelled when the decision has been made to start insertion of the phaco probe.
- Avoid hesitancy during insertion. The anterior chamber will start to collapse if too much time is taken as fluid will leak from the corneal wound.
- Once inside the eye, briefly hold the tip in the safe zone. This pause allows the surgeon to make any necessary adjustments to the probe grip. It also allows the anterior chamber to fully inflate and provides a moment for the novice surgeon to decide on the next step.
- The section is a self-sealing wound and needs to be opened slightly to allow the smooth insertion of the phaco tip. Using an instrument to lift the section can make it easier.
- The sleeve (irrigation openings) can catch on the corneal section. A slight rotary screwing motion can aid the passage of the tip into the anterior chamber. Use the forceps if needed to help open the wound if this occurs.
- The posterior lip of the corneal wound can be depressed slightly to further open the wound and aid rapid probe insertion. A small amount of downward pressure on the posterior lip can be applied using the phaco probe as it is inserted.
- Some surgeons prefer to enter the eye with the phaco tip bevel down and then rotate back to the primary position once inside the eye. This is a personal choice, but this technique requires an extra step of manipulation and handling to return the probe back to the primary position once inside the eye. The Trainer will help decide which method to use.
- The foot pedal sequence is important:
  - Briefly irrigate the eye to wet the ocular surface and ensure a good corneal view. This reduces the need to ask for drops to be applied to the corneal surface during insertion. Under topical anesthesia, drops can cause inadvertent sudden ocular movement or an attempt by the patient to close their eye. This lid squeezing may cause the globe to rotate upwards if a strong Bells' Phenomenon is present. Brief irrigation will provide an indication of whether the patient may react to any drops applied.
  - Before tip insertion commences, ensure no irrigation (and definitely no aspiration) is applied. This ensures the cornea is not obscured by fluid. Instead, commence irrigation, during or after placement of the phaco tip into the wound and advancement into the anterior chamber. Aspiration should be avoided to prevent inadvertent iris damage. Listen to the machine noise to help determine the foot setting used.
  - Sudden rapid insertion of the phaco tip can occur as the sleeve navigates the corneal section. The surgeon should be prepared to stop pushing and pull the probe back to prevent lens or iris damage.

11.1.3 Palming of Forceps

As soon as the phaco probe is inside the eye the forceps can be palmed (see Chap. 7).

There is no requirement to insert a second instrument at this stage and the free fingers of the non-dominant hand can be used to support and steady the phaco probe. Some surgeons may prefer to insert the second instrument before any sculpting is attempted, (this will depend on the Trainer's preference). Novice surgeons are advised to only introduce the second instrument once the initial trench has been sculpted. This allows a smooth transition between insertion, pseudo-*groove* and a true *groove*. Furthermore, without the second instrument in situ, the novice surgeon can concentrate on obtaining a *groove* of the correct depth without the temptation to use the second instrument and move to the rotation stage too quickly. The caveat to this is that, in situations where the eye is moving excessively, the second instrument may be introduced early to keep the eye steadier during the initial *groove*. Alternatively, forceps could be used to hold the side port. In practice this is rarely needed.

11.1.4 Pseudo-*Groove*

A pseudo-*groove* probe movement is a practice warm up for subsequent *grooving*. After insertion into the anterior chamber the probe is moved forward and backwards over the lens capsule surface without the phaco tip touching anything (movement *without* phacoemulsification). This will ensure the phaco sleeve is not caught on the corneal section. Furthermore, as each corneal wound created may be slightly different, the pseudo-*groove* allows the surgeon to feel the resistance of probe movement within the corneal section. Once inside the eye, it is recommended that one or two pseudo-*grooves are* performed as part of standard practice.

11.2 The Phacoemulsification Triad

During phacoemulsification, as the phaco tip is moved along the surface of the lens, the material in contact with the tip will be emulsified. The resistance to the phaco probe movement depends on three interacting factors:

1. The lens material density.
2. The amount of material that is engaged within the mouth of the phaco tip.
3. The amount of phacoemulsification energy applied.

The key to successful lens *grooving* and trench creation is an understanding of how these three factors interact and how to adapt the surgery accordingly.

Attempting to phacoemulsify too much lens material in a single forward movement within the phaco mouth, will require higher phaco energy to maintain smooth *grooving* movement (unless the lens is very soft). If the phaco power is insufficient, the tip will be unable to cope with emulsifying the lens material. Consequently, the tip will refuse to cut through the lens and instead cause the whole lens to slightly shift forwards and backwards (*lens rocking*) as pressure from the phaco is applied and released. This can cause stress on the zonules and inadvertently lead to zonular dehiscence. A shallower bite during the phaco stroke is advised. This allows a thinner, more manageable layer of lens material to emulsify in any one phaco *groove* movement.

It is common for surgeons to program the phaco machine so that the foot pedal can only trigger up to about 45–60% of the maximum ultrasonic power output of the phaco machine. The pre-set amount chosen by the surgeon is adequate to deal with and emulsify cataracts with a range of densities. If the lens is very dense, and requiring repeated attempts to emulsify a thin layer of lens material, then a higher maximum phaco power should be made available. This can be done before surgery starts, if a higher setting requirement is predicted, or during phaco surgery if unexpected density is noted. For more experienced surgeons, another technique may be preferred in this situation, such as chopping the nucleus.

11.3 The *Grooving* Mantra

11.3.1 Phaco on. *Groove*. Phaco off and Return Silently

It is important to appreciate the foot pedal sequence required to control phacoemulsification during *grooving*. This can be aided by the surgeon familiarising themselves with the pattern of sound the phaco machine makes during the various modes of irrigation, aspiration and phacoemulsification. These sounds alert the surgeon if one mode changes to the next, or if a mode is left on unintentionally. By listening to the machine, the surgeon can appreciate additional auditory feedback.

A suggested sequence of applying the various foot pedal modes during *grooving* is as follows:

(a) Irrigation on to maintain the anterior chamber (surgeon may prefer constant irrigation machine setting).
(b) Phaco on (transition to phaco is done straight away without pausing on aspiration-only mode).
(c) Start to *groove*.
(d) *Groove* stroke complete. Phaco off and aspiration off.
(e) Return stroke back to starting point.

Commonly, inexperienced surgeons use the following sequence during *grooving*:

(b) Irrigation on.
(c) Aspiration on.
(d) Start movement to attempt *groove*.

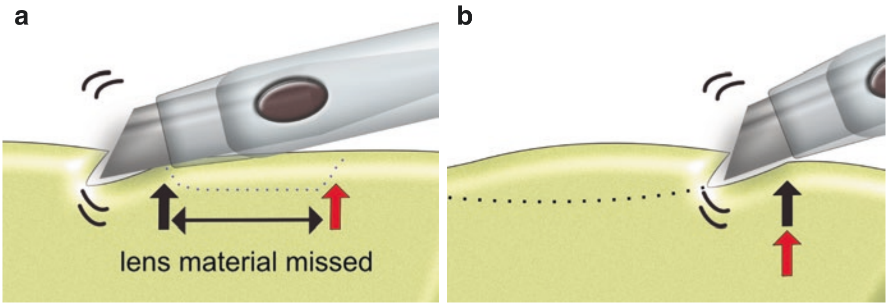

Fig. 11.13 Application of phacoemulsification during *groove* stroke. (**a**) Timing of application incorrect. Phacoemulsification power applied (*black arrow*) after *grooving* movement commenced (*red arrow*). Distance between double headed arrow indicates *missed* potential lens material (*dotted line*) during movement. (**b**) Timing of application correct. Phacoemulsification power applied (*black arrow*) simultaneously when *grooving* movement (*red arrow*) commenced. Lens material to be emulsified (*dotted line*)

(e) Phaco on.
(f) *Groove* attempt complete: phaco off or power reduced and return stroke commenced whilst still aspirating.

The latter sequence develops a technique in which targeted lens material may not be removed during phaco stroke. In the later sequence, the initial part of the intended *groove* (from the start of the movement) will not be emulsified as the surgeon applies phacoemulsification *after* the stroke movement has begun (Fig. 11.13).

Additional *grooving* strokes may thus be required. Furthermore, lack of phaco power application whilst trying to engage the lens will increase the likelihood of *lens rocking*.

In a similar fashion, if aspiration is applied during a return stroke the phaco tip will try to maintain an aspiration hold on the lens nucleus material and *lens rocking* will be noted. Simply put, the *grooving* mantra is 'Phaco on. *Groove*. Phaco off and return silently'. With experience this will be done automatically, but in the initial stage of *grooving* it should be consciously adhered to.

11.4 The Phaco Starting Position

The *grooving* mantra 'Phaco on. *Groove*. Phaco off and return silently' has been explained. However, an additional caveat is required: 'Tip in the correct position'.

When ready to commence an actual *groove*, the surgeon should pull the phaco tip back so that it is close to, but not touching, the rhexis edge. This is referred to as the *starting position,* (Fig. 11.14).

It is common to hesitate and pause whilst mentally preparing to start sculpting the initial *groove*. Hesitation near the starting position can lead to wound hydration or even a phaco corneal burn (if applying phaco energy). Performing a pseudo-*groove* provides the opportunity to make a firm decision to apply phacoemulsification on the next forward stroke, reducing any hesitation.

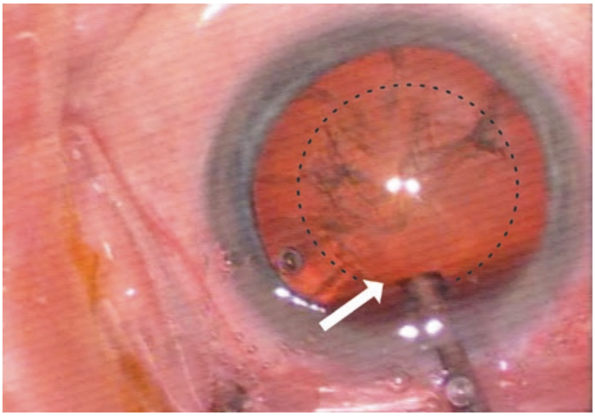

Fig. 11.14 Phaco starting position. The phaco tip is pulled back as close to the rhexis edge (*dotted line*) as possible. This is the starting position for applying phacoemulsification (*arrow*)

11.4.1 Grooving

The initial *groove* should aim to remove a superficial layer of lens material and delineate the boundary on the opposite side of the rhexis. This can help avoid accidental damage to the capsule during subsequent sculpting by keeping within the distal boundary of the initial *groove*.

During the *groove* stroke, the eye may rotate away from the surgeon. This should be anticipated with the expectation that this will correct as the phaco tip is returned to the starting position (Fig. 11.15). The sculpted effect of the *groove* is visualised once the probe has returned to the starting position (Fig. 11.16).

11.4.2 *Groove* Depth

A common question is: "how deep should I make the initial *groove*?". The simple answer is: 'deep enough to ensure that undue lateral force is not required to *crack* the floor of the trench'. Thus, for the more experienced surgeon with a better *cracking* technique, the depth can vary.

For a beginner, a better question to ask is: "how do I tell when the *groove* is deep enough and no further phaco-sculpting is needed?" This can be answered in 3 ways:

1. As lens material is removed the red reflex at the base of the *groove* will become brighter.
2. The supervising surgeon will inform the Trainee
3. By creating a reference level for depth appreciation:

- After the first *groove*, a second *groove* is performed to widen the first by half phaco tip width. This is done on the right side of the initial *groove* (Fig. 11.17).

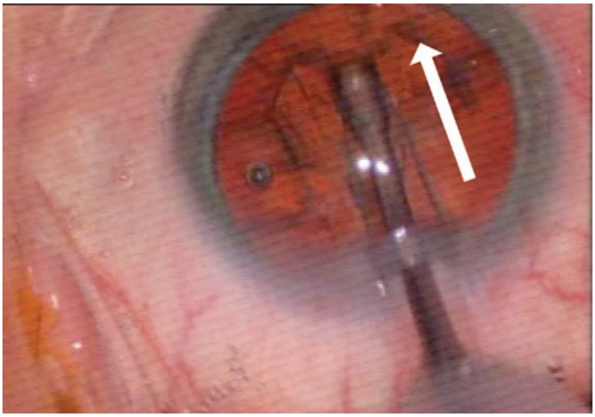

Fig. 11.15 Initial *groove* stroke. During the *groove* stroke (*arrow*) downward rotation of the eye is expected

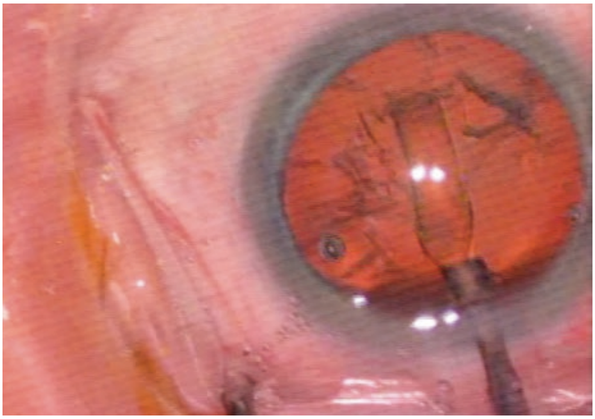

Fig. 11.16 The sculpted effect of the initial *groove*

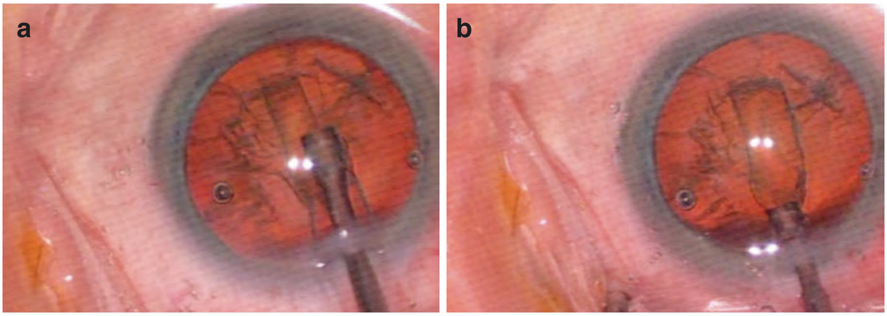

Fig. 11.17 Enhancing depth perception. (**a**) Initial *groove* is widened by half phaco width. (**b**) Widened *groove* appearance

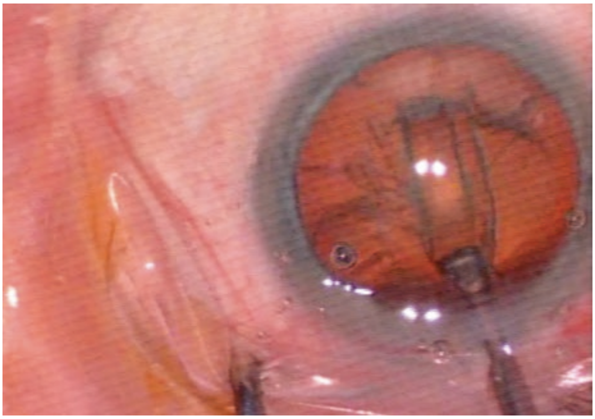

Fig. 11.18 Enhancing depth perception. As *groove* is deepened the residual right hand side ridge helps the surgeon appreciate trench depth

Further *grooving* should continue using the left-hand side of the original trench wall as the guideline for the stroke movement. Deepening, but not widening, the trench on the left creates a small residual shelf of lens material on the right-hand side. This depth-perception ridge is used to help judge the depth of the *groove* (Fig. 11.18).

Box 11.2 Surgical Tip for Initial *Groove* Strokes

- Care is needed not to make the *groove* too wide on the second *grooving* stroke, (avoid a trench more than two phaco widths in diameter). Subsequent depth *grooving*, if not maintained on one side of the trench results in an ever-widening central trench. Thus, a central, bowl-like effect is created. As the walls of the trench are not in close proximity to each other, *cracking* in this situation can be difficult. For the novice, dealing with a lens bowl may not be possible early on in training.
- When dealing with very soft cataracts, leaving the *groove* as narrow as possible may facilitate *cracking* as trench walls remain slightly more rigid. Another technique for a soft lens is to intentionally create a residual bowl. Subsequent aspiration of the residual pliable lens plate into the middle safe zone will allow gentle phaco-aspiration. Novices are likely to find soft lens extraction more challenging and cases are better attempted when more experienced.

11.4.3 Deepening the Initial Trench

Three aspects are important in deepening the trench:

1. Firstly, the shape of the lens should be borne in mind. It is biconvex, with the maximum thickness at the centre. Thus, for a *cracking* technique, it is the centre of the lens that phacoemulsification *grooving* focuses on.

2. Second, an attempt to commence each phaco stroke at the "starting point" is recommended. As depth is gained, a downward sculpting stroke is promoted. Deepening the *groove,* in this briefly held oblique probe position, will help the novice learn how to *groove* in patients with a deep anterior chamber, for example; highly myopic eyes.
3. Finally, the *grooving*-stroke phaco tip trajectory needs to be understood. As the *groove* is deepened a "J" shaped movement is required. The movement alters with each *groove* stroke to ensure central area is deepened.

The initial deepening *groove*-stroke begins with a small vertical downward element but quickly flattens. At the end of the *groove*-stroke, the tip should level off and an upward movement made to ensure no tongue of lens material juts out on the opposite side of the trench (Fig. 11.19a). Phacoemulsification can be eased off during this upward movement.

With each deepening attempt, (Fig. 11.19b–d), the surgeon should angle the probe more vertically at the starting position and 'go for depth' rather than *groove* 'length'. Again, at the end of each stroke, a small upward movement is needed to ensure no tongue of lens material is left behind.

Multiple short (and usually) ineffective strokes that focus on the central area of the nucleus should be avoided as this develops a jerky *grooving* style. A smooth continuous *grooving* motion from the starting position to the end of the trench should be attempted on each phaco stroke, using the left-hand side of the trench wall as the guideline for the stroke movements.

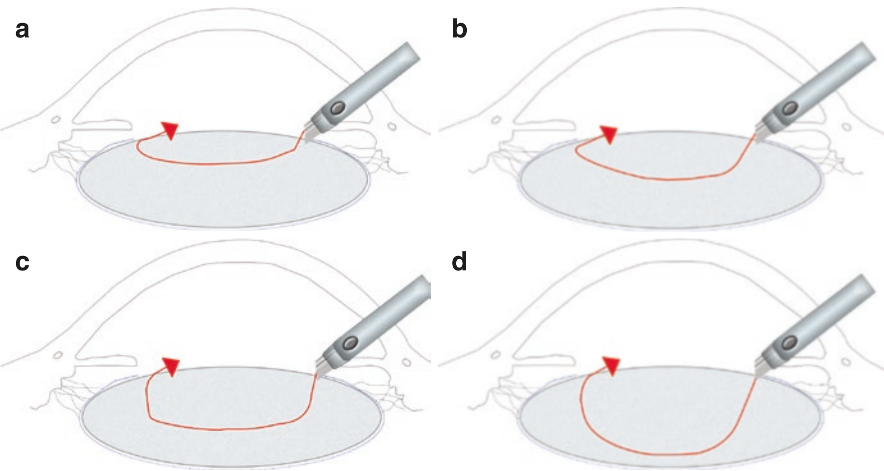

Fig. 11.19 Deepening the initial trench. (**a**–**d**) Adjustment of 'J' shaped movement during phaco stroke to accommodate shape of lens

Box 11.3 Surgical Tip for *Groove* Strokes

- The temptation to remove too much lens material in one *groove* stroke is not recommended.
- After each *groove* stroke is performed, a judgment is required by the surgeon on whether a suitable trench depth at the centre of the nucleus has been reached. The view of the posterior pole of the lens can be obscured by the phaco probe tip. By returning the probe tip to the starting position near the corneal section the central trench depth is more easily visualised by the surgeon and the Trainer.
- Trainees may pause in between each *groove* stroke as they decide if addition lens material needs to be removed to deepen the trench depth. The Trainer may automatically provide 'Go for depth.' instruction to suggest another *groove* stroke is required. This may give the Trainee the impression they are being rushed as the decision is made before they come to the same conclusion. Initially the Trainee needs to accept that the Trainer instruction will be made almost instantly so one *groove* stroke follows on to the next and they need to concentrate on mastering the grooving technique. As this competency is acquired the Trainer will offer less instruction and the Trainee will need to make the depth assessment themselves.
- The lens material just in front of the phaco tip provides the surgeon with a focal point to observe. Phacoemulsification and disappearance of lens material just ahead of the phaco mouth can be visualised. Coupled with an increasing red reflex as the *groove* is deepened these two signs can be used as indicators of an effective *groove* stroke.
- As phaco emulsification is eased off on an upward stroke, the novice is advised to listen and appreciate the decrescendo phaco sound emitted.
- If phaco is "*on*" the phaco tip, to avoid applying phaco energy unnecessarily within the eye the tip needs to be grooving and emulsifying lens material. Pausing to consider what to do next with phaco 'on' is not advised.

11.4.4 Subsequent Grooving

After formation of the initial *groove*, the novice surgeon has three major technique choices:

1. Perform immediate *cracking* of the lens and then continue repeating the sequence of repeat *grooving* and immediate *cracking*, or
2. Sequentially rotate the lens and *groove* all the trenches needed before any *cracking* attempt, or
3. The trench can be *cracked* and then the whole nucleus rotated 180 degrees and *cracked* again, with or without additional *grooving*. Each heminucleus is subsequently *grooving* and *cracked* into two halves.

It is up to the novice surgeon to choose which technique to follow (under the guidance of the Trainer). In practice, surgeons vary what they decide to do from case to case, and as experience develops they introduce new techniques (such as chopping) to disassemble the nucleus. The principles behind *grooving* of subsequent trenches remain the same as the initial trench but with some minor adjustment in technique.

After rotating the lens, the *grooving* trench is positioned horizontally, effectively dividing the lens into a distal and proximal half (Fig. 11.20a). *Grooving* of the distal half of the nucleus beyond the horizontal trench can be hindered by proximal heminucleus lens material preventing free movement of the phaco probe (Fig. 11.20b). If anticipated, or if lens rocking is noted, the surgeon can consider making an initial *groove* in the proximal half of the lens (Fig. 11.20c). This will form the superficial basis of the trench needed in the proximal half of the lens when it is later rotated into a distal position. Furthermore, it allows the phaco probe better access to distal heminucleus lens material, as the probe is less likely to rub accidentally on the proximal lens surface (Fig. 11.21). For more experienced surgeons, this may not be required. This step can, however, prove useful for novice surgeons who are have difficulty sculpting the correct depth of the distal trench.

Grooving continues in a systematic fashion, applying phaco to progressively remove lens material. It is tempting to *groove* a trench in the distal half by using short *grooving* strokes. Short *grooving* strokes can hinder visualisation of the posterior pole as the phaco tip continually obscures the view. Consequently, residual material is left at the posterior pole that hinders complete *cracking* and fragments

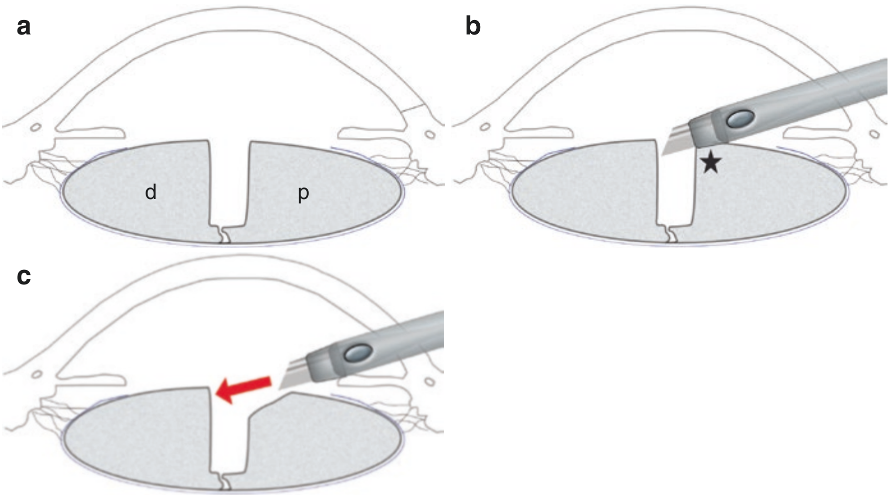

Fig. 11.20 *Grooving* of the proximal half of the nucleus part 1. (**a**) Nucleus has been rotated to position trench in horizontal orientation. Proximal heminucleus (p) and distal heminucleus. (**b**) *Grooving* of the distal heminucleus can be hindered by the lip of the proximal trench wall (*star*). (**c**) *Grooving* of proximal lens fragment creates a passage for phaco probe to reach the distant fragment

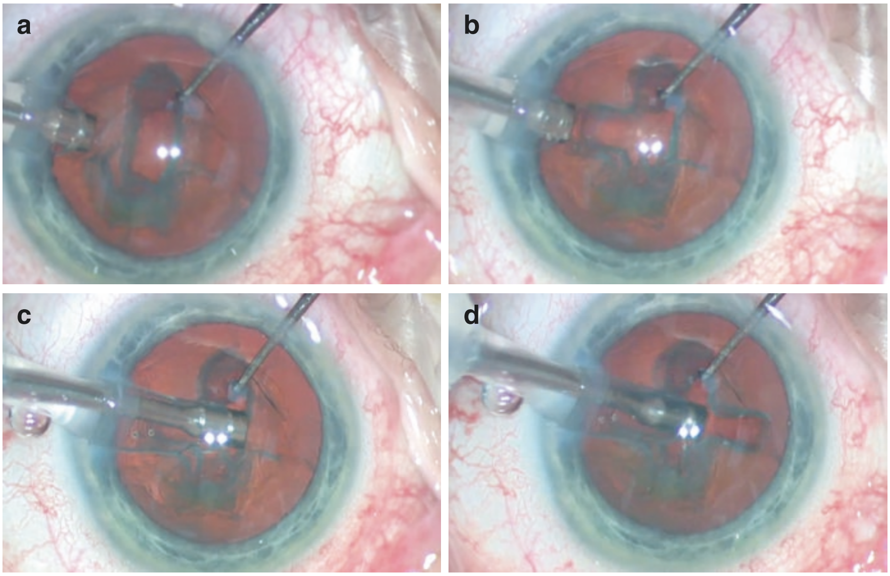

Fig. 11.21 *Grooving* of the proximal half of the nucleus part 2. (**a**) Phaco probe positioned ready to *groove* proximal heminucleus. (**b**) Small *groove* made in proximal heminucleus. (**c** and **d**) *Grooving* of proximal lens fragment creates a passage for phaco probe to reach the distant fragment

can remain hinged together in this region. To ensure trench depth is correctly obtained, it is recommended that the phaco probe tip is intermittently pulled back towards the primary starting position or after each *groove* stroke. This will allow visualisation of residual lens material and allow the surgeon to decide what aspect of the trench needs to be modified to ensure adequate trench length and depth. Once the depth assessment has been made the probe tip is positioned closer to the distal lens material ready for the surgeon to apply the *phaco mantra* whilst taking into consideration the shape of the lens to ensure a 'J' shaped sculpt is performed.

11.4.5 Cracking

The *cracking* sequence can be broken down into four steps:

11.4.5.1 Minor Rotation

To facilitate *cracking*, a minor rotation of the lens is performed using the second instrument (5–10 degrees in a clockwise direction) (Fig. 11.22). This simple step is performed before the *cracking* attempt and allows the novice surgeon a bit of lee-way in correct depth placement of the phaco tip and second instrument. As experience grows the surgeon may not require this step, but for novice surgeon it is

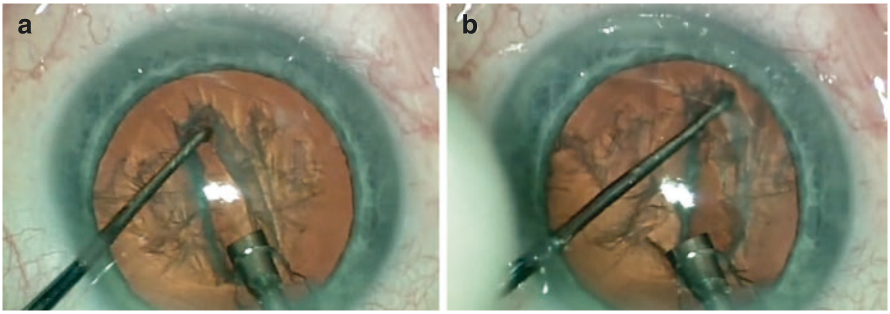

Fig. 11.22 *Cracking*: minor rotation. (**a**, **b**) Trench rotated by 5–10 degrees in a clockwise direction

recommended. It is useful to introduce this step (if not performed already) if struggling to fully *crack grooving* segments.

11.4.5.2 Making Use of the Shape of the Phaco Tip

Cracking is performed by applying pressure to the opposing walls of the *grooving* trench. Since the phaco tip is commonly longer inferiorly (Fig. 11.5) rotating the phaco tip anti-clockwise will increase the surface area in contact with the right-hand side of the trench wall. This can provide an advantage when *cracking*. The lateral force applied by the phaco probe tip is spread over a larger surface area of the trench wall, thus facilitating the *cracking* process. Once the *grooving* trench is *cracked*, the phaco tip can be rotated back to the primary position as it is withdrawn from the trench. Again, the technique is useful as allows the surgeon a bit of leeway in depth placement of the phaco tip and second instrument. It is a straight forward to perform, but many novice Trainees forget to apply phaco probe rotation before placement into the trench—unless reminded by the Trainer.

Technique: whilst the second instrument maintains the lens in a minor rotation position the rotated phaco tip is inserted into the trench (Fig. 11.23).

11.4.5.3 Correct Trench Placement of the Phaco Probe and Second Instrument

The two instruments ideally need to be placed as deep as possible into the trench. If placement is too superficial, it results in compression force of the lens material below the instruments rather than separation of the lens material (Fig. 11.24). This may result in a failed *cracking* attempt, or require the surgeon to use more force to spread the walls of the trench further apart. This forceful technique to split the lens material at the base of the trench may cause the walls of the lens to crumble and apply unwanted force to the capsule or zonules.

Technique: the tip of the second instrument is placed into the *grooving* trench, roughly opposite where the phaco tip has been placed and the obliquely slanted phaco tip placed deep within the trench (Fig. 11.25).

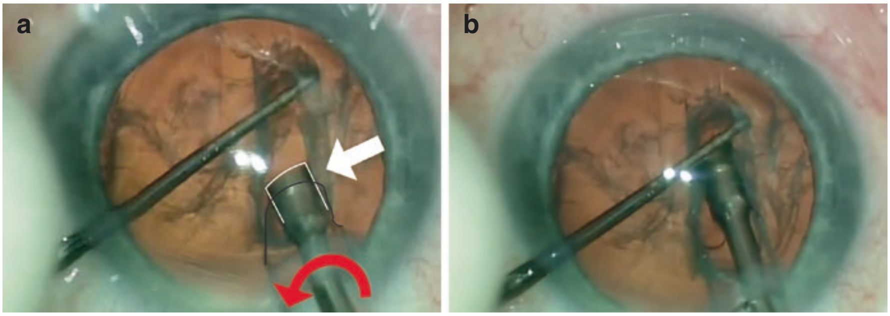

Fig. 11.23 *Cracking*: maintenance of minor rotation and placement of phaco tip. (**a**, **b**) minor rotation maintained with applied pressure from second instrument. Phaco probe rotated (*curved arrow*) and inserted into the trench with its long axis (*white outline*) against right hand wall (*arrow*). Phaco sleeve border (*black outline*)

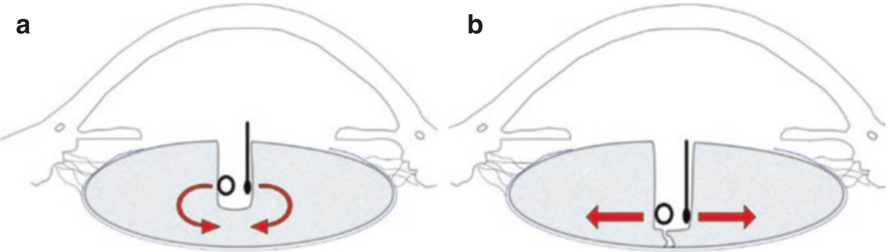

Fig. 11.24 Correct depth placement of instruments. (**a**) Superficial placement of instruments causes compression of lens material below base of trench during *cracking* attempt. (**b**) Placement of instruments into a deep trench causes splitting of lens tissue below base of trench during *cracking* attempt

Fig. 11.25 *Cracking*: placement of instruments into trench. Phaco probe maintains minor rotation as second instrument is repositioned.

11.4.5.4 Cracking

Cracking can produce various clinical signs that can help the surgeon determine if instrument adjustment is required during the *cracking* attempt.

- To *crack* the *grooving*-trench, lateral movement in a horizontal plane is required as the two instruments are pulled apart. Downward pressure should be avoided (seen as a downward out-of-focus shift of the lens). This usually occurs if the instruments are placed too superficially within the trench and increased forced is applied.
- As the trench base begins to split, and the lens fragments move apart, a linear shaped brightness in the red-reflex will appear. This clinical sign allows to surgeon to gauge that lateral pressure can be eased off. Confirmation of the split is usually achieved by performing an exaggerated separation resulting in a wide red-reflex wedge (Fig. 11.26). With experience, visualisation of a slim wedge of red reflex can be used to confirm the lens is *cracked* and an exaggerated separation is not necessary.
- The split direction should ideally be along the floor of the trench. Sometimes it can veer to one side and creating irregular shaped fragments. This can then hinder fragment extraction as adjacent fragments may lock together in a jigsaw fashion. Repositioning the instruments within the *groove* (usually just using the second instrument) can help redirect the separation force as the dynamics applied change, allowing a better *crack* to be achieved.
- During insertion of the instruments and sequent *cracking*, the lens may spontaneous try to rotate anti-clockwise. This is a common occurrence and does not affect the *cracking* process.

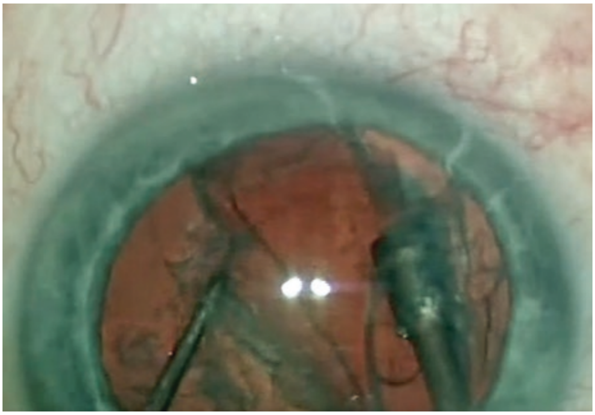

Fig. 11.26 *Cracking*: confirmation of separation of nucleus. Instruments are separated to *crack* lens nucleus. Wedge shaped red reflex noted as base of lens is split

Another technique for applying pressure to the walls of the trench is for the two instruments to cross over whilst *cracking*. When the instruments are in the *grooving*-trench they are crossed over each other, so that the phaco probe applies pressure to the left- and the second instrument to the right-hand side of the trench walls respectively.

11.5 Major Rotation

Major rotation of the lens is required to position the lens in preparation for the next trench creation. Two potential situations need to be considered: major rotation post *cracking* or major rotation without prior *cracking* of the *grooving* trench.

11.5.1 Major Rotation Post Cracking

Following *cracking* of the *grooving* trench, a potential split extending peripherally is present. The second instrument can be placed into this split just beyond the end of the *grooved* trench. This placement can be done before the removal of the phaco tip from the trench, immediately after *cracking* completion. In doing so, the residual tension applied by the phaco probe on the right-hand side of the trench-wall keeps the lens segments slightly apart to facilitate the second instrument placement. The lens can be rotated clockwise at a *constant* rate by applying pressure to the fragment with the second instrument. During the rotation, the phaco can be withdrawn and returned to the primary position. The peripheral placement of the second instrument provides effective torque for the rotation. To allow lens nucleus rotation, the phaco tip needs to be lifted up to allow the shaft of the second instrument to pass underneath it. This facilitates a smooth nucleus rotation of at least 90 degrees. Subsequent *grooves* are made at 90 degrees to the last *groove* and the process repeated until all fragments are created (Fig. 11.27).

11.5.2 Major Rotation Without Previous Cracking

The phaco probe should be withdrawn from the *groove* and maintained in the primary position. The second instrument is then used to rotate the lens by placing it into the peripheral part of the trench. Avoid nudging the lens repeatedly to get it moving, instead try to apply constant torque in order to rotate the lens and avoid causing the walls of the trench to crumble. Downward pressure during the rotation is not recommended. The lens can be *grooved* once it is in a suitable position and the process repeated until all *grooving* trenches have been created. The *cracking* process can then be done as previously described.

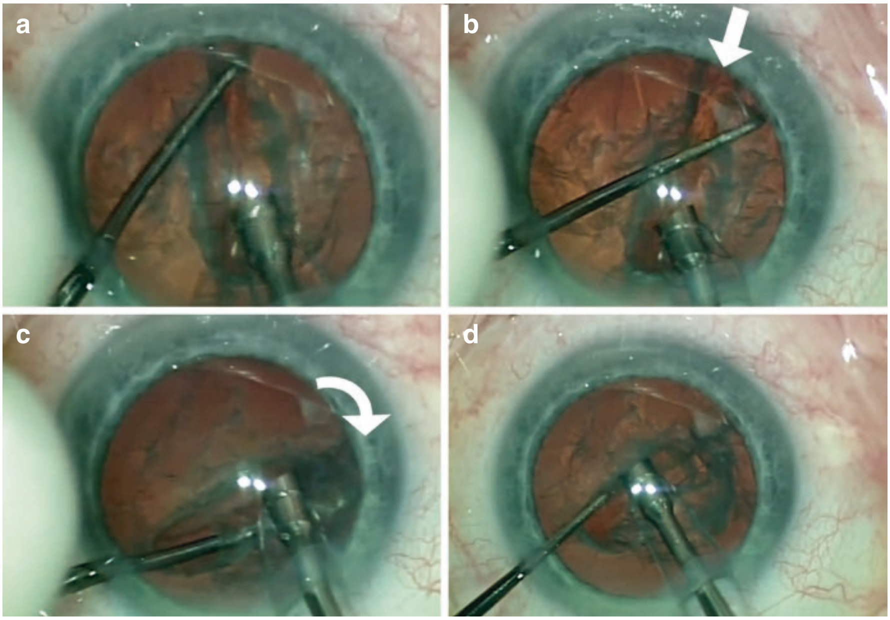

Fig. 11.27 Major rotation. (**a**) Second instrument placed into peripheral split before phaco probe is withdrawn. (**b**) Phaco tip withdrawn and simultaneously rotated back to the primary position whilst the second instrument rotates the lens. The rotation further separates the *cracked* fragments (*arrow*). (**c**) Second instrument continues to rate the nucleus and passes under the phaco tip. (**d**) Lens is in a position for further sculpting and second instrument is withdrawn out of the sculpting path of the phaco tip

Box 11.4 Surgical Tips

- It is common for novice surgeons to try and visualise too much of the phaco mouth aperture during grooving. This effectively flattens the angle approach and is not recommended as it can lead to ineffective depth grooving. Reviewing the novice's record of surgery can help detect this.
- If the phaco tip sleeve prevents smooth grooving strokes, the surgeon should ensure the deepening trench is widened.
- With experience a minor rotation before *cracking* may not be required.
- As training progresses the surgeon may wish to try the following *cracking* variation:
- If the surgeon is confident that the trench only requires one more final grooving movement, instead of pulling the probe back to visualise the posterior pole the phaco probe can be left in the distal aspect of the *groove* after the stroke. The second instrument can be inserted into the trench and the lens *cracked*. During the lateral *cracking* movement, the phaco tip can be rotated to facilitate the *crack*. If complete *cracking* fails to occur, a cross-over *cracking* technique can be attempted, or if preferred the surgeon can resort to a minor rotation and re-attempt the *cracking*.

Box 11.5 Trainer Teaching Pearls

The aim of surgical training is to enable the Trainee to become a ‘lazy phaco surgeon’. The definition of which is ‘A surgeon who uses good technique, does as little as possible within the eye and ensures efficient, safe surgery.’ This process can take time but is facilitated by modular training under instruction. It is recommended that the Trainee be taught fragment *cracking before grooving*. It requires the Trainer to pre-*groove* the lens before handover. If needed, the Trainer can perform all the steps up to that stage, or allow the novice to only perform the capsulorhexis and hydrodissection parts and then *groove* the lens accordingly.

Performing *cracking* first introduces this module in smaller steps and promotes a situation in which the novice surgeon only has to concentrate on *cracking* the lens in which well-*grooved* trenches are in place. It also ensures continuous progress as the novice surgeon is more like to successfully disassemble the lens and complete the remaining parts of the operation. Once familiar with the *cracking* the lens, *grooving* training can then be commenced. The Trainee is more likely to successfully *crack* their own sculpted partial-depth *groove*s if they have had *cracking* training.

Often Trainee surgeons who experience difficulty have tried to perform a combination of basic and intermediate (and sometimes advanced) techniques. The fundamentals are not quite understood and thus the expectation of what the novice should be able to do is not met. Allowing the novice to attempt to mimic the Trainer’s well-practiced advanced techniques should be avoided in the early stages of training. Constructive feedback is recommended as soon as possible (e.g. in between cases, whilst scrubbing or after theatre). Changes in technique can be implemented quickly before poor technique becomes engrained and more difficult to rectify.

The Trainer must be aware that Trainees can get frustrated that their technique (initially) does not seem to work efficiently compared to that of their Trainer. Trainees should be reassured that this will improve with time. It should be expected that Trainers may occasionally have to take over if the case requires senior input.

Initially it is recommended that the Trainer double-check the phaco tip assembly until the Trainee is capable of managing sleeve adjustment.

Although novice surgeons can usually insert the phaco probe (following on from previous fragment removal training), as the corneal incision often feels slightly tight for the first insertion, additional help might be required.

At the start of *grooving* training it is recommended that the *grooving* mantra “Tip in the correct position. Phaco on. Groove. Phaco off and return silently” is reiterated.

To avoid over-widening the initial *groove,* novice surgeons can be instructed to make the second widening *grooving* stroke movement slightly convex in shape. This ensures that, at the end of the stroke, the tip almost ends up back in the original *groove*. It is then easy for the return stroke to follow a straight line back to the starting position.

During *grooving*, once the phaco has been returned to the starting position, the Trainer can visualise how deep the central portion of the *grooving* trench is. Novice surgeons are often fearful of going too deep and require encouragement. A good instruction phrase to use is “go for depth”. This allows the novice to realise further shaving of the trench base is required. If the *groove* length is too short the Trainee can instruct to “go for length”. If the first *groove* is performed without a second instrument in the eye, then, once the initial trench is deep enough, the Trainer can recommend it be inserted.

For the novice surgeon crossover *cracking* technique requires a higher level of skill and it is recommended the Trainer initially ensure novice surgeons focus on performing the standard *cracking* movements. Cross-over can be introduced at a later stage to facilitate the Trainee *cracking* their own sculpted trenches.

11.6 Summary

Grooving and *cracking* is an essential technique to learn. The steps can be broken down into set movements so the steps are learnt and can performed under instruction. Over time, nucleus disassembly can be performed by varying the *grooving* and *cracking* sequence and technique. These principles should ensure phaco *grooving* and *cracking* training is easy and enjoyable not only for the Trainee but for the Trainer. See Videos 11.1 and 11.2.

Reference

1. Gimbal HV. Divide and conquer (video). Presented at: The European Intraocular Implant Council meeting. 1987.

12 Phacoemulsification: An Easy Stop, Chop and Crack Technique

The technique of 'groove-and-crack', coupled with the ability to debulk large fragments, is a useful method for tackling the majority of cataracts. However, as training progresses, surgeons may wish to develop the nucleus *chopping* method of creating fragments. A *chop* technique requires the phaco tip to be embedded the into the lens nucleus whilst the second instrument cleaves the lens nucleus apart. The original *chop* [1] has been adapted and refined into two chopping techniques, vertical and horizontal [2]. The vertical and horizontal phaco chop are advanced techniques, best attempted once Trainee surgeons have become highly skilled in standard methods.

This chapter describes a variant of stop and chop [3] and phaco quick chop [4]. Skills previously gained in the modules of grooving, cracking and debulking can be utilised. Using this technique, Trainees can tackle moderately dense cataracts and keep the overall phacoemulsification time as short as possible without the need to place the chopper instrument under the capsulorhexis and out to the equator of the lens.

The technique is relatively simple to perform but requires additional bimanual skills. It assumes that the surgeon can perform the grooving-and-cracking technique, debulk large fragments, and remove them using well-controlled phacoemulsification. Once phaco and second-instrument control have been developed, the technique can be taught in a step-by-step manner. It may even be possible to do this quite early on in training, as part of modular nucleus disassembly training, before or after corneal incision training.

If initial attempts at using the chop technique are unsuccessful, it is possible to revert to a standard grooving-and-cracking technique as a means of completing lens separation. Additional attempts can subsequently be made after the lens has been rotated.

As in previous chapters, it is advisable to read the whole chapter in order to gain a clear understanding of the technique. Trainer teaching pearls are at the end of the chapter.

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12.1 Fundamentals

Three fundamental principles need to be understood (Fig. 12.1a–d):

1. The technique requires the application of phacoemulsification in order to bury the phaco tip into a solid part of the lens nucleus. There is no requirement to try and extract the lens from the bag before the chop—indeed this should be avoided. Phacoemulsification is turned off after the phaco tip is buried into the lens. The amount of aspiration is kept to a minimum or also turned off. The phaco tip will maintain its hold on the nucleus unless the probe is pulled backwards by the surgeon.
2. The lens nucleus is impaled by the second instrument tip (any suitable chopper). The chopper tip needs to be inserted just distal to the phaco tip, ideally to the left of midline (but well inside the rhexis margin to avoid a capsule tear).
3. The two instruments are separated laterally (as if performing a standard *crack*) with the phaco moving to the right and the second instrument to the left. Cleavage will result, with the lens nucleus split into two halves. If required, a *reverse-crack*, using a cross-over technique can also be applied to ensure adequate separation of the lens pieces.

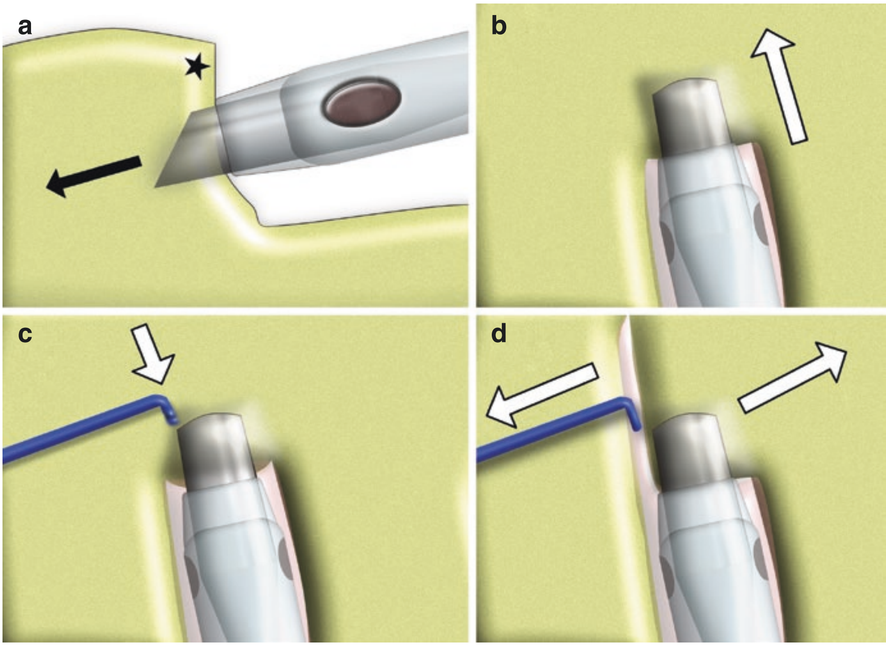

Fig. 12.1 Fundamental chop technique. (**a**) Side profile of embedded phaco tip. The probe is embedded below the surface (*star*) of the lens into nucleus in an oblique direction (*arrow*). (**b**) Microscope view of embedded phaco tip. Phaco tip is buried directly into lens (*arrow*). (**c**) Whole of chopper tip is inserted vertically into lens substance just distal and to the left-hand side of the phaco tip. (**d**) Cleavage. The instruments are pulled apart laterally (*arrows*) and the lens nucleus spilt

12.2 Step-by-Step Approach

A key component of chopping is maintaining the phaco tip in a steady position whilst the chopper impales the lens nucleus. Novice surgeons often try to pull the lens centrally into the safe zone. This occurs because there is a perception that the chopper needs to be placed away from the phaco tip; or that the chopper should be kept peripheral to the lens equator, under the capsulorhexis. This is not required for this chop technique. Movements are all performed within the boundaries of the capsulorhexis.

12.3 Step-by-Step Training

The technique can be learnt in steps and attempted at convenient, suitable moments during surgery.

12.3.1 Pre-Cracking Training

The novice surgeon should perform a slightly altered groove-and-crack technique. During sculpting, there comes a point when a final groove is required for correct trench depth. This last groove should be performed in the standard fashion, but at the end of the stroke the phaco probe should be held and maintained in the distal aspect of the groove. The phaco should *not* pulled back to verify the trench depth and a minor rotation before cracking is not performed. The chopper is then inserted into the groove, adjacent to the phaco tip, and the nucleus cracked. Once the surgeon is able to hold the phaco probe steady and place the chopper tip into the groove step 2 can be attempted.

If cracking is unsuccessful, novice surgeons should resort to a standard grooving-and-cracking technique to complete lens separation. After the lens has been rotated further grooving is preformed and the phaco kept in the groove on the last stroke and a cracking *attempt* can once again be attempted.

12.3.2 Initial Chop Attempt After the Initial Trench is Formed

A grooved trench should be created, with the groove stroke commencing at the starting point adjacent to the capsulorhexis near the corneal incision. The groove required for a chop attempt needs to be short and deep (i.e. novices should "go for depth" not length) (Fig. 12.2a). Instead of trying to crack and divide the trench in a standard fashion, the phaco tip is first embedded at an oblique angle into the distal part of the trench wall. This is performed below the superficial epinucleus, grooving directly into a solid part of the nucleus (Fig. 12.2b). A J-shape upward movement should *not* be performed. Phaco application should be stopped once the tip is embedded.

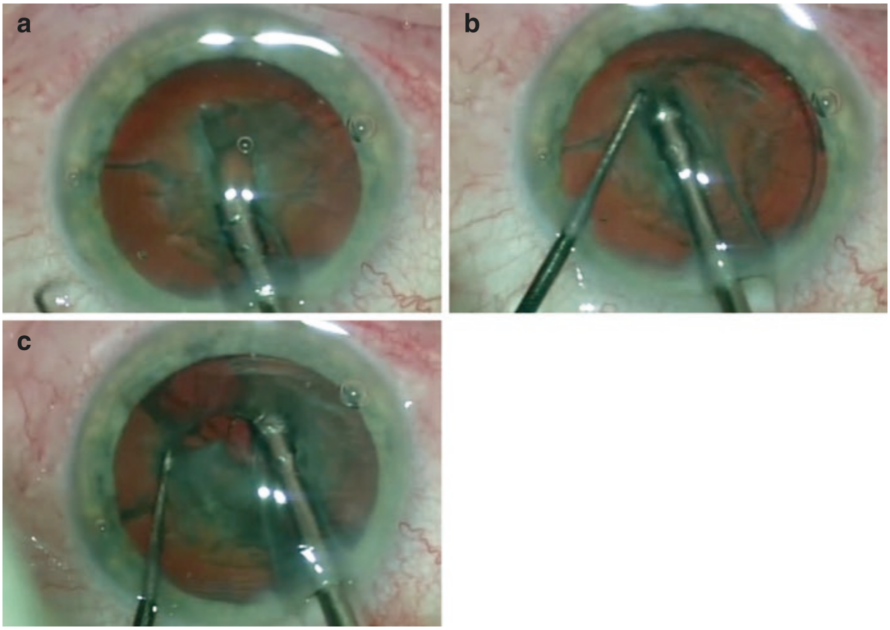

Fig. 12.2 Initial chop attempt. (**a**) A short sculpted trench is created. (**b**) The phaco tip is embedded into the nucleus and the second instrument tip impaled into the lens adjacent to the phaco tip. (**c**) The nucleus is separated by pulling instruments apart

A tongue of lens material will be held within the mouth of the phaco tip, and as long as the phaco is not pulled backwards the tip will remain embedded in the lens nucleus.

The second instrument tip is then fully inserted into the lens substance, just distal to the phaco tip. Ideally insertion should be to the left of the centre of the phaco tip (Fig. 12.2b). This ensures that the phaco tip has the tongue of lens material within its mouth to hold onto as the nucleus is separated (Fig. 12.2c).

The chopper tip may sometimes be inadvertently placed into the lens substance slightly more distally than intended (but still well within the boundaries of the capsulorhexis). This is not a concern as the natural tendency is to draw the chopper tip towards the phaco tip before trying to separate the two instruments. Again, the chopper needs to be drawn to the left-hand side of the phaco tip to ensure the tongue of lens material within the phaco tip mouth is not disturbed during the separation phase.

As the fragments separate, the split will allow a visible change in the red reflex. It may or may not be necessary to perform a reverse cross-over technique to ensure ether pieces are fully separated from the periphery to the centre of the lens.

It is important to remember that, if the chop manoeuvre fails to split the lens, it is simple to resort to a standard grooving-and-cracking technique to complete the lens separation. The lens can then be rotated and surgery continued.

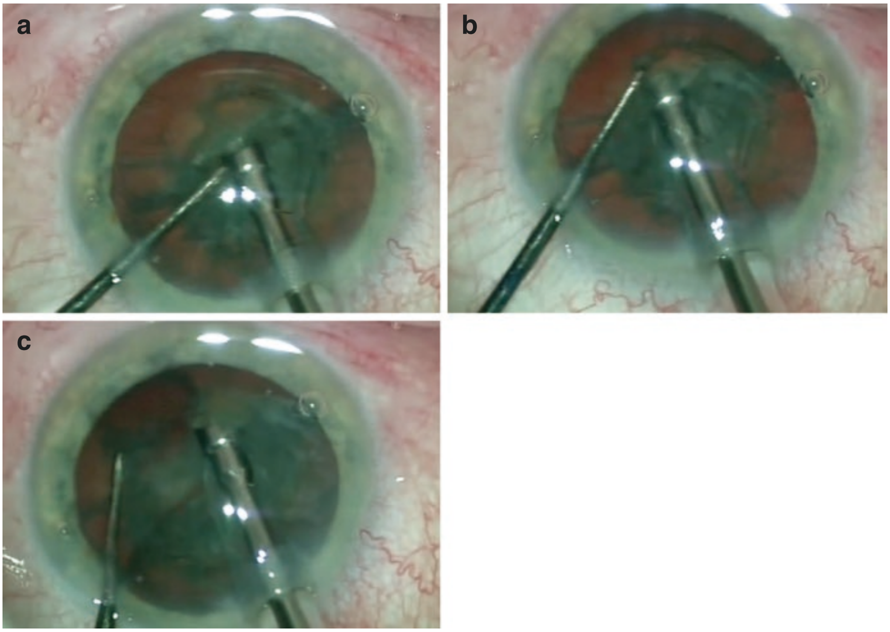

Fig. 12.3 Heminucleus chop. (**a**) Phaco probe is positioned obliquely to embed tip obliquely into lens nucleus. (**b**) Second instrument tip impaled into the lens adjacent to the phaco tip. (**c**) The heminucleus is separated by pulling instruments apart

12.3.3 Divide Each Heminucleus into Two Quadrants Using Chop Technique

Two heminuclei should be created (either as described above in step (b), or by grooving-and-cracking in a standard fashion) and then the *chop* technique used to further divide each heminucleus (Fig. 12.3). In this situation, the heminucleus is not pre-grooved. The phaco tip is embedded directly into nucleus below the surface of the lens, the chopper inserted and the nucleus split. The lens is rotated and further chopping attempt can be tried on the remaining heminucleus.

12.3.4 Divide Each Heminucleus into Three Pieces Using Chop Technique

Alternatively, instead of trying to create 4 large fragments by dividing each heminucleus into two, each heminucleus may be *chopped* into three pieces. Rotate the lens until the initial sculpted trench is angled slightly obliquely to the phaco probe (this avoids having to pivot the phaco probe if the heminucleus is perpendicular to the phaco tip). Embed the phaco tip into the heminucleus so that a third of the heminucleus will be formed on the right and two-thirds on the left-hand side. Perform a *chop* to separate the pieces. The lens can be rotated and larger *two-thirds* sized fragment *chopped* again. Using this method, the whole lens can be divided into small pieces, simplifying further surgery.

The small-sized fragment that remains embedded on the phaco probe can be extracted immediately from the bag (by switching from phaco 1 to phaco 2 mode, or by using the dual-linear setting). It can then be further debulked and removed. This has the benefit of creating space within the bag to facilitate fragment rotation and extraction. If preferred, the whole lens can be divided into multiple small fragments that are each removed in turn.

12.4 Common Difficulties

Difficulty in *chopping* may be caused by one of the following situations:

12.4.1 Difficulty 1: Fear of Burying Phaco Tip into Nucleus

This can be avoided by creating a short, deep groove. The full depth of the groove, and the distal aspect of the trench wall, can then be visualised. This allows an oblique, downward grooving stroke to be performed (with confidence) aiming towards the distal trench wall and not into the base of the trench. Phacoemulsification-with minimal aspiration (phaco 1 sculpting setting or dual linear) can then be applied until the phaco tip sleeve rests on the lens nucleus (so that the phaco tip is completely buried).

12.4.2 Difficulty 2: Incomplete Nucleus Cleavage is Observed

Chopping does not require a great deal of force to split the nucleus. A common error for a beginner is pulling the phaco tip backwards. This causes it to release its hold on the nucleus and separation becomes more difficult.

To aid the cracking aspect, during the separation of the instruments the phaco tip can be rotated slightly anticlockwise. This can help separate the nucleus. If partial separation of the nucleus occurs, the split can be completed with a reverse-cracking technique.

If this is unsuccessful, it may be that the lens is too soft for the *chopping* technique and surgery will need to be completed using further grooving-and-cracking in a standard fashion.

12.4.3 Difficulty 3: The Fragment Does Not Remain Steady Whilst Trying to Insert the Chopper

Usually this is not a problem if no other fragments have been removed from the bag (e.g. when *chopping* a heminucleus). If more capsular bag space exists, the targeted segment can move for two reasons. The phaco tip may not be sufficiently buried within the targeted lens material to maintain its hold—this can be corrected by increasing the length of the exposed phaco tip by adjusting the phaco tip sleeve. Alternatively, the surgeon may apply aspiration during the chopper insertion and consider inserting the chopper closer to the embedded phaco tip.

12.4.4 Difficulty 4: Lens Nucleus Separation does Not Create a Clean Split but Leaves a Residual Tongue of Lens Material Jutting Out from One of the Fragments

Sometimes, a tongue of lens material may remain after a chopping attempt, jutting out from one of the separated lens fragments. This occurs if the chopper is placed too far from the phaco tip. Although the fragment can be removed with phacoemulsification, it will require a little more manipulation and space to extract as the fragment is more likely to interlock together with an adjacent fragment. To avoid this, and create a cleaner division, the chopper should be inserted closer to the phaco tip on the left-hand side. This ensures the chopper tip is fully inserted into the lens, creating a better separation (Figs. 12.4, 12.5, and 12.6).

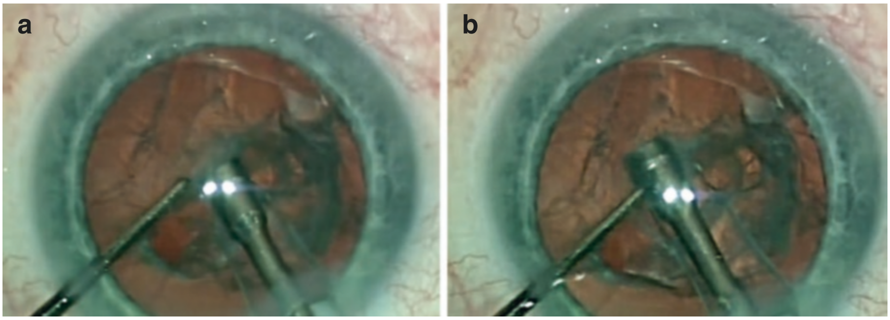

Fig. 12.4 Chopping difficulty explanation 4– part 1. (**a**) Good initial phaco probe positioning. (**b**) Phaco tip embedded into the heminucleus

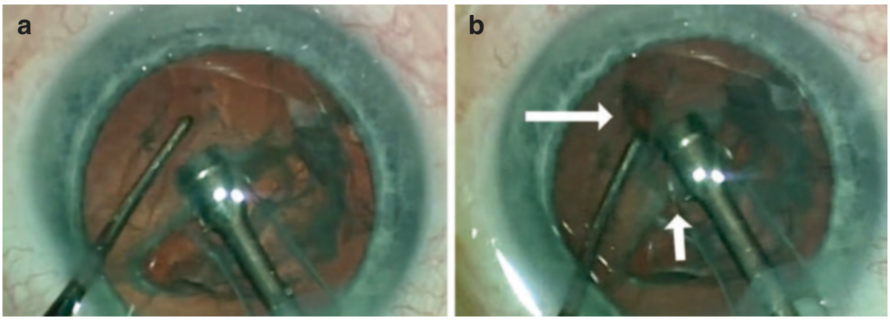

Fig. 12.5 Chopping difficulty explanation 4– part 2. (**a**) Chopper placement. The second instrument is placed distal to the phaco tip and is consequently not fully inserted into the lens nucleus. (**b**) As the instruments are separated, the peripheral part of the nucleus starts to split (*long arrow*) but the central area between the two halves remains attached

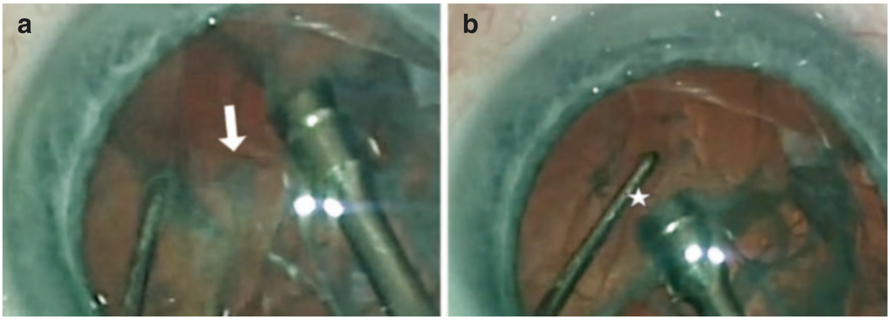

Fig. 12.6 Chopping difficulty explanation 4– part 3. (**a**) Magnified view. A wide separation is required to split the lens fragments. A tongue of lens material (*arrow*) juts out from the apex of the fragment. (**b**) Correct position to insert second instrument (*star*)

Box 12.1 Trainer Teaching Pearls

It is possible to make a transition from a grooving-and-cracking approach, to a mixed groove and chop approach. This technique works well for the majority of cases and does not require insertion of the second instrument under the capsule, making it a relatively stress-free supervised procedure. It is a simple technique to learn, and if initial attempts are unsuccessful then the novice surgeon can revert back to a standard technique.

It is recommend that the Trainer decides when a *chop* should be attempted. Novice surgeons may not be able to gauge the ideal lens consistency for initial attempts. Attempts on soft lenses should be avoided.

During phaco training, a practice step before *chopping* is to request that the phaco tip is not withdrawn on the last definite groove stroke before a crack is performed. This ensures the novice surgeon is used to keeping the phaco still, without pulling the phaco tip back. Novices will need to be told before the final groove stroke *not* to pull back, but instead keep the phaco tip in the groove and then crack the lens. They will also need reminding to rotate the phaco tip during the cracking attempt. Cracking should proceed smoothly since the phaco tip is held much deeper in the trench – this will facilitate the cracking process.

With practice, further refinements can be made to mimic the Trainer's own style of vertical or horizontal chop technique. These advanced techniques are not covered in the book, but are well described elsewhere Chang [5].

If the lens very dense and difficult to disassemble, the Trainer should take over, divide the lens in to small fragments and consider letting the Trainee deal with the remaining operation. This will build on confidence whilst ensuring patient safety is maintained. This way, the abilities of novices can be stretched without additional stress. Cases should not be *difficult; it should be* within the novice's ability to perform them well. A good rule of thumb is: if, after completing a case, the novice is in a good state to do the next case, *and* you as a Trainer would be happy immediately teach and supervise again, then training is proceeding well. If not, then it may be appropriate that the Trainee return to performing more suitable modular parts.

It is recommended that nucleus phacoemulsification instruction is continued for at least the first 40 whole cases. Instruction on the other aspects of surgery can be slowly withdrawn to allow more independent operating. This ensures overall operating time is keep to a minimum, good technique is promoted, and training has a less impact on service provision.

12.5 Summary

Once a novice surgeon familiar with a groove-and-crack technique, additional intermediate skills can be introduced to vary the method by which the lens nucleus is disassembled. The *easy chop* technique can be introduced in stages and attempted if suitable opportunities during surgery arise. If the lens fails to divide successfully, the Trainee can resort to a more standard technique and continue with the surgery. See Video 12.1.

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13 The Paracentesis Incision

The main corneal and side-port paracentesis incisions are the last modules for the Trainee to learn before combining all the cataract steps to perform whole case surgery. This chapter discusses the paracentesis incision whilst Chap. 14 deals with the main incision. Rear-ended modular training provides Trainees with the opportunity to observe many corneal side port paracentesis incisions before their first attempt. However, it is only natural to remain hesitant about holding a blade near the eye and creating an incision. The paracentesis step can be learnt as a separate step to the main incision providing the opportunity to quickly overcome this anxiety.

Alternatively, once the principles are understood, and several paracentesis attempts have been made, the two modules could be practised simultaneously.

13.1 The Paracentesis

The paracentesis is also referred to as the *side-port.* It is an incision made to accommodate a second instrument (the phacoemulsification probe is the primary instrument) or can be used to inject viscoelastic or other fluids into the eye. The side-port is usually created 60- to 90-degrees away from the main incision, however the location can vary according to the preference of the surgeon (*at this stage of rear-ended modular training, the Trainee will appreciate the standard paracentesis incision location usually made by their Trainer*).

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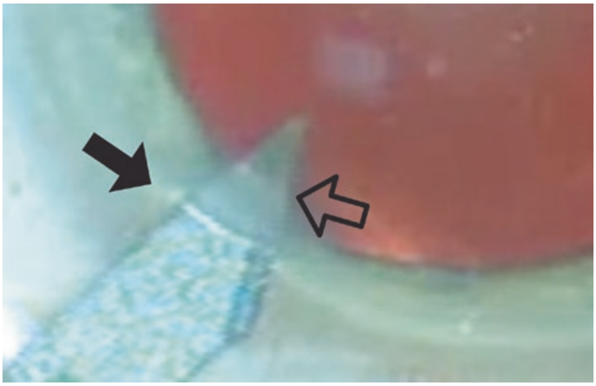


Fig. 13.1 Paracentesis side port. External ostium (*solid arrow*), internal ostium (*open arrow*)

The side-port wound is created by pushing a blade through the cornea to create an internal and external ostium (Fig. 13.1). The width of the second instrument, at the level of the shaft, dictates the diameter of the paracentesis. A small size allows the incision to self-seal, but it is common for surgeons to hydrate the side port wound at the end of surgery to ensure it does not leak in the immediate post operative period.

Trainees should aim to reproduce a consistent incision in every case, but commonly encounter problems as they are learning. These may include:

1. Paracentesis is too wide.
   This allows excessive fluid to escape from the anterior chamber during phaco surgery. It can also promote iris prolapse, anterior chamber shallowing and lens fragment trapping in the incision or the iridocorneal angle.
2. Paracentesis is too narrow.
   This can hinder complete insertion of the second instrument, or cause distortion of the corneal tissue during insertion.
3. Paracentesis is too long.
   A long side-port tunnel runs the risk of second instrument insertion difficulty into the anterior chamber and possible corneal distortion as the instrument is manipulated.
4. Paracentesis is too short.
   This can prevent self-sealing and increase the risk of pathogenic organisms gaining entry into the eye.

13.2 Instrumentation

Various blades can be chosen to make the side-port incision. These include: a diamond blade, a microvitreoretinal (MVR) blade, a 30-degree blade or even the disposable keratome used to construct the main incision. The choice of instrument

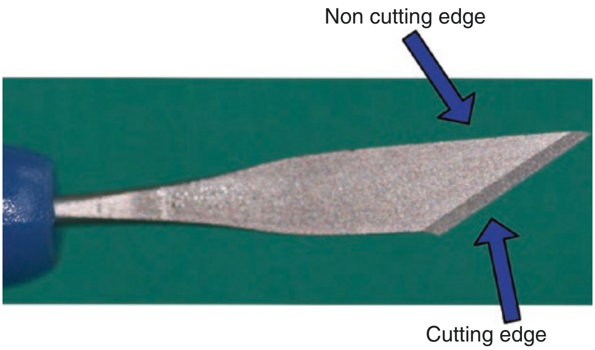


Fig. 13.2 The 30-degree blade

depends on surgeon preference and will be dictated by the Trainer. In order to illustrate the basic principles, a 30-degree tapered blade is used in the examples outlined in this chapter.

The tip of the blade has both cutting and non-cutting edges (Fig. 13.2). When creating the side port, the applied pressure should be directed towards the cutting edge. If the non-cutting surface is inadvertently used, the blade will cause rotation of the eye and require a lot of counter traction to keep the eye steady. As more force is applied, the direction of the applied pressure will eventually alter towards the cutting-edge surface. At this point the blade may rapidly cut through the cornea. Uncontrolled entry into the eye in this manner can cause an unintentional large, leaky wound. The blade may also damage the iris or lens capsule.

It is important to stop enlarging the side-port once the internal ostium reaches the correct size. The ability to judge the correct size will develop over time, but initially Trainers should advise when to stop cutting and remove the blade.

13.3 Stabilisation of the Eye

Stabilisation is required whilst making the side-port. This is achieved by using counter-traction on the opposite side of the cornea, or by holding the eye still with a fixation instrument, such as forceps. Forceps should not be used to grip the conjunctiva, nor should the forceps tip used to apply counter traction, as either manoeuvre may result focal conjunctival trauma or sub-conjunctival bleeding (Fig. 13.3). Instead, the long edge of the forceps should be placed over the globe to provide the necessary counter-traction. This distributes the pressure across the globe, along the length of the forceps, making it less likely to cause conjunctival trauma (Fig. 13.4).

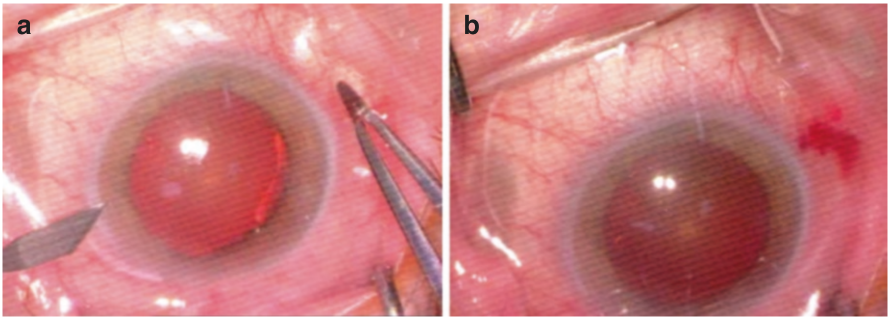
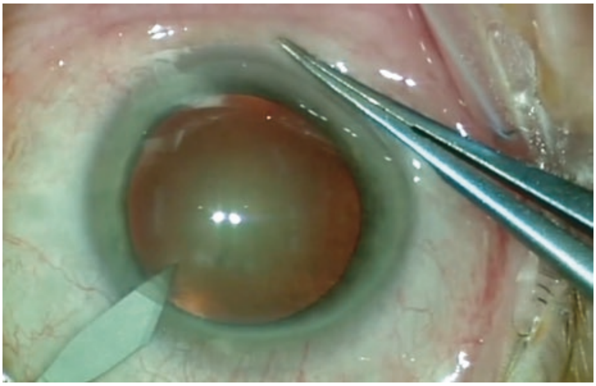


Fig. 13.3 Side port counter traction-incorrect placement of forceps. (**a**) Focal conjunctival pressure applied using forceps tip during paracentesis incision. (**b**) Focal pressure results in conjunctival bleed after removal of the forceps instrument

Fig. 13.4 Side port counter traction-correct placement of forceps. Recommended application of counter traction using the long edge of the forceps



13.4 Step-by-Step Paracentesis Creation

1. Position the 30-degree blade in the left hand and forceps in the right; the blade next to the incision site and the closed forceps (long edge) near the other side of the cornea opposite the intended side-port incision site (Fig. 13.5a).
2. Place the tip of the 30-degree blade on the corneal surface and immediately rest the long edge of the forceps on the globe, opposite the side port incision site (Fig. 13.5b).
3. Insert the blade, aiming the tip centrally. The blade angle should be but adjusted so that the blade tip does not cut the iris or capsule on entry. Apply pressure on the cutting edge whilst aiming for the centre of the anterior chamber. The blade should be held flat during entry. Any rotation during insertion will cause an oblique incision. Avoid depressing the limbus (seen as corneal contour distortion).
4. Stop when the correct incision size is obtained (roughly one third of the length of the cutting surface). At this stage, Trainees may unintentionally depress the limbus with the flat under-surface of the blade. Before retracting and removing the blade, lift the blade up and re-establish the normal corneal appearance (*no*

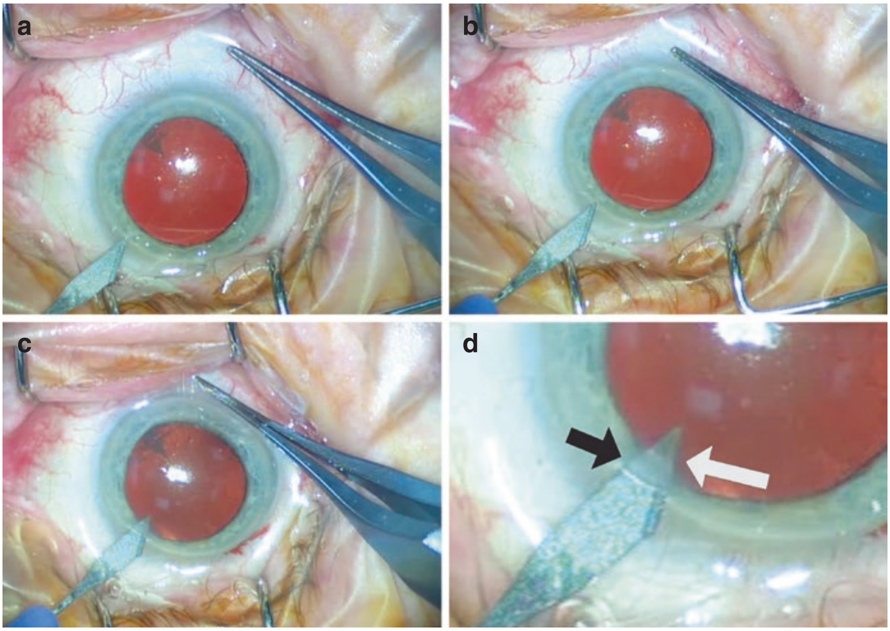


Fig. 13.5 (**a**–**d**) Side port creation. (**a**) Forceps are held ready, hovering above ideal position for counter traction opposite chosen site for side port. Blade tip just starts to embed into the cornea. (**b**) Counter traction immediately applied. (**c**) Paracentesis created. (**d**) Magnified view of blade position before removal. The blade has been lifted up to avoid distorting cornea. No corneal stress lines are visible. Clear view of internal ostium (*white arrow*) and external (*black arrow*) ostium

corneal stress lines at the incision site) (Fig. 13.5c, d). This reduces the pressure applied to the posterior lip of the wound and reduces risk of leakage.

5. Remove the forceps and then withdraw the blade.
6. Ensure the blade is safely handed back to the scrub assistant.

Box 13.1 Surgical Tip

- The blade must be carefully observed as it enters the anterior chamber. This internal ostium landmark will increase in size as the blade is inserted, allowing a more precise assessment of the paracentesis size.
- Trainees should become practiced at embedding the blade tip on the cornea before placing the forceps. This skill becomes useful when operating from a superior position. If the lid margin covers the limbus, the forceps can be used to gently move the lid out of the way. This can improve the view of the potential paracentesis site. The blade can then be placed on the cornea at the correct location and the forceps immediately repositioned to apply counter traction.

- The blade should be lifted up (to decrease any corneal distortion) as it is removed from the eye. The surgeon should avoid a *stroking* movement as the blade is removed. *Stroking* occurs when the surgeon inadvertently makes a downward movement when withdrawing the blade. This can cause unintentional downward pressure on the limbus resulting in anterior chamber collapse (as fluid escapes from the side port). It can also cause tissue trauma if the blade edge or tip catches the conjunctiva.
- Appreciating the resistance of corneal tissue during the creation of the paracentesis wound is a tactile skill learned from practical experience. Nevertheless, simulation practice is recommended. Trainees are advised to practice the sequence of placing the blade then the forceps on the eye; as well as the reverse sequence of removing the forceps then the blade.

Box 13.2 Trainer Teaching Pearls

Creation of the corneal section and side-port should not be taught at the start of modular training, but rather left as one of the last things to do. This reduces the likelihood that problems associated with a poorly constructed wound will be compounded throughout the operation. However, depending on the ability of the Trainee, side-port and main incisions may be taught simultaneously.

Simulation practice of the paracentesis and main incision is recommended before attempting an incision on a patient (described in Chap. 14).

For side-port instruction, the Trainer's aim is to ensure novices can make a controlled incision that does not collapse the anterior chamber. It is possible to re-inflate the chamber with viscoelastic after the paracentesis, but it is recommended that Trainees learn to maintain the anterior chamber by learning a technique that minimises fluid loss during the paracentesis incision.

Slow and deliberate movements are recommended at the start of training so that novices have the opportunity to gain understanding and control. It also allows the Trainer to observe the actions of the novice and the position of the blade. Instruction can be given on the angle of approach, any blade rotation correction, how to apply pressure to the cutting edge, and appreciation of the internal ostium size.

Common errors in technique requiring correction include:

- Tilting the blade during insertion into the cornea. This results in an oblique paracentesis cut. This incision may cut into the conjunctiva, causing a bleed. Alternatively, if one end is very superficial and near the margin of the corneal epithelium, the incision may extend during surgery.
- Failure to apply pressure to the cutting edge of the blade (i.e. using the non-cutting edge). This may result in increased force being required, or the

blade not being fully inserted (Trainees may feel as if they have been given a blunt blade to use).

- Failure to direct the cutting edge of the blade towards the centre of the eye. Additional force will be required to create the paracentesis if the cutting edge is not directed correctly. It may be useful to imagine a line drawn along the cutting edge of the blade to the centre of the eye.

The side port blade is incredibly sharp. Novice trainees should be advised to hand back blades *handle first* to the scrub assistant. This is an important habit to promote as novice surgeons are often unable to look up from the microscope – leading them to blindly hand back blades to the instrument trolley.

13.5 Summary

Paracentesis creation can be learnt in deliberate steps that require the surgeon to develop control of the instruments used. This will enable the Trainee to consistently produce an ideally sized, well-placed incision in a controlled fashion during every case. See Video 13.1.

The Main Corneal Incision

14

Over time, experienced surgeons will develop a preferred technique for creating the corneal wound. This will automatically take account of several factors: available access to the corneal surface, corneal astigmatism, anterior chamber depth, ocular movement and ocular co-pathologies.

During rear-ended modular training, novice surgeons have the opportunity to observe many corneal incisions. Despite this, novice surgeons commonly hesitate when performing the incision themselves. This frequently occurs if: the patient's eye is moving slightly, the chosen site is obscured by the lids, or if an unfamiliar incision site is chosen.

This chapter deals with the fundamentals of making the main incision. It assumes that Trainees have completed all of the previous modules of cataract surgery training.

14.1 Fundamentals

14.1.1 Corneal Orientation

The choice of where to place the main corneal incision varies between surgeons. Some surgeons prefer to always operate from the temporal aspect, others from the superior aspect. Some surgeons vary the site according to the corneal topography – by adjusting the incision in relation to the greatest degree of astigmatism (*on-axis surgery*) the amount of postoperative corneal astigmatism may be decreased.

For novice surgeons, the decision where to place the main wound site is usually dictated by their supervising surgeon. Novices may be instructed to place the incision in the *temporal* or *superior* positions. Alternatively, instructions may include the number of degrees at which the incision should be placed. Convention dictates the horizontal meridian (when looking down the microscope from the superior

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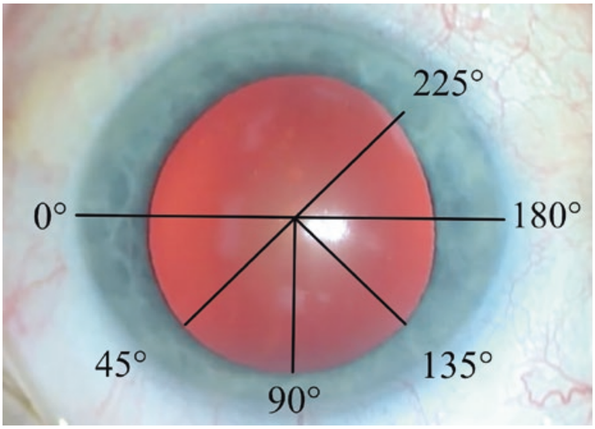
Fig. 14.1 Corneal orientation (*right* or *left* eye) given as degrees of a circle as if viewing from a superior operating position looking down the microscope



position) is labelled as the 0 to 180 degree line (Fig. 14.1). For left eye temporal incisions the cut is made at about 0°, and for a right eye the temporal incision is made at about 180°.

14.1.2 The Keratome

The choice of blade used to make the corneal incision will vary between ophthalmology units. Whilst some will prefer reusable diamond knives, the more commonly used disposable keratome is described in this chapter.

The keratome is angled at about 45-degrees. The tip and sharp side edges are used to cut the cornea. The distance between the widest points defines the size of the keratome. These two points will be referred to as the *shoulders* of the keratome blade. It is important to appreciate that, once past the shoulders of the cutting edge, the remaining edge is blunt and cannot be used to enlarge or cut the corneal section (Fig. 14.2).

14.2 Keratome Movements

14.2.1 Tip Up/Heel Down Verses Tip Down/Heel Up

A variety of movements are required to create a stepped, self-sealing corneal incision. Additional movements may be required to help overcome the resistance of the corneal stroma whilst entering the eye with the blade. It is important to appreciate the various movements and various positions the keratome may need to make.

The cutting direction of the keratome can be altered by pivoting the keratome on the vertical axis into three positions (Fig. 14.3):

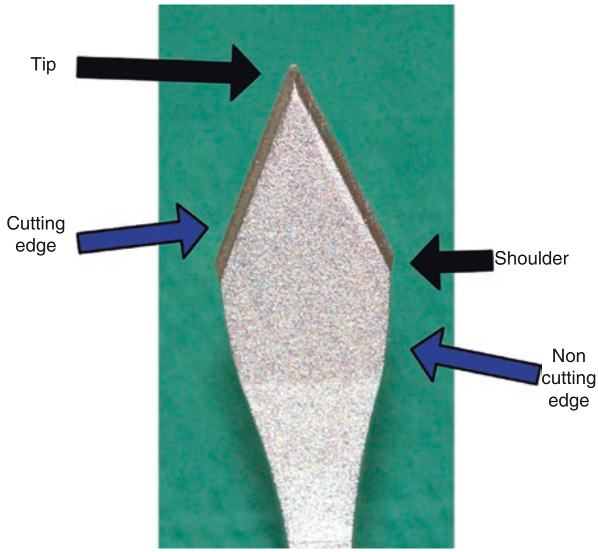


Fig. 14.2 Disposable steel keratome

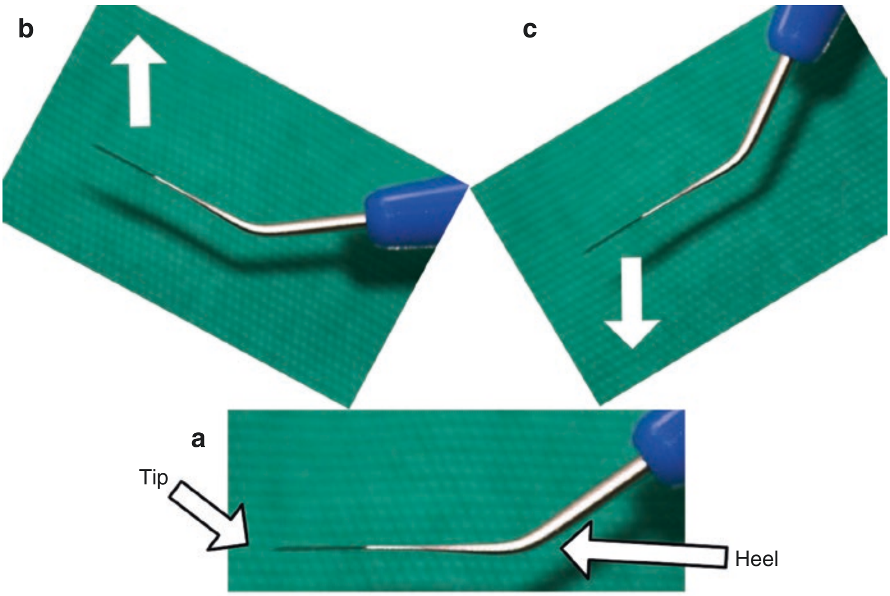


Fig. 14.3 Keratome positions as seen in side view. (**a**) Flat, position. (**b**) Tip up, heel down. (**c**) Tip down, heel up

1. The keratome blade can be kept flat.
2. The keratome can be tilted *heel down* causing the tip to point upwards.
3. The keratome can be tilted *heel up* causing the tip to point downwards.

14.2.2 Keratome 'Snake-Like' Movement

It is common for novice surgeons to find the keratome occasionally sticking whilst trying to cut through the corneal stroma. Additional force may be needed to overcome the resistance, and if force is applied in an uncontrolled fashion it can lead to rapid keratome entry into the anterior chamber. To avoid this, counter-traction may be applied by holding the side port (if already made) or using a fixation device. It is also possible to perform a snake-like cutting action as a means of maintaining control of the keratome.

The snake-like movement is performed directing the tip from one side of the wound to the other. Each small change of direction will make a cut, gradually enlarging the internal ostium. The sideward movement encourages the cutting edges of the keratome to enlarge one lateral edge of the wound and then the other. As the resistance is overcome, and the internal ostium is widened, a controlled, gradual forward motion of the keratome can be achieved.

This technique is a useful is a useful one for novices to learn if a fixation device is not routinely used. Appreciation of when to use a snake-like keratome movement is useful as it can avoid the necessity of gripping the side port or any part of the ocular surface (Fig. 14.4).

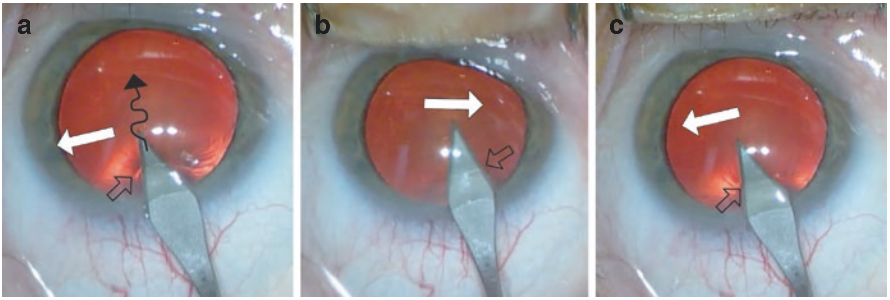


Fig. 14.4 Keratome 'snake-like' movement. Keratome encounters corneal resistance and struggles to pass through the corneal tissue. (**a**–**c**) Pressure is applied to the cutting edge on one side of the blade (*open arrow*) by pivoting the blade tip to one side (*arrow*) of the incision and then the other, following a snake-like movement (*curvy-linear arrow*) as the keratome blade is inserted. The successive small cutting actions enlarge the internal ostium

Box 14.1 Surgical Tip

- Novice surgeons may encounter several problems during the initial learning phase:
  1. Difficulty making continuous incision movements.
  2. Getting *stuck* in the corneal stroma (with the keratome tip failing to breach the endothelium).
  3. Shallowing of the anterior chamber whilst making the incision.
  4. Pranging of the capsule with the keratome blade.

Learning a controlled, stepped incision takes practice and confidence. Using rear-ended training, Trainees should be able to continue with the surgery even with a wound that is not perfect.

14.3 Obtaining an Adequate View

Making an incision on the temporal aspect of the cornea allows unhindered access to the intended temporal incision site, as the lids to not obstruct the limbal view (Fig. 14.5).

If the intended corneal incision site is more superior, it may be obscured by the upper lid, even after speculum insertion. This can be due to patient factors, for example: a tight palpebral aperture, a strong Bell's phenomenon, or the patient trying to squeeze both eyes shut. Although a view can be obtained by asking the patient to look down, or by manually pulling the eye down, this requires the eye to move out of the primary position. Also, conjunctival trauma may result from gripping the eye. Alternatively, the following manoeuvres can be tried in any order to gain a better view of the incision site:

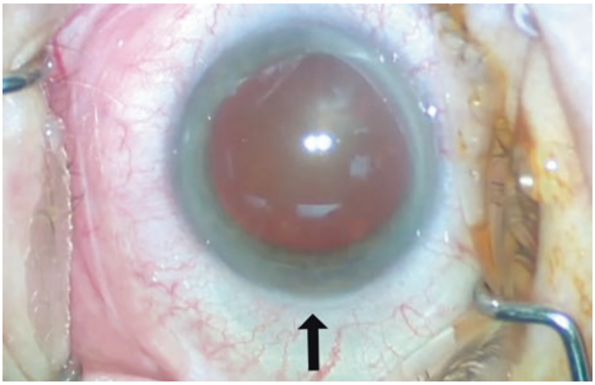


Fig. 14.5 Temporal based view of surgical field of left eye. The temporal limbus (*arrow*) is not obstructed by the lid margins

1. Inspect the drape and check to see if it has been adequately cut.

   This should not be an issue in rear-ended training as normally the Trainer would have performed this part.

2. Ask the patient to open *both* eyes. This simple request may help gain an adequate view.

   Giving a direct instruction is recommended, as opposed to, for example, asking the patient to relax.

3. Using closed forceps (held in the non-dominant hand) place the opposed tips over the draped lid margin and retract the upper lid (Fig. 14.6). It is helpful to have the have the blade ready to start the incision when an adequate view of the intended incision site is obtained. The major advantage of this technique is that the globe is maintained in the primary position. The surgeon is not required to either manually rotate the globe downwards, or ask the patient to look down.

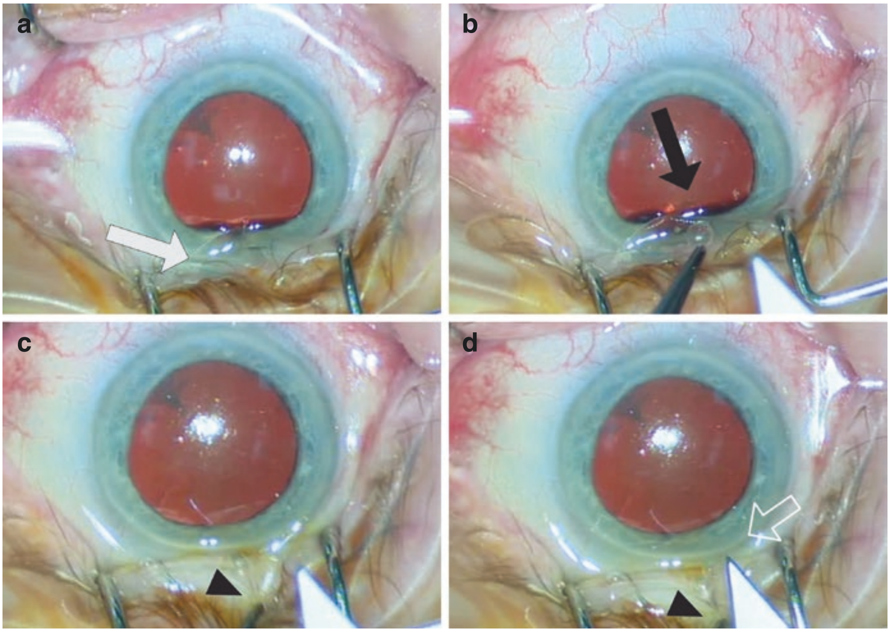


Fig. 14.6 Obtaining an improved view of the superior corneal incision site. (**a**) Superior limbus is obscured by the draped lid (*arrow*). (**b**) Forceps are positioned on the draped lid with the tip of the keratome blade poised ready above the intended incision site. Direction of intended retraction (*arrow*). (**c**) Forceps (*arrowhead*) are used to retract upper lid. (**d**) Limbus view obtained and keratome tip (*open arrow*) begins incision. Forceps just visible (*arrow head*)

14.4 The Clear Cornea Incision

Three types of corneal incision are possible during phacoemulsification surgery: clear cornea, scleral tunnel or limbal. The most common of these is a clear cornea incision, and this is the incision type focused on in this chapter. The clear cornea incision has evolved over time in response to the ability to insert a foldable intraocular lens implant through a small corneal incision.

A clear corneal incision has several advantages:

- Cautery is not required as little or no bleeding occurs.
- At the conclusion of surgery there is a sutureless, self-sealing wound.
- There is minimal astigmatic effect.
- Post-operative recovery is rapid.

The aim is to consistently construct good, corneal incisions in every case. As the ideal wound size is proportional to the diameter of the phaco probe used, an appropriately sized blade will have to be selected for each incision.

For Trainees, wound construction can pose some common problems. These issues are similar to the problems encountered with paracentesis creation (see Chap. 13) but in summary include:

1. A wound that is too wide.
2. A wound that is too narrow.
3. A wound that is too long.
4. A wound that is too short.

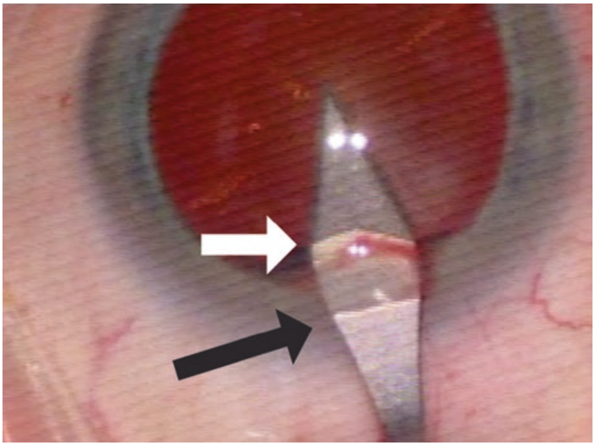
A clear corneal incision is made as close to the limbus as possible. It passes through clear cornea (to avoid bleeding) without disturbing the overlying conjunctiva (as this can cause conjunctiva ballooning during surgery). During insertion, it is important to try and prevent anterior chamber collapse, whilst avoiding trauma to the iris or lens as the blade is inserted into the eye.

A controlled insertion of a keratome blade through the cornea should form a square or rectangle-shaped, self-sealing wound (*the base length governed by the maximum width of the keratome*). This is needed to form an internal and external ostium (Fig. 14.7). The internal ostium is an important landmark to recognise as the keratome is inserted.

Corneal wounds may be created as a one-, two- or three-step incisions (Fig. 14.8). Surgeons will have their own preference for a particular incision: uni-planar, bi-planar or tri-planar. For the novice surgeon, their Trainer will dictate this decision.

For a one-step incision, the blade is inserted into the eye slightly tip up from the horizontal plane and then directed posteriorly in a ‘dimple down’ technique to cut through Descemets membrane. The uni-planar direction is then re established to continue the cut in a straight-line configuration. A one-step incision is generally not performed now.

Fig. 14.7 Corneal incision. Internal ostium (*short arrow*), external ostium (*long arrow*)



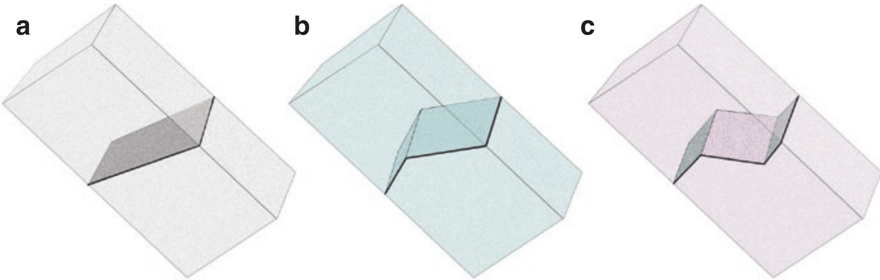


Fig. 14.8 Clear corneal incision types in side profile. (**a**) One step uni-planar. (**b**) Two step bi-planar. (**c**) Three step tri-planar

For a two-step incision, the surgeon is required to manipulate the direction of keratome blade whilst traversing the dome shaped cornea. The initial cut follows the upward slope of the cornea before changing direction cutting down through Descemets layer into the anterior chamber. The stepped corneal incision promotes self-sealing and does not usually require a suture at the end of surgery.

A three-step differs from the two-step by performing an addition vertical corneal cut as the first step of the incision. The surgeon will then proceed to complete the second step making an upward linear corneal stromal cut, before directing the blade downwards in a similar fashion to the two-step incision (Fig. 14.9).

The resistance of the corneal tissue during the creation of the wound is a tactile sensation that is acquired through experience. Simulation practice is recommended however, as even a 15-min practice is sufficient to allow to the Trainee to appreciate the various keratome movements and become familiar with Trainer instructions required during surgery. A thin, 2 mm layer of clear flexible Perspex is ideal for simulation practice. Artificial eye models or animal eyes can also be used (Fig. 14.10).

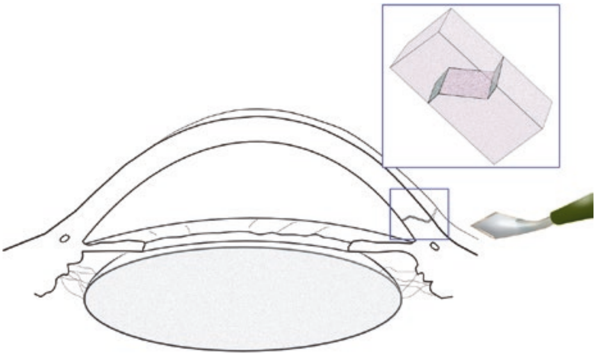


Fig. 14.9 Corneal dome: 3-step incision. Cross section diagram of main corneal incision. Corneal is dome shaped. Incision changes direction to accommodate 3-step incision. Magnified view of incision (insert)

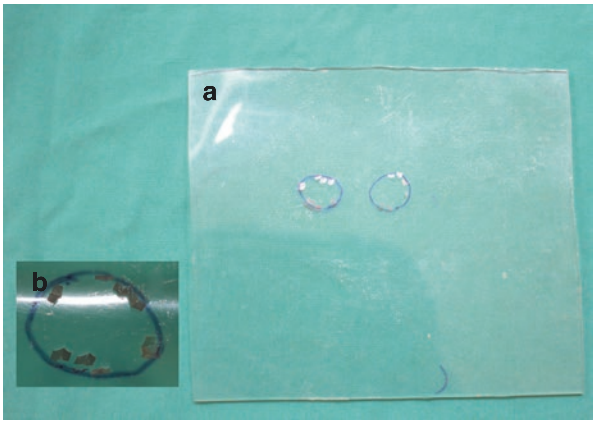


Fig. 14.10 Simulation material. (**a**) Sheet of Perspex used for corneal incision simulation. (**b**) Magnified view of Perspex surface with drawn circle containing multiple incision attempts

14.5 The Clear Corneal Main Incision

A step-by-step example of creating the main incision using a 30-degree blade, keratome and forceps (without using counter traction for the main incision site) is as follows:

14.5.1 First Step (Fig. 14.11)

Place the closed forceps on the upper lid and move back to improve the view. Have the 30-degree blade ready.

Use a 30-degree blade to score the cornea along the chosen site (first step) to the desired length to match the keratome blade diameter used*. Novice surgeons should avoid holding the blade completely vertically as the tip will usually ruffle the epithelium without cutting underlying stroma. The cutting edge of the blade should make a cut into the superficial corneal stroma, *(if the edges of the wound split during the surgery then the initial incision needs to be deeper in future cases)*. A common mistake is for the applied pressure of the blade to increase as the blade is moved

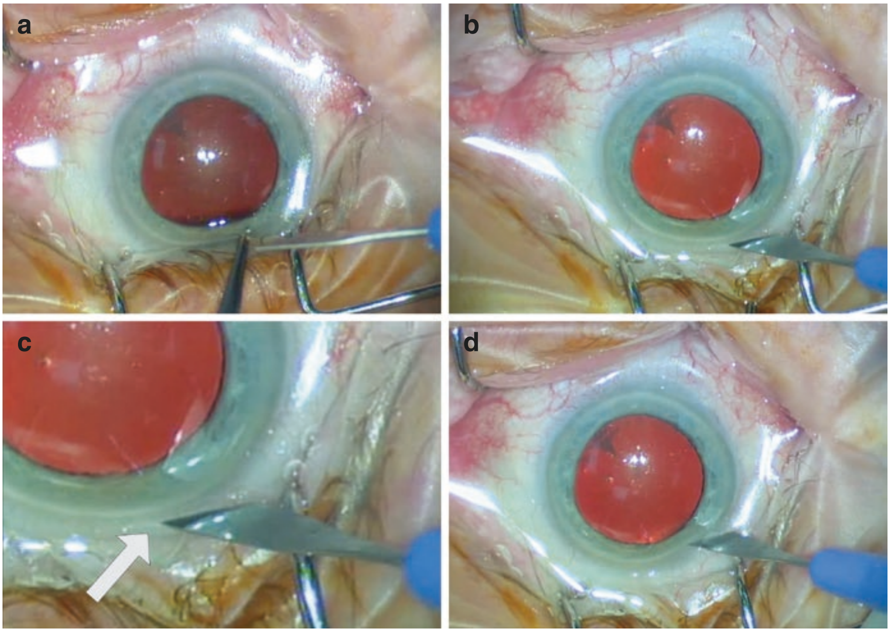


Fig. 14.11 Main incision first step. (**a**) Forceps placed on upper lid to facilitate view of the limbus, by moving upper lid out of the way. 30-degree blade is held in close proximity ready to be used. (**b**) 30-degree blade placed onto corneal surface. (**c**) Magnified view of blade position. Cutting surface of blade edge (*arrow*) is used in preference to just the tip of the blade. (**d**) Initial first step completed.

across the cornea which can give rise to an oblique first step. Instead, as the cornea is scored, the applied blade pressure can be eased off towards the end of the cut.

*If the Trainer prefers, the use of a 30-degree blade can omitted and the keratome tip inserted into the cornea with the heel immediately lowered for a tip-up position ready for step two. In this scenario the keratome can also be used for the paracentesis incision, however care is needed not to make the paracentesis too wide. During initial training, if a 30-degree blade is used for this initial step it can also be immediately used to create the paracentesis before moving onto the second step with a keratome blade.

Box 14.2 Surgical Tip

- Novice surgeons can worry about the eye moving. In practice, pausing with the instrument poised and ready, allows the eye to stop moving. Once the blade is placed on the eye, the first step can be made with ease and completed without any sudden eye movement. If the eye moves between surgical steps (usually as a response to wetting drops), pause for a moment and wait until the eye becomes still before proceeding. It is only necessary for the eye to be still *during* a surgical step. It does not matter if it moves between steps.

- With practice, it is relatively straightforward to make the corneal incision without holding the globe. Forceps can be rested onto the upper lid and maintained in this position whilst the incision is made. If required, the forceps can be easily repositioned on the opposite side of the limbus or used to hold the side port to provide counter-resistance. Furthermore, if required the forceps can be palmed into the non-dominant, freeing the fingers to support the keratome during its insertion into the eye.

14.5.2 Second Step-Part A

Rest the closed forceps on the upper lid and retract the lid again, if needed, to gain an ideal view of incision site. Place the keratome tip centrally, within the lip of the scored incision, and immediately lower the heel into a tip up position (Fig. 14.12).

The second step requires the keratome to cut upwards into the stroma, following the sloped direction of the domed shaped cornea. Push the blade into the stroma for about one third of the distance between the tip and the horizontal line connecting the keratome shoulders. The length is approximately 1.5 mm (Fig. 14.13).

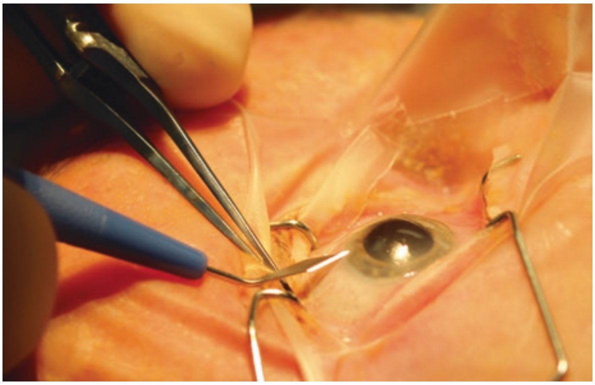


Fig. 14.12 Side profile of keratome position: second step part A. Keratome tip is placed into the corneal and held heel down, tip up to direct the blade upward into the corneal stroma. The forceps are used to help retract the upper lid

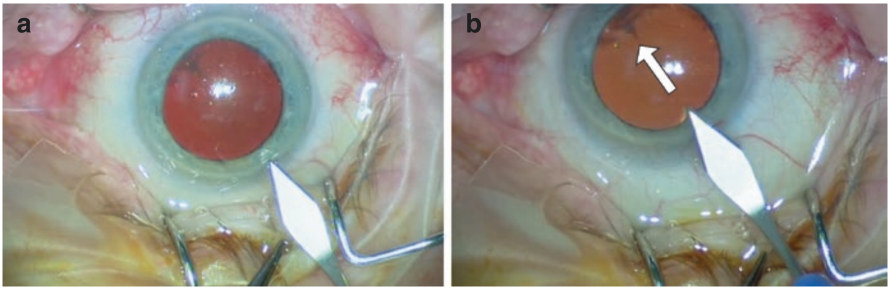


Fig. 14.13 Main incision second step-part A. (**a**) Forceps rest on upper lid and retract lid out of the way. Keratome blade is inserted into initial cut. (**b**) Tip up, heel down angulation of keratome. No corneal depression stress lines visible, as downward pressure is not exerted. Stroma insertion follows direction of upward slope of cornea (*arrow*)

14.5.3 Second Step-Part B

Once the stromal cut has been made, the keratome is repositioned in a tip-down, heel-up orientation to flatten the keratome blade (Fig. 14.14). The surface of cornea will now form stress lines radiating from the tip of the keratome (Fig. 14.15)

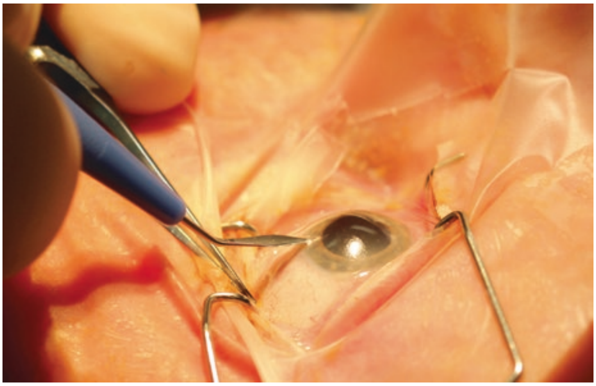


Fig. 14.14 Side profile of keratome position: second step part B. Keratome tip is repositioned into tip down, heel up position. The forceps rest on the upper lid

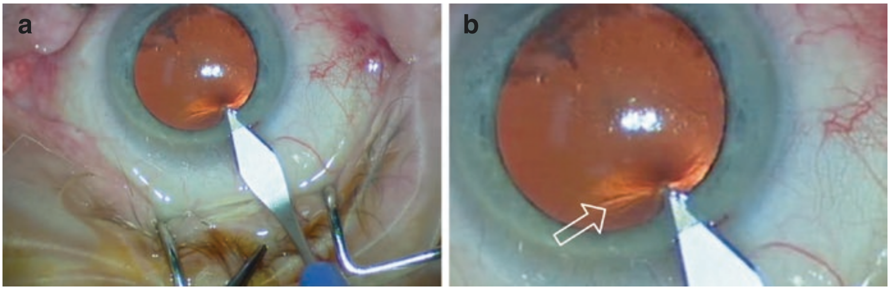


Fig. 14.15 Main incision second step-part B. (**a**) Tip down, heel up angulation to flatten keratome. (**b**) Magnified view end of step two. Corneal stress lines radiate from tip of keratome (*open arrow*)

Box 14.3 Surgical Tip

- A good way to estimate the angle of approach is to look at the gap between the blade and the conjunctival surface. Only a minimal gap should exist.
- Try not to depress the cornea whilst inserting the blade, as it can cause the eye to roll downwards slightly. Instead, lift the keratome slightly as if taking the weight of the cornea onto the keratome as it is pushed into the stroma. If required re-position the microscope.

14.5.4 Third Step

The keratome should be flat (*parallel to the iris*), or pointing slightly tip-down, as it is pushed through the endothelium. Once the tip has breached the endothelium, ensure the keratome is lifted up slightly, as if the keratome carries the weight of the cornea. This will make the cornea take on a near-normal contour close to the incision site (Fig. 14.16). The blade can then be fully inserted through the cornea so that both shoulders pass through the internal ostium (Fig. 14.17). It is at this point that the corneal resistance is fully overcome and rapid forward movement of the keratome can occur. It is possible to predict when this moment will occur by observing the position of the keratome's shoulders and the internal ostium. Thus, it is possible to be ready to halt any sudden forward movement of the blade.

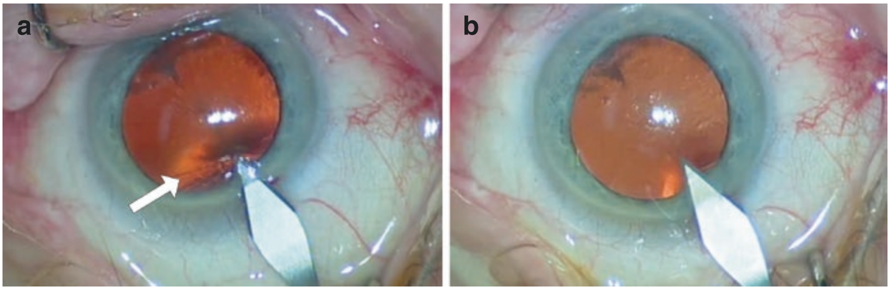


Fig. 14.16 Main incision third step: part A. (**a**) Keratome is pushed forward parallel to the iris until the tip breaches the endothelium. Corneal stress lines (*arrow*) are present appear as the keratome is held in a tip down position. The eye has rotated inferiorly. (**b**) Downward pressure on the globe is released by lifting the keratome up as the corneal endothelium is breached. Corneal stress lines disappear and eye assumes a more central position

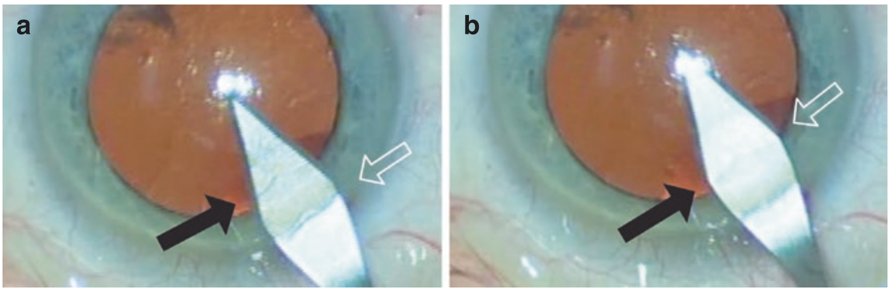


Fig. 14.17 Main incision third step: part B. (**a**) Widest point between the shoulders of the keratome (*open arrow*) have not passed internal ostium (*black arrow*) and further insertion of the keratome is required. (**b**) Widest point between the shoulders of the keratome (*open arrow*) is now past the internal ostium (*black arrow*)

If the blade meets resistance and cannot be pushed forward, a snake-like keratome movement can be used, cutting one side of the incision wall and then the other.

Box 14.4 Surgical Tip

- Trainees are advised to lift the cornea to maintain a normal contour appearance during the incision. This slight change in technique can make a large difference in maintaining the control of the blade as it is pushed through the corneal stroma.

14.5.5 Widening the Main Incision

It is not usually necessary to widen the main corneal section provided the correct sized blade is used (i.e. one that results in an incision that accommodates the phaco probe). However, both the internal and external ostium aspects of the wound need to be enlarged if past surgical experience suggests that the phaco probe insertion is likely to be too tight. It is then possible to decide whether to widen the incision in one or both directions.

The technique for widening is as follows (Fig. 14.18). Following keratome insertion, the non-cutting edge of the keratome remains in the wound with the cutting edge sloping away from the wound. Remembering not to depress the posterior lip of the wound, the keratome is withdrawn slightly and pivoted so that a cutting edge of the blade abuts the lateral wall within the incision. Both internal and external wounds can be enlarged simultaneously by applying pressure on the wall and cutting as the blade is partially withdrawn. If additional widening on the other side is needed the keratome can be pivoted and the process repeated.

Box 14.5 Surgical Tip

- The keratome should remain flat and not be obliquely tilted within the wound. Any rotation can cause an oblique external incision edge, which can extend into a dog-ear corneal tear in the roof of the incision. This is likely to occur as the wound is stretched by the either the phaco or irrigation-aspiration probes, or during the lens insertion. Novice surgeons should refrain from withdrawing the blade completely during a widening step.
- If it is only part of the internal or external ostium that needs widening, rather than holding the cutting edge parallel to the side of the incision, the keratome tip is pivoted within the incision to only allow a proportion of the cutting edge to rest on the targeted area before it is enlarged.

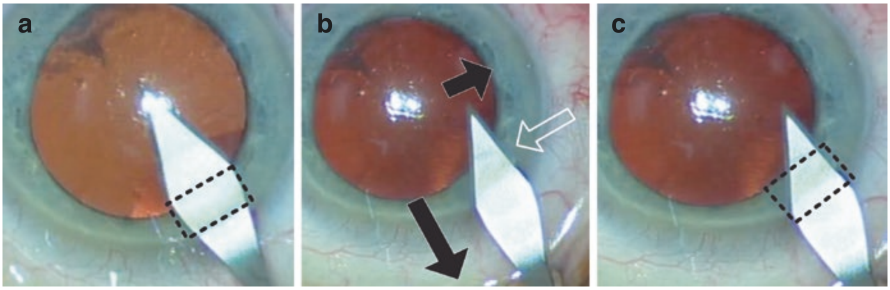


Fig. 14.18 Widening the main incision. (**a**) The non-cutting keratome blade edges are in contact with the lateral edges of the main wound (*dotted box*). (**b**) Keratome is pivoted laterally (*solid short arrow*) and withdrawn (*solid long arrow*) to approximate the cutting edge of the blade against the wound (*open arrow*). (**c**) Position of cutting edge parallel to lateral edge of main wound (*dotted box*) before wound enlarged

14.5.6 Removing the Keratome

To remove the keratome, ensure that the tip is returned to the midline of the wound (this prevents the keratome's sharp cutting edges further incising the wound edges on removal). Ensure the keratome is not pressing on the posterior wound lip. Instead, re-establish a normal corneal contour by maintaining the slight blade lift (as if taking the weight of the cornea on the keratome). Withdraw the blade; ensuring the blade does not *stroke* the eye. Stroking of the eye occurs when the blade is withdrawn in a downward motion. This can press on the wound and make the wound leak, or cause conjunctival trauma. Ensure the blade is handed back safely.

Box 14.6 Trainer Teaching Pearls

It is recommended that the corneal section is not taught at the start of modular training, but rather left as one of the last things to do. This reduces the likelihood of compounding problems throughout the operation that began with a poorly constructed wound. Novice trainees with minimal bimanual experience can quickly lose confidence in their ability if they feel responsible for creating a wound that causes surgical difficulty for the Trainer. By leaving the corneal section as one of the last things attempted in rear-ended modular training program novice surgeons will have gained the necessary skills required for this part of the procedure.

Simulation practice is recommended before attempting a patient incision attempt is done. Five or six simulation incision attempts are usually sufficient to introduce the novice to the underlying concepts at this stage of rear-ended modular surgery. It also provides an opportunity for the Trainer to highlight their preferred instruction terminology for the incision. Suggested concepts for each simulation attempt are as follows:

Attempt 1: Insertion allows the feel of resistance to the blade (without varying the keratome position horizontally or vertically).

Attempt 2: Practise tip-up position, changing to tip-down position during insertion.

Attempt 3: The keratome is lifted up as it is pushed through the pseudo stroma (effectively taking the pressure off the posterior lip of the wound).

Attempt 4: Snake-like keratome movements are practised, to enlarge and penetrate the wound.

Attempt 5: Blade removal practice requires the keratome is returned to the centre of the wound before removal, coupled with instruction to lift the keratome up slightly. This is to prevent depression of the posterior lip of the wound as the blade is fully removed.

The keratome is incredibly sharp, and novice trainees need to be advised to hand back blades with the handle pointing towards the scrub assistant.

Novices should take a deliberate, methodical approach to creating the wound. Speed will develop as the movements become familiar. Although it is rare for an eye to suddenly move when impaled by the keratome, the Trainer may feel more comfortable if the novice holds the eye or uses counter-traction.

Trainees will be unsure of when to alter direction during a stepped incision. Trainers should provide ample instruction until the novice is able to gauge the length of the incision.

Many trainees need to be reminded to lift the keratome up (i.e. not depress the posterior lip of the wound) and ensure the keratome is centred before it is removed. If a novice tends to cause conjunctival bleeding on removing the blade they should review any recordings of their surgery to see if they tend to stroke the eye on removing the keratome.

During initial training, novices may catch the capsule with the keratome tip. When this first occurs, rather than getting the novice to complete the capsulorhexis, it is recommended the Trainer does this part and then hands back over to the Trainee. The method of how to rectify and convert a capsule tear into a rhexis can be demonstrated. The novice will be made aware of what has occurred and feedback can be provided at the end of surgery.

Anterior chamber collapse is usually secondary to depression of the posterior lip of the wound during the incision. Correction of any inadvertent posterior pressure may help prevent this. If needed, the anterior chamber can be inflated with viscoelastic via the side port before the main incision attempt.

If a novice finds that the main corneal incision is tight and needs to be enlarged (e.g. it is hard to perform a pseudo-groove after the phaco probe is inserted), it is recommended that a small amount of viscoelastic is injected into the eye before the keratome is reinserted. This will inflate the eye and push back any iris, reducing the risk of the keratome tip catching anything during the second insertion. When inserting the keratome again, a side-to-side movement is recommended, as it opens the wound and reduces the risk of creating a false passage.

14.6 Summary

The corneal incision can be learnt in deliberate steps that require the surgeon to develop control of the instruments used. Simulation practice is recommended to help appreciate the change in blade direction required as the 3-step incision is made. Once the corneal incision is made by the Trainee, given previous completion of rear-ended training, progression to selected whole cataract phacoemulsification surgery is expected. See Video 13.1.

15 Essential Preparation: Draping, Safety and Surgeon Comfort

Endopthalmitis rates after cataract surgery are thankfully low, with worldwide reported rates currently between 0.03 and 0.2% [1]. The use of 5% povidone–iodine solution instilled pre-operatively into the lower fornix, and intracameral antibiotics instilled at the end of surgery, have contributed to this low incidence. Despite this, it remains essential to minimise any peri-operative exposure to microbes. Meticulous preparation of the ocular surgical field to ensure adequate antisepsis of the eye and surrounding periocular area will inhibit the patient's own ocular flora. And good hand-washing, and aseptic technique when donning the surgical gown and sterile gloves, will reduce the likelihood of introducing external pathogenic organisms during surgery.

Safe preparation for surgery is also a crucial part of the modern operating theatre. The use of "pre-flight" checklists helps ensure that theatre staff are prepared (e.g. right patient, right operation, right equipment); that they all have the same expectations (e.g. "this case may be more technically challenging because…") to enable everyone to act as a team. Explaining in advance which aspects of surgery will be devolved to the Trainee forms an important aspect of a pre-operative briefing.

With rear-ended modular training, it is recommended that the Trainer takes responsibility for the safety aspect of surgery right up until the point where the Trainee is nearly able to work independently.

This chapter covers those essential aspects of surgery that a Trainee will have to be competent at in order to work solo. This includes: draping and sterility, awareness of safety checks, and ensuring the surgeon is always physically comfortable during surgery.

15.1 Skin Preparation

Each Trainer will have their own technique for preparing the surgical field before an ocular drape is applied. Skin preparation can vary from performing a lid scrub, to cleaning the whole face, to simply applying the disinfecting solution to the periocular area. A step-by-step overview of the latter, more common method, is described:

R. Gupta, *Phacoemulsification Cataract Surgery*,
DOI 10.1007/978-3-319-59924-3_15

1. Pause to ensure the correct eye in the correct patient for surgery is identified (see section on safety).
2. Apply a generous amount aqueous povidone-iodine using suitable applicator to the periocular skin (or chlorhexidine if allergic to povidone-iodine). The surface should be coated in systematic fashion (Fig. 15.1):
   (a) With the patient's eyes closed, start at the medial canthus and work outwards towards the lateral canthus.
   Solution will flood the ocular surface, the upper and lower lid margin and lashes.
   (b) Starting again at the medial canthus, wipe one of the lids, proceeding towards the lateral canthus.
   (c) Repeat for the other lid.
   (d) Apply further solution to the periocular skin (lids, eyebrow and side of the nose) in an enlarging concentric fashion. Commence medially and work out laterally with each wipe.
   (e) Pause to allow time for the bactericidal effect to work (the time taken to cover patient with linen drapes is usually sufficient).
3. Dry the periocular surface in a similar fashion (Fig. 15.2). Start at the medial canthus and work systemically outwards in concentric fashion, remembering to start medially after each dry wipe.
4. Once completed, although the periocular skin will appear dry, the lower lid margin and lashes often are still wet (Fig. 15.3). This can remain unnoticed until the patient is asked to open their eye, (usually when the surgeon is about to apply the drape). Any residual moisture can prevent the transparent drape adhering to the eyes lashes and periocular skin. After drying the periocular skin, ask the patient to look up and ensure lower lid is wiped dry (wiping from medial canthus along the lid margin towards the lateral canthus).
5. The ocular drape can now be applied.

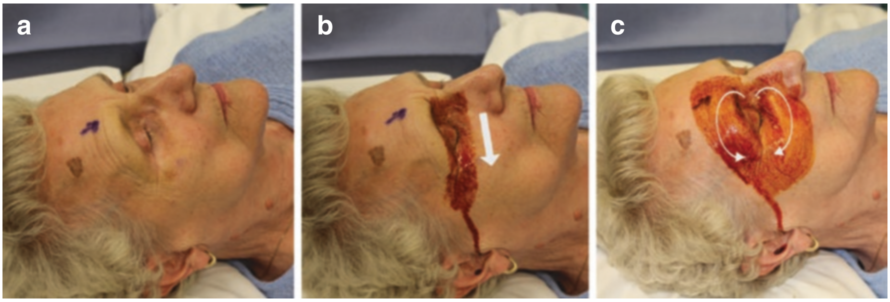


Fig. 15.1 Periocular skin preparation. (**a**) Topical anaesthetic and preoperative povidone-iodine 5% instilled into patient's right eye. (**b**) Starting at the medial canthus antiseptic is applied outwards towards the lateral canthus. (**c**) Periocular skin prepared starting at the medial canthus and wiping outwards in a concentric fashion (*arrows*)

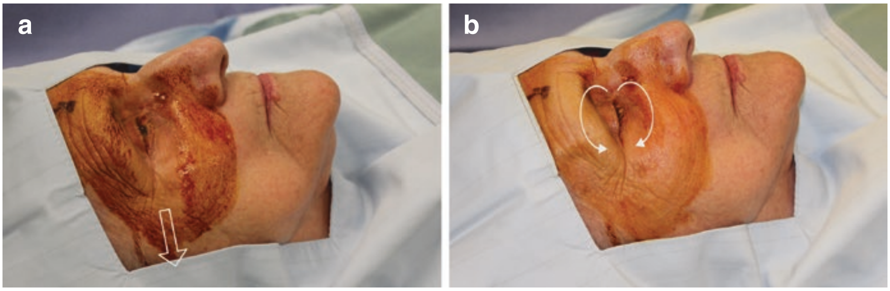


Fig. 15.2 Drying of periocular skin -1. (**a**) Linin towel with facial aperture covers patient. Starting at the medial canthus and wiping towards the lateral canthus, excess skin antiseptic solution is wiped dry (*arrow*). (**b**) Remaining periocular skin is dried: wiping outwards from the medial canthus in a concentric fashion (*arrows*)

Fig. 15.3 Drying of periocular skin -2. After periocular skin is dried the patient is requested to look up and any residual moisture on lower lid wiped dry

Box 15.1 Surgical Tip

When discarding skin preparation forceps (holding wet, used swabs) place the forceps all facing the same way the trolley surface. This makes it easier for theatre staff to pick up the forceps and avoid getting their own hands dirty when cleaning up (Fig. 15.4).

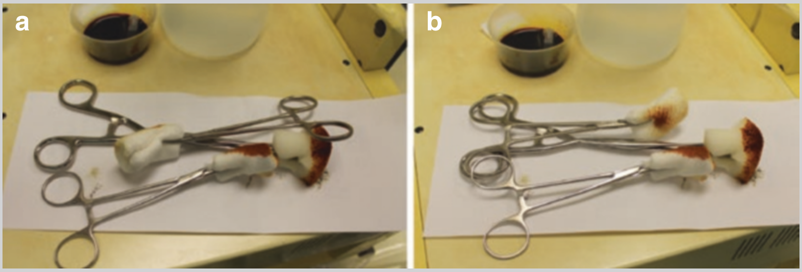


Fig. 15.4 Discarding forceps. (**a**) Dirty swabs placed on trolley surface in haphazard fashion for theatre staff to remove. (**b**) Forceps all facing the same way allow staff to conveniently remove them with minimal risk of contaminating themselves

15.2 Draping

The ocular drape is applied to the skin to maintain the sterile ocular field and act a barrier, holding the patient's eyelashes out of the way during surgery (Fig. 15.5).

A disposable transparent drape is commonly used. Two main types are available: a stand-alone drape or one with an attached pouch to catch waste fluid. Orientation arrows on the drape help ensure the pouch is correctly opened on the temporal aspect of the patient's face. An aperture must be cut into each drape before speculum insertion.

The choice of which drape to use is decided by the Trainer, who will teach the Trainee their preferred draping method.

A simple step-by-step method, using the common pouch-less drape, is described to explain the fundamentals and additional techniques that may be used:

Preparation of the transparent adherent drape (Fig. 15.6).

1. Fold the drape in half and hold it with the right hand (backing cover facing outwards and the fold on the left-hand side).
2. Remove the backing cover (as if opening a book) ensuring the drape does not become stuck to itself (if it does gently pull it apart).
3. Rotate the drape so the fold is positioned inferiorly and stretch the fold between your hands to take up the tension.

Application of the drape without using additional implements to hold back the lids (Fig. 15.7).

1. Position the fold by the lower lid and *then* ask the patient to look up. Immediately place the drape onto the lower lid and push the lid away.

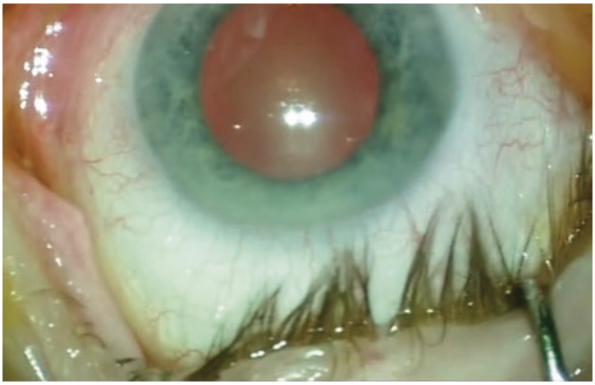


Fig. 15.5 Example of unacceptable draping. Numerous protruding upper lid lashes are present after draping and speculum insertion

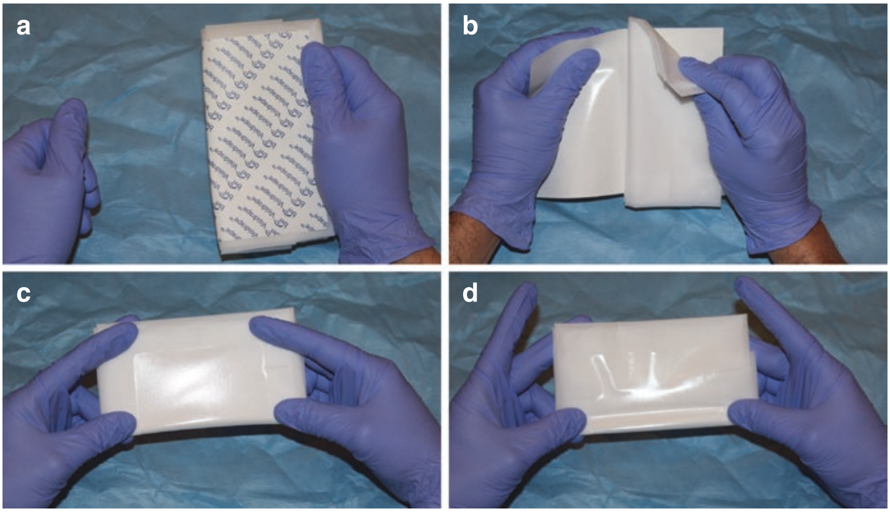


Fig. 15.6 Preparation of the transparent adherent drape. (**a**) Drape is folded in half and held with the backing cover facing outwards. (**b**) The backing cover is removed. (**c**) The drape is held with the fold positioned inferiorly. (**d**) The fold is held stretched under tension ready to apply to the patient

Do not ask the patient to look up and then move the drape inferiorly over the eye. This causes the patient to close their eye in response to the drape movement.

2. Open the drape fully and gently press down onto the periocular skin. Avoid pressing it down completely over the medial canthal area as space below the drape is needed for safe puncture of the drape and insertion of the scissor tip (without hitting the ocular surface).
3. Apply some tension to the drape using the fingers of the left hand and gently insert the scissors to pierce the drape. Make a small vertical cut in the medial aspect of the drape.

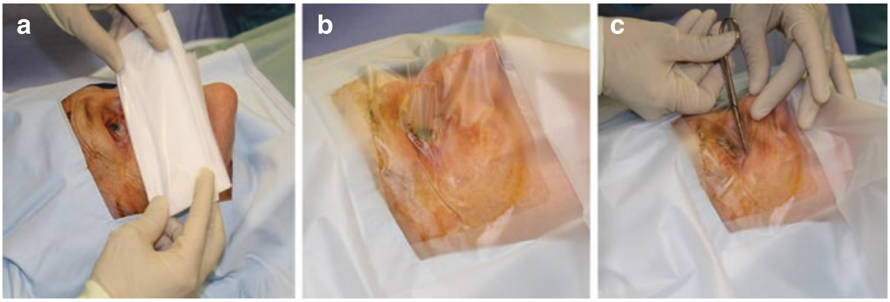


Fig. 15.7 Application of the transparent adherent drape. (**a**) Folded drape held taught is placed onto the lower lid whilst the patient looks up. (**b**) Drape fully opening and gently pressed against lids and periocular skin. Drape is not pressed down in medial canthal area. (**c**) Drape is pieced with scissors and initially cut vertically and then horizontally. The drape covering the palpebral fissure is divided two thirds superiorly and one third inferiorly

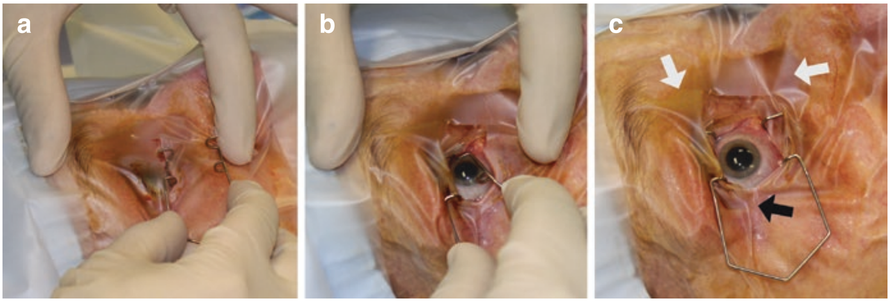


Fig. 15.8 Insertion of speculum. (**a**) Upper arm loop of the speculum is inserted first. The loop is about to catch the drape so it is rolled under the upper lid as the speculum is inserted. (**b**) The speculum is held under tension and the lower arm of the speculum inserted. The lower lid is pulled down slightly and the inner corner of the lower arm loop inserted before the outer corner. (**c**) Following speculum insertion, the drape is examined for any areas tenting (*arrows*) and cutting adjustment made before firmly adhering the drape to the skin

4. Cut the drape horizontally so the aperture is divided two thirds superiorly and one third inferiorly.

During initial draping attempts, whilst cutting the drape aperture, Trainees often lift the drape well away from the surface of the globe. This will pull the drape off the lashes despite having stuck them down.

Insertion of speculum (Fig. 15.8)

A wire speculum is commonly used to retract the lids. The upper and lower arms of the speculum have loops which fit around the lid margin.

1. Squeeze the speculum to take the tension out of it and insert under the upper lid first.
   (a) *Place the upper arm loop on the drape and let it roll under the lid margin as the speculum loop is inserted. The outer aspect of the loop is easier to insert first near the medial aspect of the lid.*
   (b) *Continue to insert the inner corner of the upper arm of the speculum using a slight counter-clockwise rotation of the speculum. There is no requirement to try and pull the upper lid to create space. If cut correctly, there should be ample redundant drape material to wrap around the lid margin.*
2. Insert the lower arm loop of the speculum under the lower lid:
   (a) *With the speculum still rotated slightly counter-clockwise insert the outer corner of the lower arm loop first. Pull the lower lid down with the left hand if needed.*
   (b) *The inner corner of the lower arm should easily be inserted with a clockwise twist.*
3. Check the drape to ensure there is no visible tension. If tensions is present, further incisions may be required to release any tented areas. Ensure the drape is fully pressed down to the periocular skin especially the lateral canthal margin. This will help prevent water trickling under the drape and soaking the patient's ear and hair.
4. If required, cut away any excess drape covering the patient's mouth and nostrils.

The above method has the advantage of not requiring additional instruments or assistance to retract the lids.

If the patient has a very deep-set eye, the drape can be cut closer to the lower lid to ensure enough drape material is available to roll under the upper lid margin—or more of the drape can be left over the palpebral aperture before it is stuck down superiorly over the brow.

Although the aim is to completely keep the lashes out of the way, even with meticulous preparation the occasional eyelash may protrude onto the surgical field.

15.3 Draping: Application Using Additional Implements to Retract the Lids

Some surgeons prefer to use other devices to hold open the eye, or to facilitate placement of the drape, for example: forceps, cotton buds, or a needle sheath cover. These can be used to pull one lid back, or to pull back both together (Fig. 15.9).

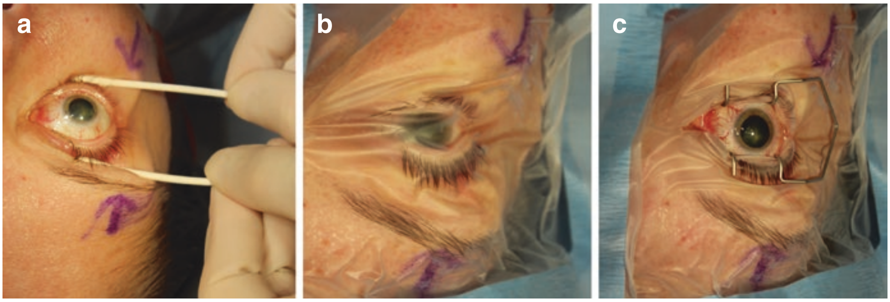


Fig. 15.9 Draping: use of additional implements to retract lids. Patient under general anaesthetic. (**a**) Both lids pulled back using cotton buds. (**b**) Application of adherent drape with lashes firmly kept out of the way. (**c**) Speculum in position

15.4 The Oily Tear Film

An oily tear film may obscure the view at the start of, or during, surgery. Balanced salt solution (BSS) can be applied over the ocular surface as droplets or a jet of fluid via a cannula. This will wet the cornea but usually fails to completely eradicate the oily tear film. Instead, the cannula tip should be removed from the BSS bottle or syringe and the ocular surface flushed directly. The larger gush of fluid is a far more effective method.

15.5 Safety and Surgeon Comfort

In June 2008, the World Health Organization launched the ‘Safe surgery saves lives’ campaign. Since then, each ophthalmic unit will have adapted the latest set of safety checks [2] into their own safety protocols. Every surgeon will be acutely aware that such pre-operative checks are essential for patient verification, preventing wrong eye surgery, and preventing insertion of the wrong intra ocular lens. Trainees should actively take part in these checks, which will initially be led by the Trainer.

Each theatre member has a predefined role and contributes to the overall success of a surgical list running smoothly. Experienced theatre staff can provide novice surgeons with a wealth of information. A useful tip is for novice surgeons to occasionally ask a member of the scrub team to actively watch and provide feedback on how they perform a surgical scrub and don a gown/glove up.

Maintaining sterility is also important. Good awareness of surroundings is needed to minimise the risk of exposing the patient to external pathogens introduced by the surgeon. It is very easy to accidentally become unsterile, and this may not even be noticed by the operating surgeon. Theatre staff have an important role in highlighting the need to change gloves, microscope handles, or any of the surgical instruments.

It is common for ophthalmologists to suffer from neck or back pain during their career. It is important for surgeons to protect their neck and back from the outset of training. Poor posture can develop during various stages of cataract surgery and operating in an uncomfortable position may affect the surgical outcome. Excessive stooping and neck flexion can occur if bending over a patient whilst draping. During surgery, if the trolley height is incorrect, the surgeon can end up perched on their seat uncomfortably. Over time this can contribute to musculoskeletal problems. Trainees are urged to pay attention to any elements that result in poor posture, and take appropriate action to remedy them. For instance, the trolley can be adjusted to a suitable height to facilitate draping and then readjusted for surgery. The microscope should be also be adjusted and the eyes pieces angled correctly. A platform can be used if there is a height difference between surgeon and assistant. This can raise the foot pedals for the main surgeon if the patient trolley or headrest need elevating. Alternatively, it can provide a step for the assistant to stand on.

As Trainer instruction is slowly withdrawn (to promote more independent surgery) the Trainee is reminded to ensure the safety of the scrub assistant is maintained by handing sharp instruments back in a safe manner. This is important as over time the Trainee will maintain concentration down the microscope and simply reach out to hand back instruments or simply place them on the scrub trolley. The Trainee is advised to set down instruments with blunt end pointing towards the scrub assistant. Though these concepts and techniques are acquired as the surgeon develops maturity, reviewing them early on in training can promote good practice from the outset.

Box 15.2 Trainer Teaching Pearls

Although draping is an essential part of the cataract procedure, it is recommended that this is one of the later skills taught to novice surgeons. Poor draping can lead to anxiety if the Trainee feels they have caused problems at the start of the procedure. This may impact on confidence and performance during surgery. Furthermore, draping done by the Trainee can use up valuable training time as the drape may require adjusting or even replacing. The Trainer is advised to allow novices to concentrate on other aspects of rear-ended modular training, with novices only draping once they are capable of operating on the whole case.

Trainers should still advise on suitable patient head position after draping has been performed, as well as and double-checking the microscope. Trainees may forget to check head position if previously always performed by the Trainer and may overlook cleaning of residual splashes on the microscope lens if performing consecutive cases.

Trainers should actively comment on the posture of novice surgeons during draping and surgery. Trainees should be told if they are adopting bad posture and every attempt made to correct bad habits so they are not allowed to persist. The mantra “protect your neck, protect your back” may be useful.

15.6 Summary

The start of the operation requires the surgical team to all take part in important patient safety checks led by the Trainer. Trainees are encouraged to take an active role, rather than acting as a bystander. It is recommended that draping is one of the last aspects of the procedure performed by a Trainee during rear-ended modular training. As such, the Trainee will be aware of their Trainer's own method to prepare the surgical field and drape the patient.

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Glossary

Aspiration fishing The act of successive attempts to engage soft lens cortical material with the irrigation aspiration probe. Aspiration is increased during each attempt as the aspiration port is moved in a circular motion starting at the point of intended soft lens material capture and ending within the safe zone. During the fishing attempts the required holding aspiration needed to capture soft lens material is eventually reached and engagement of soft lens material within the aspiration port is visualised.

Bag The lens is sheathed in an elastic basement membrane and this is referred to as the capsule bag.

Capsulorhexis The continuous curvilinear aperture created in the anterior aspect of the lens capsule.

Capture During lens nucleus disassembly, multiple fragments are created. Capture refers to phaco tip engagement of a fragment chosen for removal from the eye. Capture of a fragment also allows the capfragment to be manipulated as an extension of the phaco tip.

Cardinal points Arbitrary anatomical reference points used to help intraoperative surgical orientation. Regardless of the site of the incision, the main incision *once* made is used as a fixed reference point and labelled as the 12 o'clock cardinal point. Subsequent cardinal points are labelled 3, 6 and 9 o'clock.

Chopper An appropriately shaped instrument used to manipulate the lens nucleus and cleave apart the nucleus if a chopping technique is used.

Chopping The process of lens nucleus disassembly in which the main action is separation of the nucleus to create fragments using an instrument (the chopper) to cleave apart the lens nucleus fibres rather than using phacoemulsification.

Circular drag The act of peeling engaged cortical material off the capsule that is held by the aspiration port by moving the irrigation aspiration probe tip in a circular movement. The trajectory follows a circular path under or adjacent to the edge of the capsulorhexis initially and ends within the safe zone in a port up position.

Clear cornea incision Modern cataract surgery favours an incision made through the cornea, as close to the limbus as possible but ensuring the site is devoid of any visible blood vessels.

Cortex The immediate lens layer that lies beneath the lens capsule.

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Crack/cracking The process of disassembling a nucleus in which sculpted trenches within the lens nucleus formed during phacoemulsification are manually separated.

De-bulking The act of using the second instrument to fully or partially split a captured lens fragment into two smaller segments to facilitate phacoemulsification.

Dialling The process of manipulating the artificial intraocular lens following insertion into the eye to ensure the lens optic and lens haptics are fully inserted into the capsule bag.

Direct drag The act of moving the irrigation aspiration probe directly to the central safe zone with the port held in a rotated position. A circular motion of the probe tip or rotation of the aspiration port to the port up position is not the main action of the movement. Engaged soft lens material is held and peeled off the capsule during the movement.

Divide-and-conquer A method of lens nucleus disassembly in which sculpted grooves in the shape of a cross are made using phacoemulsification. Each groove is then cracked and separated in turn to form four fragments. Each fragment is subsequently removed from the eye.

Donut effect The appearance of partially emulsified lens fragment after it has been disengaged from the phaco tip, in which an unintentional passage can be visualised from one side of the fragment to the other side of the fragment. The passage with surrounding lens material thus resembles a donut with a central hole.

Dual-linear mode This refers to the foot pedal control mode in which both the vertical and the horizontal yaw foot pedal moment is used to control phacoemulsification and the maximum aspiration independently of each other.

Emulsification The mechanical ultrasonic vibration generated by the phaco probe tip used to break the bonds that hold the lens nucleus fibres together, thus creating a fine emulsion of lens material.

Endonucleus The lens nucleus can be split into a central endonucleus layer and a more peripheral outer epinucleus layer. This separation can be achieved during hydrodelineation of the nucleus.

Epinucleus The semi-soft layer of lens material between the nucleus and cortex.

Foot-down This act of full depression of the foot pedal to achieve maximum aspiration during soft lens and viscoelastic material removal.

Groove/grooving The act of applying phacoemulsification to form a sculpted trench within the lens using the phaco probe.

Haptics The artificial lens optic has side struts that ensure the lens is supported when placed within the capsule bag; these are referred to as haptics.

Heel The heel of an instrument refers to the portion of the instrument that is curved or angulated between the shaft and tip of the instrument. The heel can be used as a reference point for pivoting the instrument in a vertical fashion.

Heminucleus During disassembly of a lens the nucleus can be divided into two halves, each is referred to as a heminucleus.

Holding aspiration The act of controlled foot pedal depression to apply aspiration that achieves engagement of soft lens material within the irrigation aspiration port.

Hydrodelineation The act of injecting fluid to separate the epinucleus from the endonucleus or the creation of multiple layers of outer lens material from the central endonucleus.

Hydrodissection The act of injecting fluid to separate the nucleus from the cortex and capsule. Cortical cleaving hydrodissection refers to separation of the nucleus with the cortex still attached from the capsule.

In-the-bag This is the space within the lens capsule bag. It can refer to the location of instrument manoeuvres, lens material or placement of the intraocular lens.

Leading haptic The initial haptic that is inserted into the capsule bag during intraocular lens insertion.

Lens rocking The act of unintentional forceful movement of the lens resulting is applied stress to the zonules during a phacoemulsification groove stroke. The lens can be pushed on the forward movement or the lens pulled on the return movement of the phaco probe.

Linear mode This refers to the foot pedal control mode in which only the vertical yaw foot pedal moment is used to control the two phacoemulsification settings needed for initial sculpting and subsequent fragment removal.

Major rotation The act of using a second instrument to rotate the lens nucleus into a suitable position for subsequent grooving. A major rotation usually refers to a 90-degree rotation of the lens.

Make-a-space The conscious act of creating adequate space within the eye to facilitate fragment extraction from the capsule bag and during fragment phacoemulsification.

Minor rotation The act of using a second instrument to rotate the lens nucleus into a suitable position to facilitate the act of cracking a preformed trench. A minor rotation refers to a 5- to 10-degree rotation of the grooved trench.

Mushroom A second instrument with a bulbous, mushroom shaped tip.

Optic The central circular refracting portion of the artificial lens.

Palming The act of retaining and positioning an instrument so it can be held within the palm of the surgeon's non-dominant hand. This allows the surgeon to free up the thumb, index and middle fingers of the same hand to perform other tasks.

Paracentesis incision The paracentesis or side port is an additional port made in the cornea to accommodate the second instrument.

Peeling aspiration The act of controlled foot pedal depression to apply aspiration that maintains the irrigation aspiration port hold of soft lens material and allows the cortex material to be detached from the capsule as the probe is moved into the safe zone.

Phaco The term phaco can refer to various aspects of the instrumentation involved in or the act of removing the lens using ultrasonic phacoemulsification energy. Instrument examples include the phaco probe, the phaco machine, the phaco tubing or the phaco foot pedal.

Phacoemulsification triad A triad of interacting factors that influence resistance to the phaco probe movement during sculpting of the lens nucleus. The factors include lens material density, the amount of lens material engaged within the mouth of the phaco tip and the amount of phacoemulsification energy applied.

Phakia The existence of a natural lens within the eye.

Port up The act of ensuring the irrigation aspiration probe port is facing upwards and away from the posterior capsule or iris.

Pouch Periocular transparent drapes divided into two main types, one has a pouch to collect fluid and the other does not.

Pseudo-groove The act of moving the phaco probe forward and backward over the surface of the lens without engaging any lens material immediately after insertion into the eye. The movement allows the surgeon to determine if the probe sleeve is caught within the main incision and to help gauge the main incision resistance to probe movement.

Pseudo-removal movements The act of practicing irrigation aspiration probe movements above an implanted intraocular lens. The movements mimic the actual probe tip movements required for cortex removal during the training module of soft lens material removal.

Pseudophakia The post-operative status of the patient in which an artificial lens has been placed within the eye.

Rear-ended training A training regime in which the cataract phacoemulsification steps are taught by starting with steps performed at the end of the procedure and progressing towards steps performed at the start of the operation. Rear-ended training requires the Trainer to perform all of the steps up to the point of hand over to the Trainee.

Rhexis The rhexis refers to the border of the incomplete or completed continuous curvilinear capsulorhexis, or if referred to during capsulorhexis creation to the tearing point of the capsule.

Ripping During the act of capsulorhexis formation, force is needed to overcome the bonds that hold the capsule fibres together. Force if applied in a vector that is different to the intended tear propagation direction will spread the applied force over several capsule fibres, causing stretching of the fibres until they eventually rip apart. This is a ripping force.

Safe zone The safe zone is the deepest part of the anterior chamber and the central area within the capsulorhexis. It is the area in which the risk of catching the iris or capsule is minimised, allowing maximum aspiration or phacoemulsification.

Second instrument The primary instrument is the phaco probe. An instrument used via the paracentesis to help manipulate the lens is deemed the second instrument.

Shearing During the act of capsulorhexis formation, force is needed to overcome the bonds that hold the capsule fibres together. Force if applied in the same direction as an intended tear will apply the force on a small focal point on the capsule. This overcomes one capsule bond at a time along the direction of force. This is referred to as a shearing force.

Shoulder-fragment This refers to the lateral corners of the pyramidal base of a lens nucleus fragment. The fragment shoulders remain under the capsulorhexis and require extraction to completely free the fragment from the capsule bag.

Shoulder-intraocular lens This refers to the part of the artificial lens anatomy. It is the junction between the outer curve of the haptic and lens optic.

Side port See paracentesis.

Sleeve This is the plastic covering of the phaco tip. It has two irrigation ports and is adjusted to ensure the tip is exposed to the surgeon’s preferred phaco tip length and that the irrigation ports face horizontally when holding the probe in the primary bevel up position.

Starting position The *phaco* starting position refers to the point on the lens where phacoemulsification grooving initially commences. It is located as close to but not touching the capsulorhexis margin under the main corneal incision as possible.

Starting position space This is the space within the capsule bag that lies directly opposite to the main incision. A fragment positioned in this starting position space can be captured without lateral movement of the phaco probe.

Stroking The act of downward movement of an instrument as it is removed from the eye. A stroking movement may potentially cause trauma to the adjacent conjunctiva or cause downward depression of the posterior lip of the incision.

Target fragment The selected lens fragment the surgeon intends to extract from the capsule bag and phacoemulsify.

Trapping The act of holding back part of a fragment that has been de-bulked using the second instrument. The segment is held back until the remaining captured fragment on the phaco tip is almost completely emulsified at which point it is released so it too can be removed.

Trailing haptic The second haptic that is inserted into the capsule bag during intraocular lens insertion. The trailing haptic usually requires additional manipulation to ensure correct in-the-bag placement.

Trench A sculpted groove in the lens nucleus created using phacoemulsification.

Tri-planar incision A three-step self-sealing corneal incision. It comprises of a perpendicular groove to provide thickness to the superior lip of the incision, stromal cut along the plane of the cornea and finally downward cut through Descemet's membrane and endothelium.

Unlocking The act of separating interlocked nucleus fragments following lens disassembly. Unlocking forms part of make-a-space principles.

Un-palming The act of reversing a palming manoeuvre to make use of a previously retained instrument held within the surgeon's non-dominant hand so it can be used again.

Viscoelastic burp The act of expelling a small amount of viscoelastic from the anterior chamber before hydrodissection is performed.

Viscoelastic fill The act of injecting viscoelastic material into the eye in preparation of performing the capsulorhexis or insertion of the intraocular lens.

Wind-on-a-stick The act of rotating the irrigation aspiration port either clockwise or counterclockwise during irrigation aspiration of soft lens material. Captured cortical lens material within the port is held on tension and port rotation helps detach the cortex from the capsule.

Wobble The act of fragment oscillation and movement that occurs during phacoemulsification of a captured fragment. A fragment is partly emulsified and then allowed to rotate slightly to ensure the phaco tip has a good hold before emulsifying more of the lens fragment. This is repeated until the fragment is completely removed.

Zone 1–5 For the purpose of instruction and to aid orientation during removal of cortical soft lens material, the 360-degree circumferential area of cortex within the capsule bag is divided into five defined zones.

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