Special Article/บทความพิเศษ

Phacoemulsification

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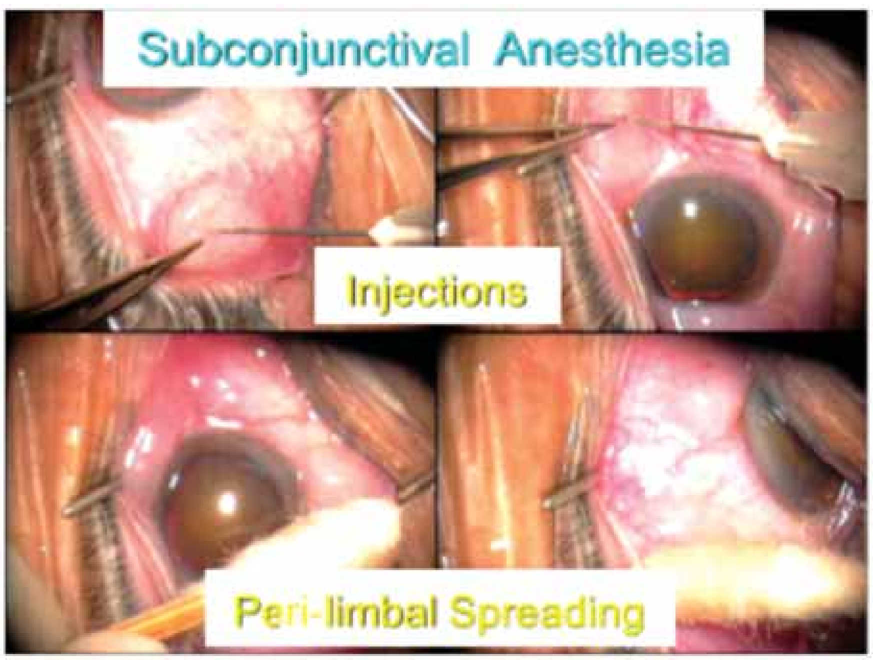
1. Surgical Steps

1.1. Anesthesia

1.1.1. Topical: an anesthetic eye drop such as Tetracaine HCl is commonly used especially in conjunction with clear corneal incision.

1.1.2. Subconjunctival / Subtenon: this type of anesthesia offers good pain control and last longer than topical anesthesia. It should be considered in a potentially complicated case.



1.1.3. Peribulbar / Retrobulbar: this block provides excellent and long lasting anesthesia. It also offers akinesia. It should be considered in a case that may need to be converted to ECCE or in case with excessive eye movements.

1.1.4. Intracamera : This type of anesthésia is used with topical anesthesia but pain control is the same as topical alone.

Mettapracharak (Wat Rai Khing) Hospital

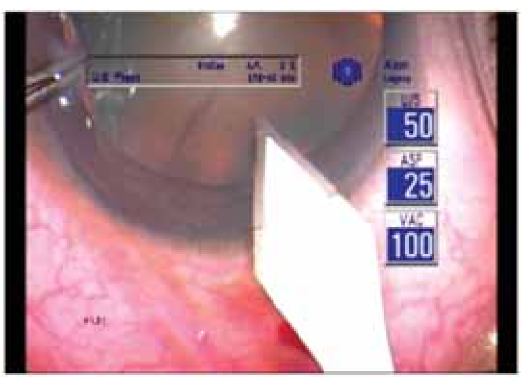
color pictures in page 75-88.

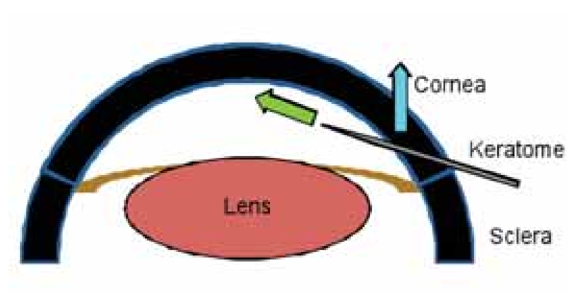
1.2. Construction of Incision

1.2.1. Scleral Tunnel Incision : This incision was popular before the advent of clear corneal incision. It has advantage of high strength and stability. Although it can be placed at any position, it is commonly placed superiorly. However care must be taken during temporal placement to avoid hyphema from the bleeding of the anterior ciliary artery. The incision starts with a conjunctival peritomy at 3 mm from the limbus. Then a groove is made on the sclera at 2 mm from the limbus. The crescent knife is used to tunnel 1 mm into the clear cornea. The total length of the tunnel is approximately 3 mm. The keratome is then used to enter the anterior chamber

1.2.2. Clear Corneal Incision : This incision has become the most commonly used incision in modern cataract surgery. It is commonly placed temporally. A superior placement may cause surgical induced astigmatism due to corneal flattening effect from the pressure of the lid. Surgeon may add a pre-groove near the limbus to construct a 2 or 3 steps incision in order to create a better seal. However, this addition may increase risk of surgical induced astigmatism.

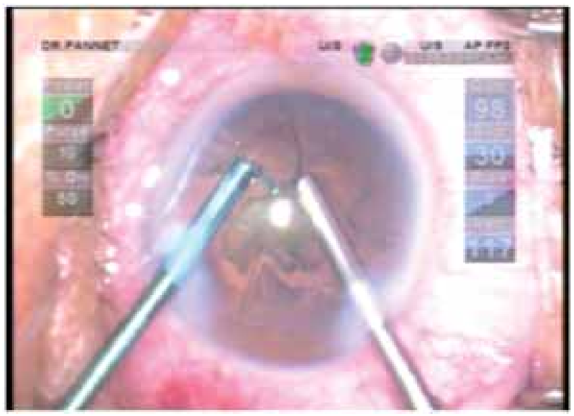
Nowadays, most surgeons prefer a single step incision (stab incision) using 1.8 - 3.2 mm keratome. The entrance makes a 15 degree angle to the sclera to create a 1.5 - 1.75 mm clear corneal tunnel. In case of a hard nucleus, an incision size 2.75 mm is recommended to reduce the risk of wound burn. The size 2.4 mm is used in cases with medium to soft nucleus. Utrata Capsulorhexis forceps can be used in 2.4 and 2.75 mm wound. However a special capsulorhexis forceps is required for 2.2 mm wound. It is observed that smaller the incision, the higher the risks of phaco burn. Also the smaller the incision, the greater chance of wound distortion due to stretching from instrument or intraocular lens. These factors may contribute to poor sealing in smaller incision.





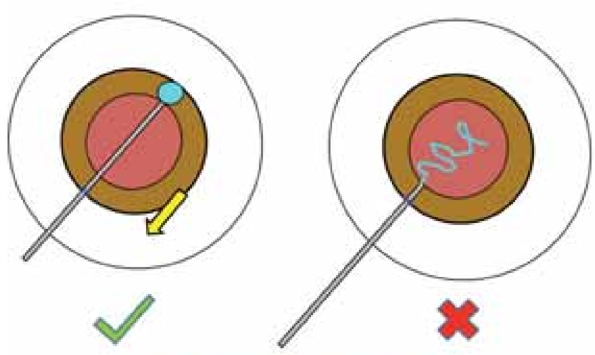
1.2.3. Side Port Incision: This incision is commonly created by 15 degree knife. However, the author prefers to use a 21 gauge needle because it is effective, inexpensive, and always available. The needle enters the cornea by exerting the forces simultaneously in two directions-forward and lifting up. This maneuver allows for stabilization of the cornea and keeps the eye center. Normally there is no need to use a second instrument with proper technique. However, surgeon may prefer to use the forceps or other instrument to keep the eye center. The author prefers to create the side port to inject viscoelastic before constructing the main incision. The incisions should be approximately 2 - 3 clock hours apart.

1.2.4. Bimanual/ Biaxial Phaco: This surgical procedure separates irrigation port from the phaco handpiece. Two approximately 1.5 mm incisions are used. One incision is for the irrigating chopper. Another incision is for the phaco needle. Small incisions reduce the risk of surgical induced astigmatism. However these nonstandard incisions require a special casulorhexis forceps and specialized IOL. In order to use the standard foldable IOLs, the incision must be extended to 1.8 - 2.2 mm depending on the types of lenses and injectors.



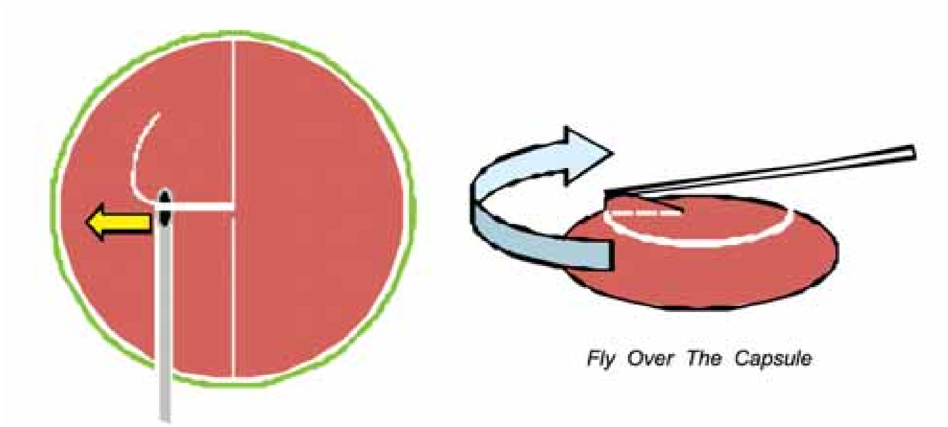
Bimanual / Biaxial Phaco

1.3. Viscoelastic Injection : The injection is usually done through the side port. It begins above the iris on the opposite side of the port to evacuate the aqueous humor and replacing it with viscoelastic until the anterior chamber is form. This provides adequate anterior chamber stability to create a well-constructed main incision.

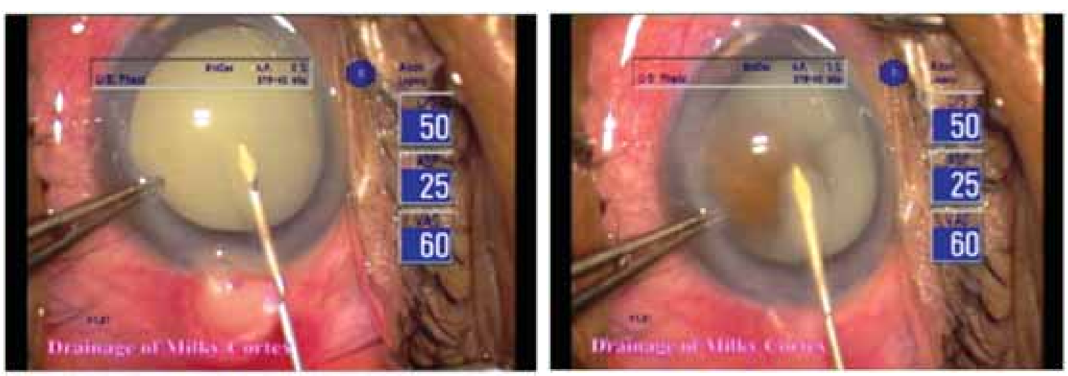


Viscoelastic Injection

1.4. Capsulorhexis : The opening of the anterior capsule can be created using cystotome or capsulorhexis forceps. The author prefers straight tip 27 gauge needle. Anterior capsule is enter at the center of the lens and extend peripherally to create a flap. Then the forceps can be used to finish the tear resulting in 5 - 6 mm diameter circular capsulorhexis. During the tear, the capsular flap needs to be regrasped several times to maintain proper position not too far from where to tear is progressing. This position allows for best control of the tear direction. If the tear becomes too wide, it must be pulled toward the center. Occasionally the technique needs to be modified according to the clinical condition. For instance, in the case with a hard nucleus or loose zonule, surgeon must create a larger rhexis (even more than 6 mm in diameter) in order to reduce the risk of increasing stress on the zonule. During the removal of a hard nucleus, the lens segment may occasionally hit the edge of the rhexis exerting stress on the zonule. In the case with a very soft nucleus where the surgical technique may call for subluxation of a part of the nucleus outside the capsular bag, the rhexis must be larger or equal to 5 mm in diameter to allow for the subluxation and rotation of the nucleus out of the capsular bag.



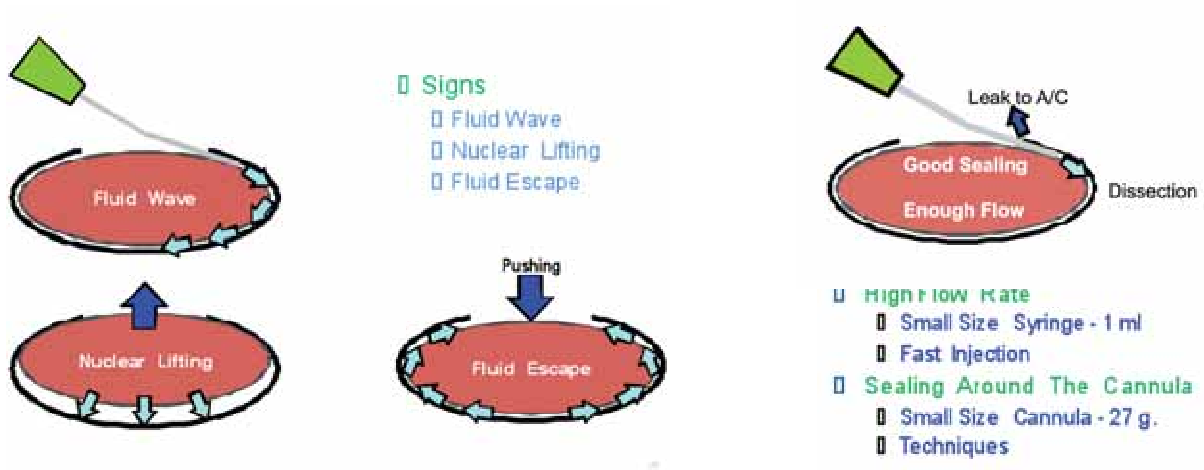
Performing capsulorhexis in the setting of a mature cataract posts significant challenge due to difficult visualization of the capsule. Increased magnification and brighter light may help. In some cases, the capsule can be stained using trypan blue. Vannas scissors may need to be used occasionally to cut through fibrosis. The cortex may become liquefied causing a spill of milky material that obscure the surgical field or exerting pressure on the capsule that extend the tear to the equator. In this case, the liquefied lens material can be drained before starting capsulorhexis. A 27 gauge needle is used to puncture the center of the capsule. The surgeon waits until the milky material is evacuated. The posterior lip of the corneal wound is pressed to release the material. Additional viscoelastic is injected before resuming the capsulorhexis.



Drain liquefied cortex with 27 G. needle

1.5. Hydrodissection: The BSS is injected beneath the edge of capsulorhexis to separate the capsule from the cortex or epinucleus in order to facilitate nucleus rotation. The fluid wave sign is seen as the BSS travels from the injection site, crosses the posterior capsule, and reaches the opposite site. The BSS will slowly accumulate behind the nucleus and lifting it to create nucleus lifting sign. The surgeon will need to gently press the center of the nucleus to cause the accumulated fluid behind the nucleus to travel backward to the capsular opening and to separate the capsule from lens at the equator toward the capsular edge. This so-called fluid escape sign indicates that the hydrodissection is successfully completed. The surgeon may choose to repeat the procedure at 2 - 3 different positions to help ease nucleus rotation.

The author uses 1 ml insulin syringe with 27 gauge cannula. This set up optimizes the hydrodissection by creating a relatively high BSS flow. In some cases, the hydrodissection is either contraindicated or should be performed cautiously. Cases with dense cataract will have poor red reflex. Surgeon, not being able to see the fluid wave sign, may inject too much BSS that accumulates behind the nucleus causing high pressure that ruptures the posterior capsule. This so-called capsular block syndrome can be avoided by slowly and gently injection alternate with nucleus pressing to release the pressure. One should avoid hydrodissecton in the case with posterior polar cataract since the existing defect in the posterior capsule amplifies the risk for hydro rupture. Surgeon will instead perform hydrodelineation by injecting BSS into the epinucleus until the golden ring sign is seen. The resulting epinuclear shell will help protect the capsular bag while the nucleus is disassembled and removed. Cases with white mature cataract may not require hydrodissection because the nucleus is already loose from the liquefied lens material.



1.6. Phacoemulsification: There are many techniques to break up and remove nucleus depending on the types of nucleus and the surgeon preferences. Modern techniques break the nucleus into small pieces for ease and safe removal. However, soft nucleus is often more difficult to fracture necessitating different techniques. An important consideration in emulsification of the nucleus is the amount of spent ultrasound energy. The heat generated during the procedure may be harmful to the wound and delicate intraocular tissues. The ultrasound energy itself may directly damage the endothelial cells. Therefore, the nucleus should be managed in the central safe zone furthest away from endothelium, iris, and posterior capsule.

1.7. Cortical Aspiration: Removal of the cortex at the first position will be the most difficult because cortical fiber still strongly adheres to the capsule. There are also resisting forces from the surrounding fibers. Therefore, it is best to start at the most accessible position opposite to the entry port. The aspiration then alternatively advances left and right until reaching the final position at the subincision. The principle of cortical aspiration is to capture the cortical fiber at the edge of the rhexis and continue to aspirate and occlude the port. After building sufficient vacuum, the cortical fiber is pulled to the center peeling it from the capsule. Once the fiber reaches the center, the vacuum can be increased to completely remove it. At the subincisional area, it may be difficult to aspirate the cortex. The port should be turned down to capture the cortex at the edge of the rhexis and then rotated upward to check that the capsule is clear. Then the cortical fiber is pulled to the center and removed.

1.8. Capsule Polishing: The posterior capsule can be polished using low vac under the cap vac mode or using regular I/A controlling by foot switch. Normally, there is no need to polish the anterior capsule since the fibrotic ring from the anterior capsule will facilitate IOL adhesion to the posterior capsule reducing the rate of posterior capsular opacity (PCO).

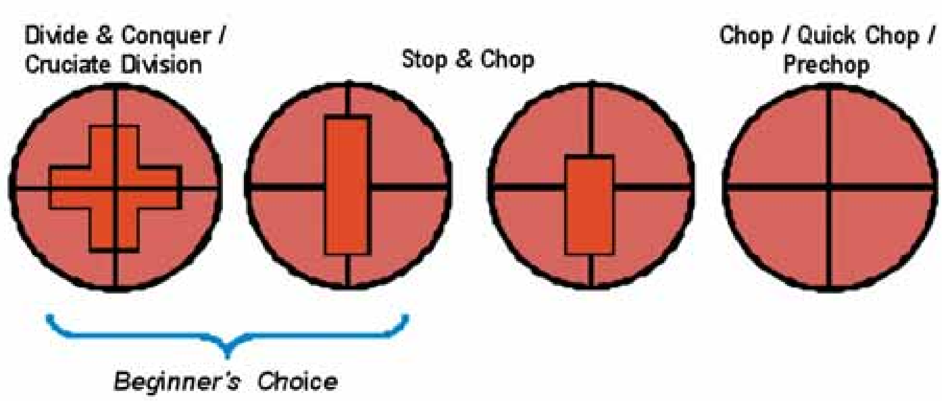
1.9. IOL Insertion: The PMMA IOLs (5 - 5.5 mm in diameter) require enlargement of the incision. Modern foldable IOLs use injectors. The required incisional size will depend on the types of IOLs or injectors.

1.10. Wound Closure: In self-sealing incision, the internal lip will act as a leaf valve that is closed by the intraocular pressure in the anterior chamber. Therefore, it is very important to form the anterior chamber at the appropriate pressure at the end of the case. In cases with poor sealing, the anterior chamber may be formed with air bubble. The corneal stroma may be hydrated using the 27 gauge cannula to inject BSS into the left, right, and external lip of the wound. The clear corneal incision larger than 4 mm usually does not have adequate wound strength and requires closure with suture.

2. Nuclear Disassembly Techniques

Modern cataract surgery involves breaking the nucleus into small pieces that can be easily and safely aspirated from the eye. Many techniques are available to achieve this goal depending on the types of nucleus and the surgeon preferences and experiences. Each technique has advantages and disadvantages. Therefore it is important to understand the principles behind each technique in order to choose the most appropriate technique for a particular clinical situation.

Before going into details of each technique, we need to discuss the general principle behind nuclear disassembly. There are two main ways to separate the nuclear mass: direct and indirect cut.



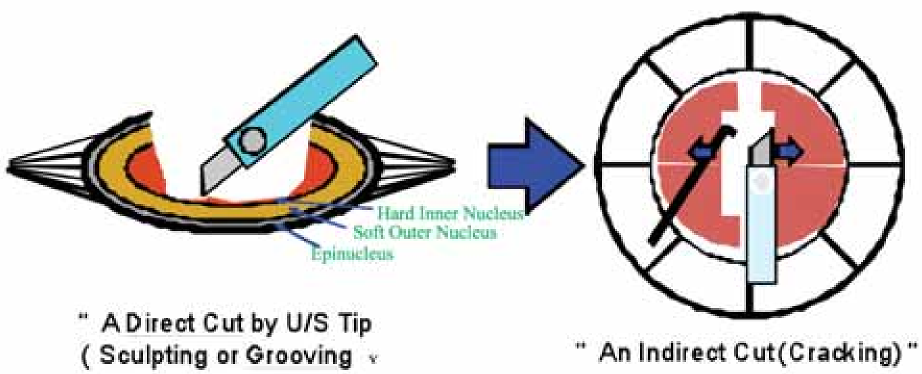
Spectrum of Nuclear Disassembly Techniques

Direct cut involves making a groove by sculpting the nucleus using the phaco head or using the chopper to cut nucleus into small pieces. In these situations, the instruments directly separate the nucleus fibers. During indirect cut, the phaco head and the chopper exert opposite horizontal forces that crack the nucleus rather than directly cut it.

In summary, direct cut involves grooving and chopping, while indirect cut involves cracking. Various nucleus disassembly techniques utilize different combinations of direct and indirect cut.

2.1. Cruciate Division: This technique involves creating two perpendicular grooves the shape of a plus sign. Then the nucleus was cracked at the end of each corner into 4 segments (quadrants). Approximately 50 - 60% of this technique is direct cut (groove). The remaining 40 - 50% involves indirect cut (crack).

The advantage of using more direct cut is that less force is required to separate the nucleus during the indirect cut portion. This is especially useful in the case with hard nucleus. The majority of the strength of the nucleus is destroyed while it is in the most stable and safest position. The deep groove also allows for a complete cracking reducing the chance of development of jigsaw interlocking. The major disadvantage of this technique is extra time requires to make the groove.

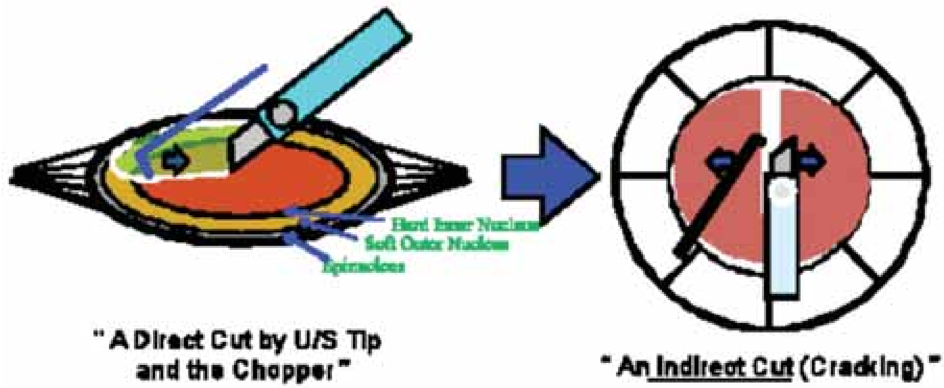


Cruciate Division / Divide and Conquer

2.2. Phaco Chop: This technique begins with using the phaco tip to bury from the surface toward the center of the nucleus. One should reach at lease 50% of the thickness of the central nucleus. Then the chopper is used to chop the nucleus moving from opposite of the phaco tip at the deepest possible depth toward the phaco tip. This action will generate forces to crack the nucleus into two separate segments. The nucleus is rotated and chopped to create 4-6 small segments that can be aspirated. Alternately, the surgeon can chop and remove the nucleus one segment at a time.

Phaco chop is a technique that completely avoid grooving, while cruciate division is the technique without chopping. These two make up the opposite ends of the spectrum of nuclear disassembly technique.

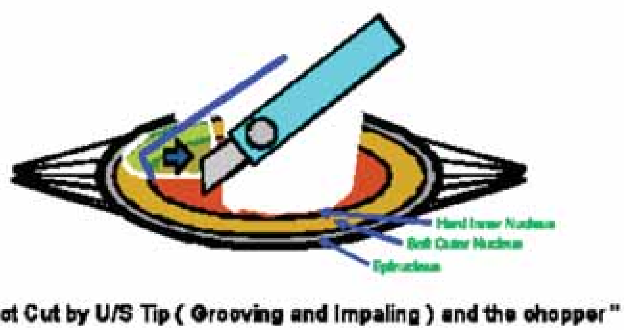
Closer inspection reveals that the direct cut portion of the phaco chop technique occurs during the burry of the phaco tip and the cutting of the nucleus by the chopper. This comprises approximately 20 - 25% of disassembled nucleus. The remaining 75 - 80% requires indirect cut by cracking. This means a greater



Phaco Chop

force is required than cracking a pre-grooved nucleus. For hard nucleus, this could lead to twisting and incomplete separation making segment removal more difficult. However, the advantage of phaco chop is the time saving from skipping the grooving. It is best for cases where the nucleus is neither too soft nor too hard.

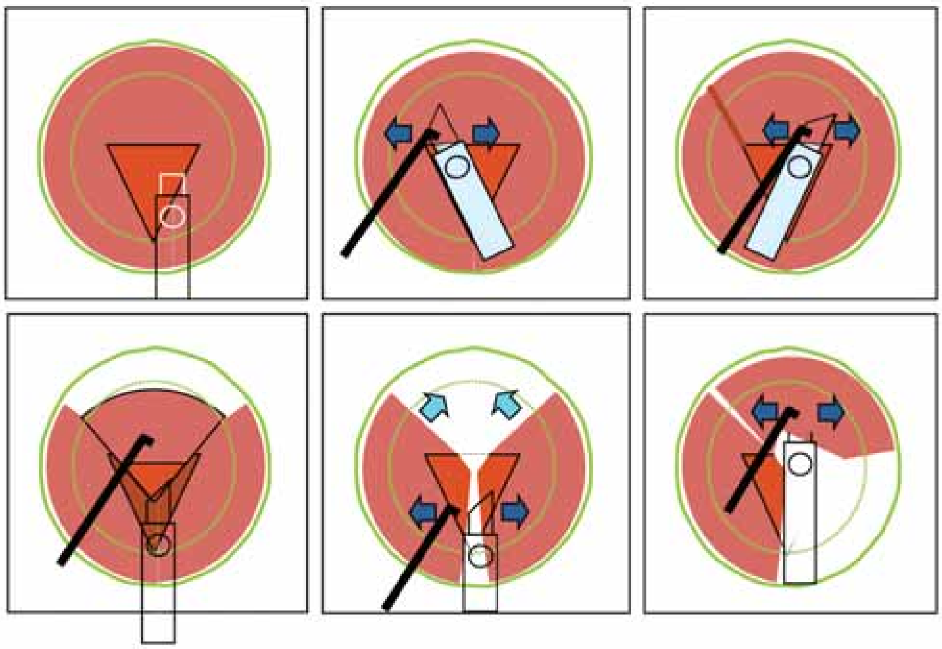
2.3. Stop and Chop: This technique combines grooving and chopping taking advantage of the benefits of each technique while lessening the disadvantages. The surgeon starts by making a 2/3 of the groove normally required for cruciate division. The distal 1/3 is then chopped. The groove is cracked in its entire length. The nucleus is rotated and chopped to produce 4 - 6 segments.



Stop and Chop

The direct cut portion of the stop and chop technique - approximately 40 - 50% -- involves the grooving, impaling of the phaco tip, and chopping of the nucleus. The remaining 50 - 60% of the nucleus is disassembling by indirect cut. This technique is well suited for hard nucleus.

2.4. Triangular Cracking: This is a modified stop and chop technique in which a groove forms a triangular shape with whose apex pointing toward the main incision and the base resting at about the middle of the nucleus. The shape looks like an up-side-down triangle when observing through a microscope from a surgeon point of view. The surgeon begins by making a triangular groove. Then the nucleus is chopped at the left and right bases to create a first segment. The space of the groove allows for ease of pulling this first segment into the central safe zone. After removal of the first segment, the nucleus is cracked at the apex of the triangle. The space previously occupied by the first nucleus allows a very efficient cracking since the left and right segments can slide into this space. Then the segments are chopped into smaller pieces and removed.

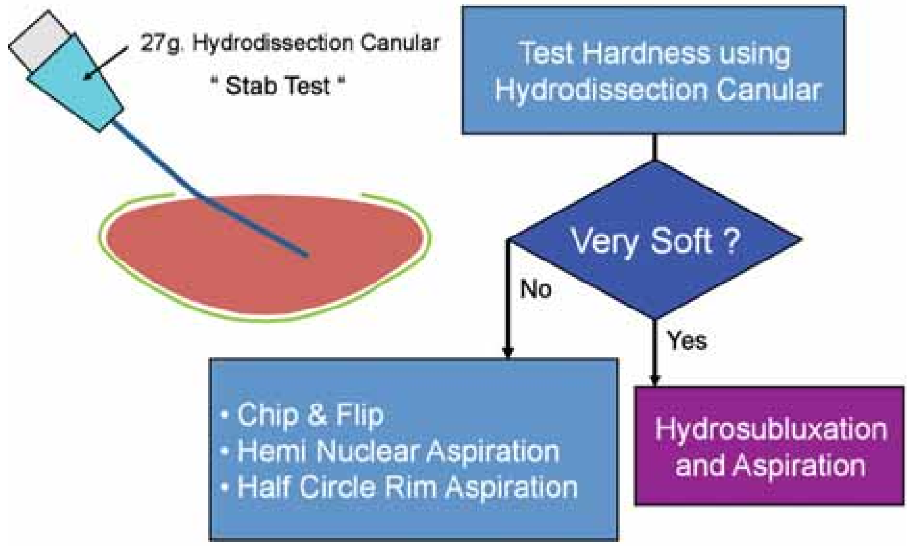


Triangular Cracking Technique

The advantage of this technique is minimal requirement of rotating the nucleus. The nucleus can simply be disassembled even when the hydrodisseection is not perfectly executed. The first segment can be removed without having to rotate the nucleus. Auto hydrodissection, the space formed in the capsular bag, and the forces generated from apex cracking will loosen the nucleus. This technique may be called minimal hydrodissection or no hydrodissection phaco. It is well suited in the case with posterior polar cataract.

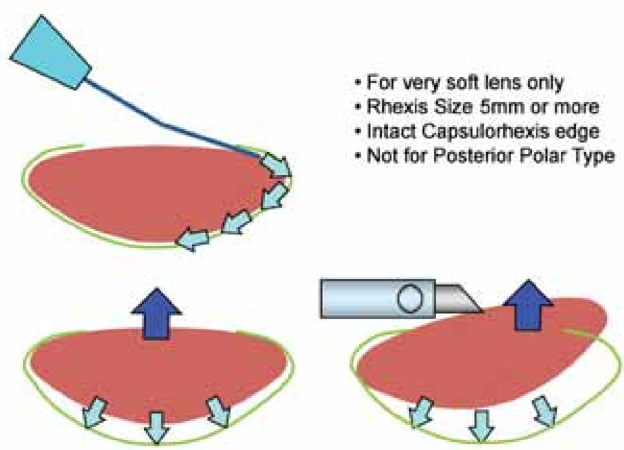
3. Soft Nucleus

Chopping, cracking, and rotating a soft nucleus can be challenging. Therefore surgeon should select a technique that does not require a lot of cracking and rotation. It is also important to create a capsulorhexis that is at least 5 mm to help ease nucleus rotation. This is especially true with a technique that involves subluxation of nucleus from the capsular bag. The density of nucleus can be tested with a stab test. Before initiation of hydrodissection, the surgeon will use the hydrodissection cannula to stab into the nucleus toward its center while observing the resistance and the movement of the nucleus. If the nucleus can be stabbed easily generating no or minimal movement, the nucleus is very soft.



The Sense of Hardness "Stab Test"

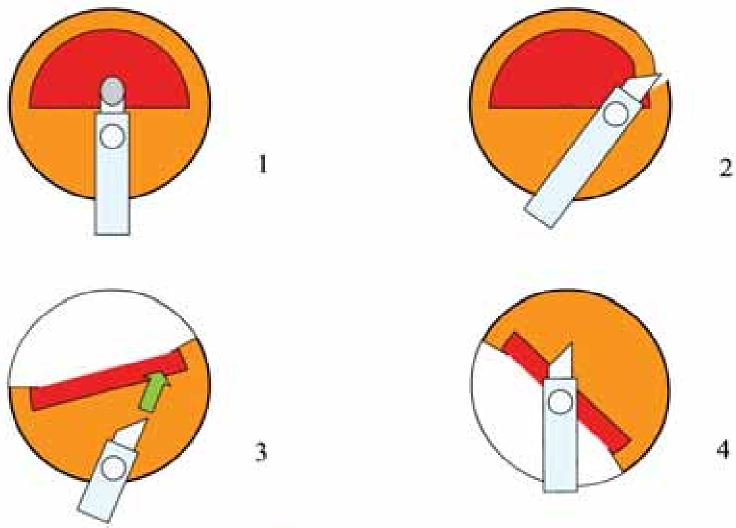
3.1. Hydrosubluxation and Aspiration: If the stab test indicates soft nucleus, the nucleus should be subluxated out of the capsular bag by aggressive hydrodissection using copious BSS. The accumulated BSS will push the nucleus forward and out of the bag. In this position, the soft nucleus can be rotated and aspirated. It is crucial to have a capsulorhexis of 5 mm or larger to reduce the risk of hydro rupture of the posterior capsule. This technique is contraindicated in the cases with posterior polar cataract.



Hydrosubluxation and Aspiration Technique

3.2. Chip and Flip: The surgeon starts by sculpting the center of the nucleus to create a bowl shaped space. Then the phaco tip is used to push the floor to flip the epinucleus pass the equator of the bag. The flip lens materials can be aspirated and removed. The flipping will be difficult if the nucleus is not very soft or there is too much residual floor thickness. When the floor is pushed without flipping, the force may create too much stress on the zonule.

3.3. Half-bowl Aspiration: The surgeon creates a half bowl shape is by sculpting the distal end of the nucleus. Then starting at the epinucleus edge the half bowl is entirely aspirated and removed creating an empty space in the capsular bag. The phaco tip is used to push and rotate the remaining nucleus in the subincisional area into this space. The nucleus is than sculpted and removed similar to the first half.



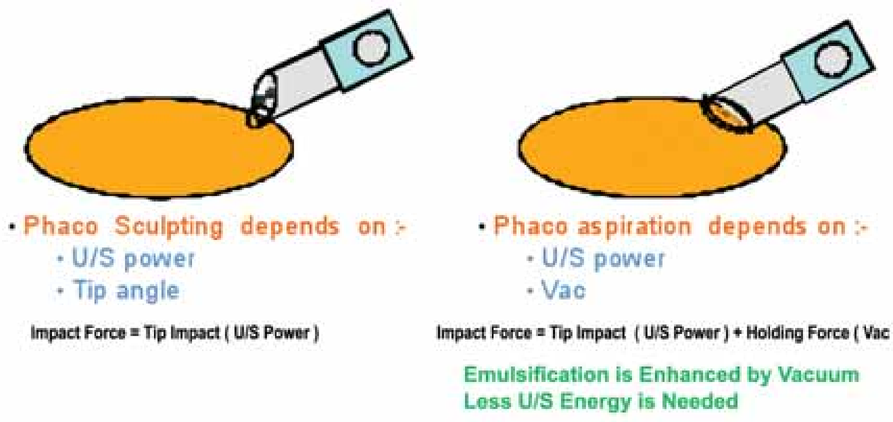
Half Bowl Aspiration

4. Position of the Bevel

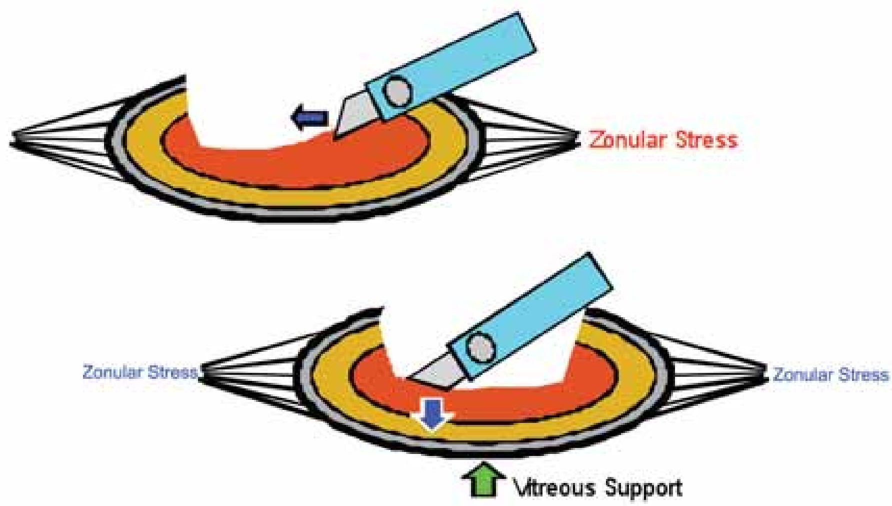
The efficiency of nucleus emulsification depends on the amount of U/S energy and the degree of the bevel of the phaco tip. The amount of nucleus covered with each passage and the velocity of phaco tip forward movement must be adjusted according to the hardness of the nucleus.

4.1. Bevel Up: A conventional position of the phaco tip to sculpt the nucleus and create the groove is bevel up. The most common setting is a 30 degree phaco tip with 50% U/S energy. In hard nucleus, we can increase the efficiency of nucleus emulsification by increasing the U/S energy and slow movement covering small amount of the nucleus at a time. Otherwise, there will be untoward stress on the zonule from excessive pushing of the nucleus. In hard nucleus, the surgeon may also choose to increase the angle of the bevel to 45 degree. However the resulting larger bevel area will lead to more difficult occlusion. It will take longer to remove the segment.

4.2. Bevel Down: In this technique, the surgeon points the bevel of the phaco tip downward emulsifying the nucleus underneath. The surgeon constructs the groove by repeating emulsification in overlapped areas until reaching proper depth. One may use a hook or chopper to help stabilize the nucleus during grooving.



Emulsification Efficiency

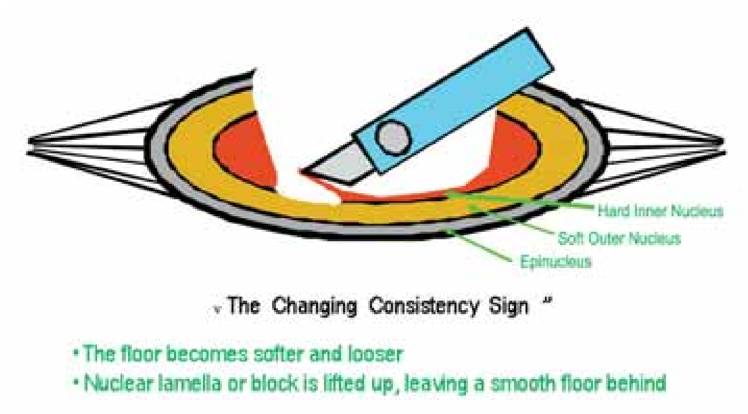


Zonular Stress During Bevel Up and Bevel Down Grooving

The advantage of bevel down is the forces on the zonule are equally redistributed 360 degree. The vitreous below the lens also provide further support downward forces. In contrast, only the zonule in the main incision area supports the forces exerted during the bevel up sculpting. Furthermore, bevel down allows for phaco aspiration because the tip is mostly occluded. The built up vacuum will help increase emulsification efficiency because the phaco tip can impact the nucleus with a greater force. Normally the vacuum is set lower than 100 mm Hg to prevent engaging of the phaco tip. In case of hard nucleus, the surgeon can increase both the vacuum and U/S power. The phaco tip should also be moved more slowly to emulsify and remove nucleus without excessive stress on the zonule.

5. Changing Consistency Sign

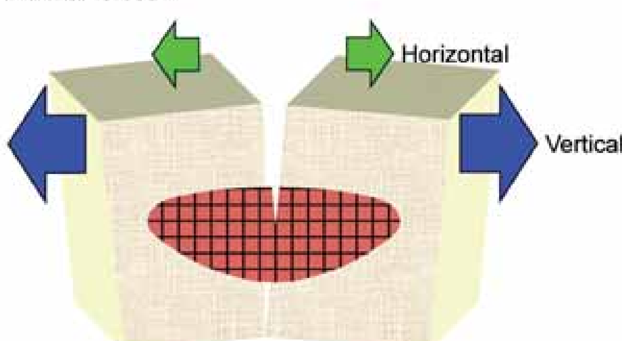
When the groove reaches the level between the outer nucleus and core nucleus (location of the posterior Y-suture), the nucleus will be softer and the lamella are less densely packed. Surgeon will notice that the lamella are lift off relatively easily exposing a smooth floor. In general, this level is located approximately at 2/3 the depth of the nucleus. However, in hard nucleus, this level may reach up to 3/4 or 4/5 of the depth. When the groove reaches this optimal depth, cracking can be executed easily avoiding jigsaw interlocking.



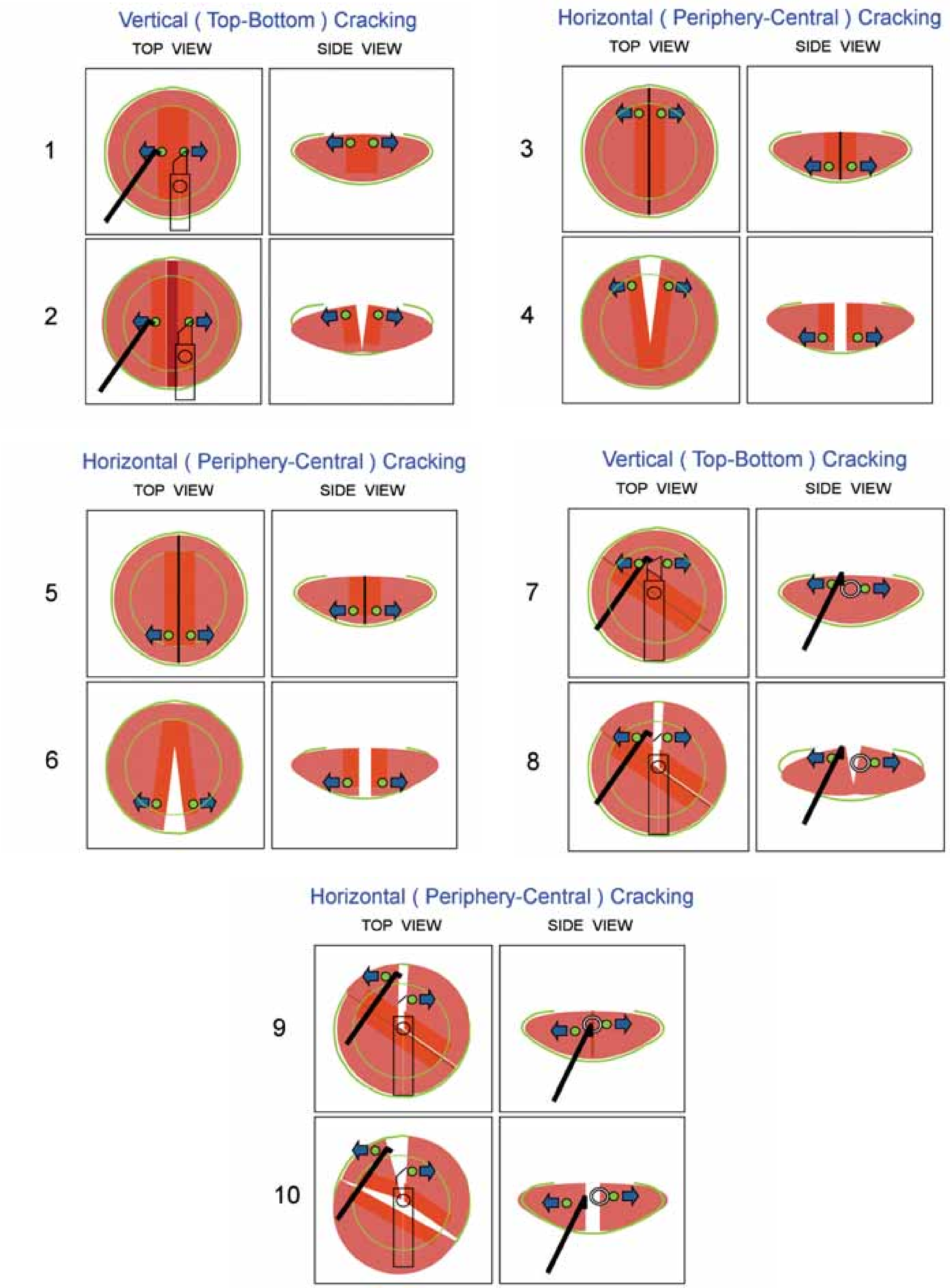
6. 3D Cracking

After creating a groove with proper length, width, and depth, the surgeon can visualize the nucleus as a 3 dimensional object. The cracking proceeds in two specific directions to achieve a complete crack with minimal force. The first direction is cracking from the top to bottom (vertical cracking) by exerting force on the upper edge in the middle of the nucleus and separating the nucleus from the surface to the floor. The second direction is cracking from the peripheral to central (horizontal cracking) by exerting the force at the front end of the groove to separate the lens fiber at the floor from the equator inward to the center of the lens. This step is then repeated on another end to complete the crack. This visualization helps to efficiently separate the nucleus one fiber at a time without requiring too much force. This is true even in a very hard nucleus.

" A cracking technique that apply forces in a specific pattern, vertically and horizontally, to separate a very hard nucleus with minimal forces "



3D Cracking (3D Divide & Chop)


Vertical (Top-Bottom) Cracking
TOP VIEW
SIDE VIEW
1
2
Horizontal (Periphery-Central) Cracking
TOP VIEW
SIDE VIEW
3
4
Horizontal (Periphery-Central) Cracking
TOP VIEW
SIDE VIEW
5
6
Vertical (Top-Bottom) Cracking
TOP VIEW
SIDE VIEW
7
8
Horizontal (Periphery-Central) Cracking
TOP VIEW
SIDE VIEW
9
10

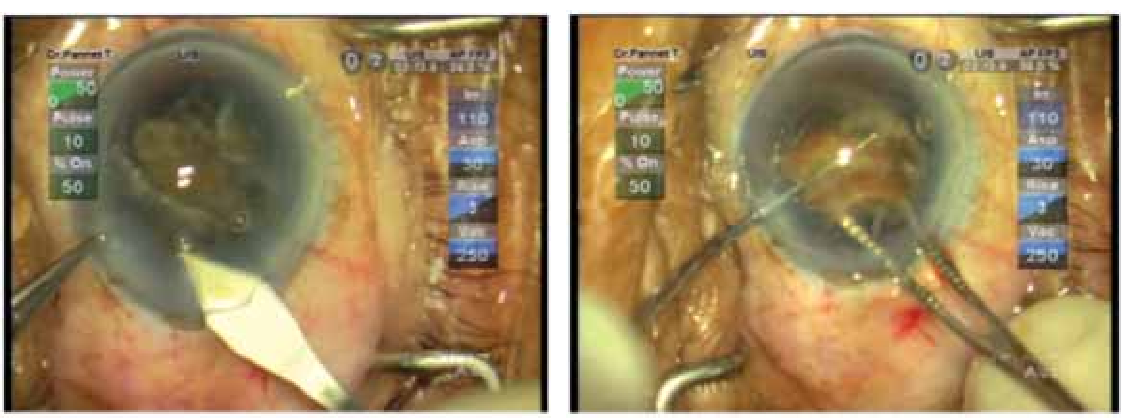
7. Complication Prevention & Management

7.1. Ruptured Posterior Capsule: When posterior capsule is ruptured, surgeon must attempt to stop the expansion of the tear, avoid vitreous loss, and prevent a dropped nucleus.

The most important step to manage a ruptured posterior capsule is to notice it as soon as it is happening. Suspicious signs include sudden unexpected increase in AC depth, failure of a fragment to come forward, downward movement of nucleus fragments, or seeing the actual tear.

When the surgeon realizes that the posterior capsule has been ruptured, the best next action is to stop emulsifying the nucleus and remove the phaco tip from the eye. The surgeon then fills the AC with viscoelastic through the side port to prevent a flat anterior chamber that may lead to tear extension and vitreous loss. Remaining nucleus fragments should be removed manually through the main incision. Surgeon may need to enlarge the incision to accommodate a large piece. In general, remaining half of the nucleus will require at least 6 mm incision. Nucleus fragments may be delivered using two hooks or the irrigating BSS from anterior chamber maintainer (ACM). Surgeon must constantly maintain the anterior chamber depth with additional viscoelastic or ACM. Once all of the remaining nucleus fragments are removed, the surgeon inspects the anterior chamber for the presence of the vitreous by directly looking for the vitreous strand or noticing the peak of the tear or papillary margins.

If there is no vitreous in the anterior chamber, the surgeon proceeds with the irrigation and aspiration of the cortex. The irrigation bottle height should be lower by 50 - 60 cm. Once the entire cortex is removed, the anterior chamber is filled with viscoelastic through the side port. If the tear is small, the IOL may be placed in the capsular bag. However, for big tear, the IOL should be placed in the sulcus. Surgeon may consider performing posterior capsulorhexis to convert linear tear into a round tear to prevent tear extension. In case where the rhexis is smaller than the IOL and is without any weak point, the IOL optic may be captured behind the rhexis. If the IOL is captured, there is no need to lower the IOL power to compensate for the vertex distance. In the case where less than 2/3 of capsular support is remained, surgeon may consider performing scleral IOL fixation.

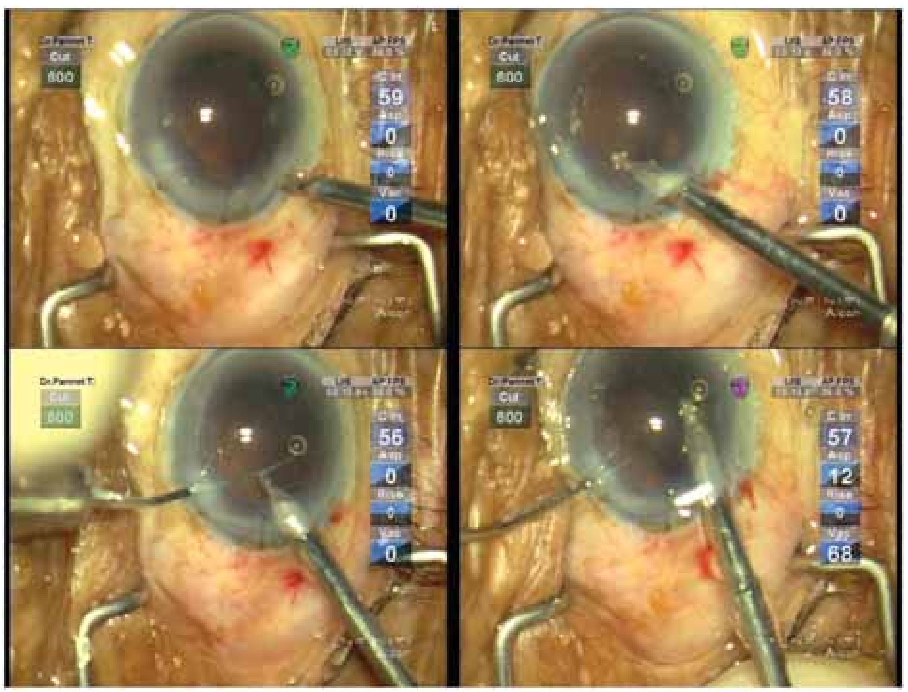


Convert to ECCE

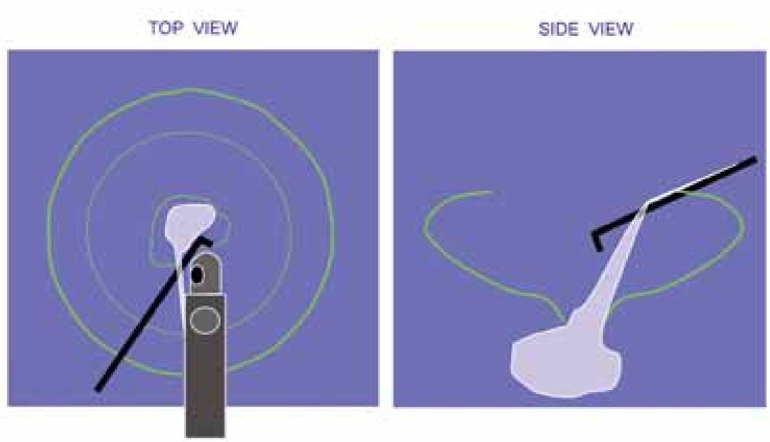
7.2. Vitreous Loss & Anterior Vitrectomy: Important considerations during the management of ruptured PC and vitreous loss are the traction on the retina and the PC tear extension. Surgeon must have a systematic approach when performing anterior vitrectomy. The procedure begins with the release of incarcerated vitreous in the wound followed by removal of vitreous in the anterior chamber near the pupil and then elimination of the vitreous from the anterior 1/3 of the vitreous cavity. It is important to notice and release the vitreous strand in the wound to prevent excessive traction on the retina.

For coaxial vitrectomy, the surgeon must avoid inserting the vitrectomy hand piece into the vitreous. This action may cause BSS misdirection leading to vitreous balloon up, vitreous displacement, and PC tear extension. Bimannual or biaxial anterior vitrectomy circumvents this risk by separating cutter from infusion hand pieces. An extra 1.5 mm incision must be created as well as enlargement of the side port.

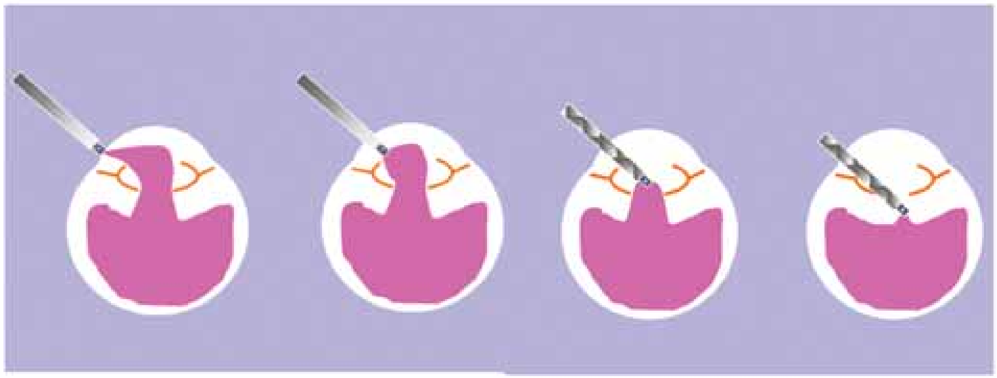
Anterior vitrectomy should be performed with the irrigation bottle height lower to about 30 cm from the patient's eye level to prevent BSS misdirection. In some case, surgeon may consider using triamcinolone staining to enhance visualization of the vitreous and increase efficiency of anterior vitrectomy.



Clear out incarcerated vitreous



Vitreous Strand Cutting

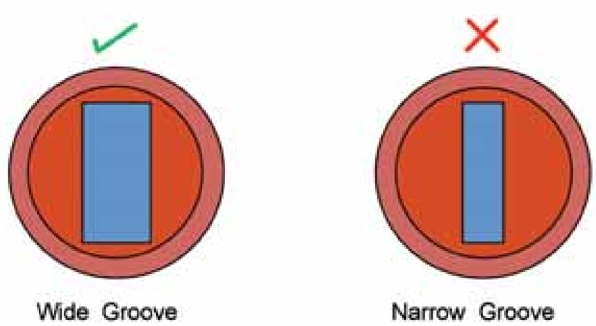


Coaxial anterior vitrectomy : " Top Down Technique "

7.3. Dropped Nucleus: A ruptured PC tear may lead to a dropped nucleus especially in the patient with preexisting vitreus syneresis. If the dropped nucleus remains just beneath the posterior capsule, it may be rescued with viscoelastic levitation and two Sinski hooks. Some surgeons prefer posterior levitation by lifting the dropped nucleus back into the AC through a pars plana sclerotomy. These techniques may cause vitreous traction and retinal tear. Therefore, detail post-operative fundus examination is essential. The nuclear fragments that are dropped to far down into the vitreous cavity should be removed with pars plana vitrectomy. This can be done at the same time if possible. However, the surgeon may choose to perform anterior vitrectomy, cortical removal, IOL placement, and close the wound. Then a retinal specialist removes the dropped nucleus at a later date.

8. Complicated Cataract Surgery

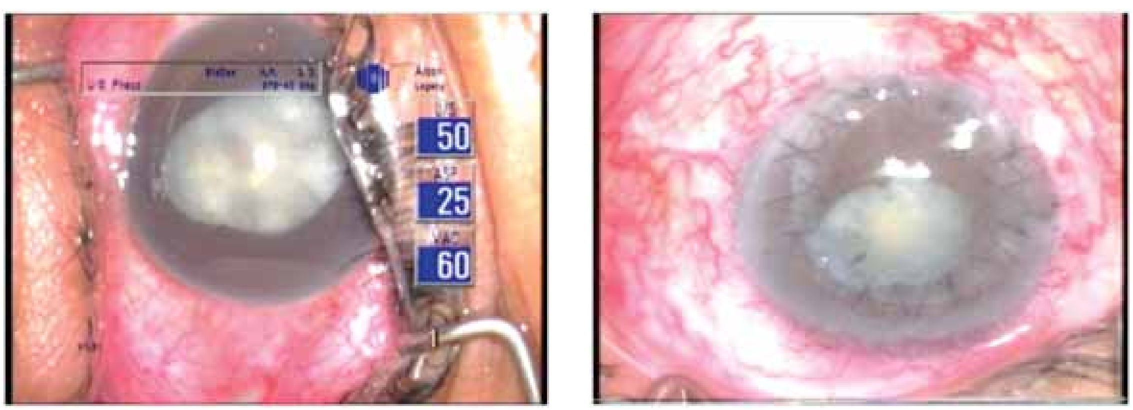
8.1. Hard Nucleus: There are many strategies to deal with hard nucleus. The incision should be 2.75 mm incision or larger to prevent wound burn. A capsulorhexis must be at least 5 mm to ensure nucleus manipulation without excessive stress on the zonule. Surgeon should only perform minimal hydrodissection to prevent hydro rupture. The groove must be wide, long, and deep to facilitate cracking. Emulsification efficiency can be enhanced using a bevel down technique. 3D cracking will allow the cracking of hard nucleus using minimal forces. Surgeon should do multiple chopping and create a clean and complete separation in order to reduce the stress on the zonule and to minimize heat generation.



Groove Dimension for Hard Nucleus

8.2. Mature Cataract: White mature cataract presents difficulty during capsulorhexis as is previously described in capsulorhexis section. There is no need to perform hydrodissection. White cataract may present with various level of hardness. The surgeon must select appropriate surgical technique based on the lens density. Occasionally, the patient may develop capsular fibrosis and brittle capsule. Surgeon must take special precaution during capsulorhexis not to force too much stress on the capsule. Surgeon may also find that the nucleus is difficult to rotate due to cortical fibrosis. In some case, most of the cortex is liquefied and is easily removed except near the equator. The surgeon must reach deeper than usual to remove this remaining cortex. It is important to avoid accidental capturing of the capsule at the equator leading to excessive stress on the zonule.

8.3. Phacomorphic Glaucoma: An intumescent mature cataract may cause phacomorphic glaucoma resulting in high intraocular pressure (IOP) and very shallow anterior chamber. The IOP should be brought under control with anti glaucoma medications and hyper osmotic agents before proceeding with cataract surgery. In case of very shallow anterior chamber, the surgeon may not be able to form the AC with maximum injection of viscoelatic. The surgeon may need to drain the liquefied cortex as described in the capsulorhexis section. This maneuver may allow additional injection of viscoelastic. If the AC still remains shallow, the surgeon must consider to possibility of fluid misdirection from malignant glaucoma. In that situation, the AC can only be formed after performing the pars plana tap. Any manipulation of the vitreous requires careful post-operative retinal examination to rule out possible retinal tear. Cataract surgery under the setting of uncontrolled or poorly controlled glaucoma puts the patient at risk for choroidal effusion or suprachoroidal hemorrhage. Sometimes, this risk is unavoidable. However, it should be mitigated by avoiding prolong flat chamber.



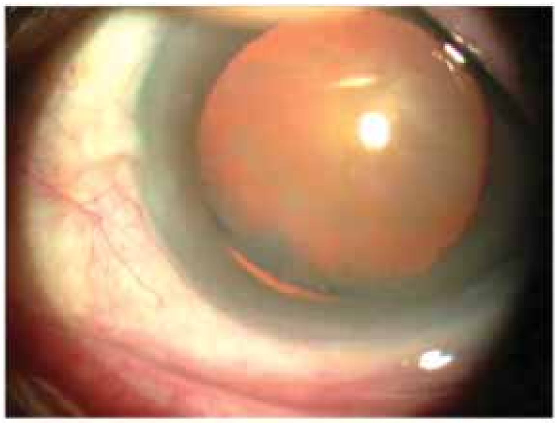
Phacomorphic glaucoma

8.4. Loose Zonule: The loose zonule may associate with diseases such as pseudoexfoliation syndrome or Marfan syndrome. It may also be caused by previous ocular trauma. In case where there is severe zonular weakness or len subluxation, the surgeon may need to perform intracapsular cataract extraction (ICCE) or pars plana lensectomy/ phacofragmentation.

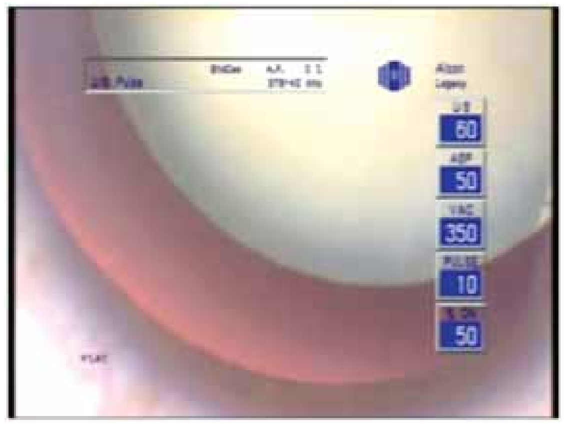
Several strategies may facilitate nucleus management while minimize stress on the zonule. The capsulorhexis must be 5 mm or larger. The surgeon must perform hydrodissection well. The surgeon should consider minimal rotation technique such as triangular cracking technique. The surgeon should ensure clean and complete separation of nucleus fragments. In some cases, capsular tension ring (CTR) may be helpful. Occasionally, the surgeon may use the iris retractor to support the capsular bag.

In cases with soft nucleus and loose zonule, the surgeon may create a large capsulorhexis and hydrosubluxate the nucleus in front of the anterior capsule but behind the iris then perform phacoemulsification in that position. This so called supracapsular phaco reduces the stress on the zonule.

If the zonule are not too weak, the IOL may be place in the capsular bag.

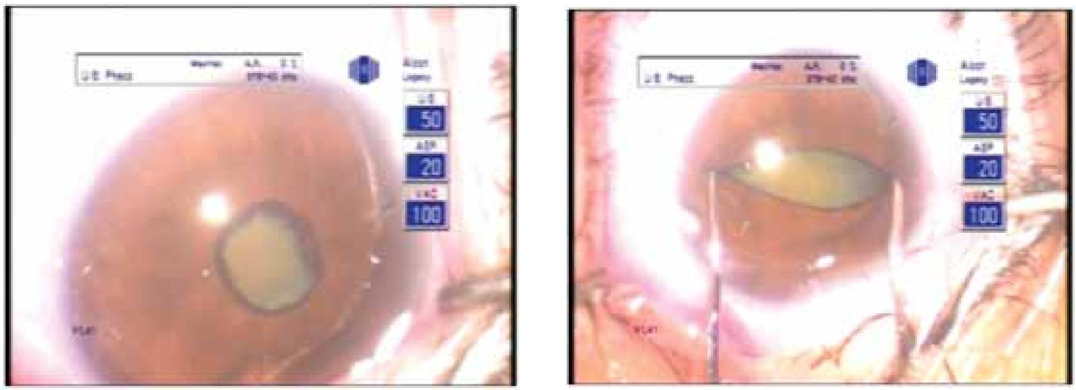


Traumatic zonular dialysis

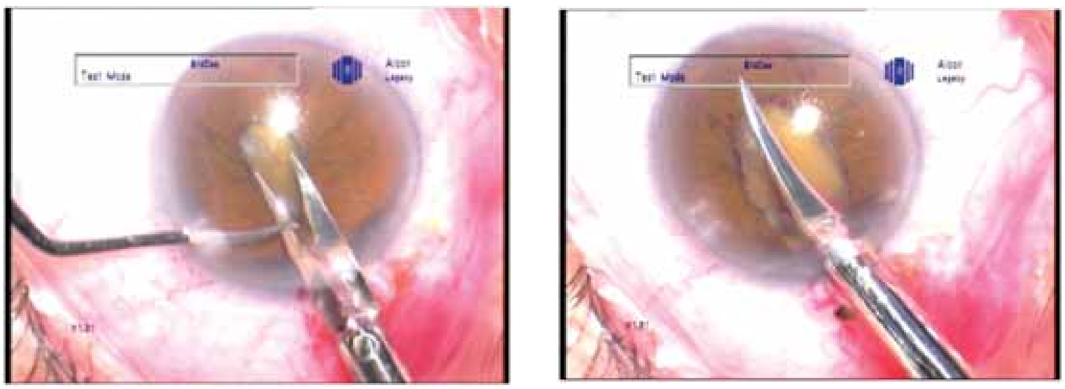


Marfan syndrome

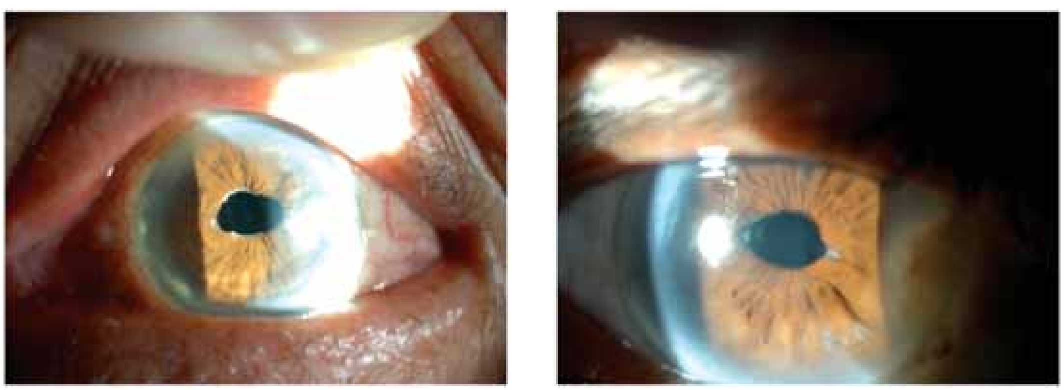
8.5. Small Pupil: In the case with posterior synechia, the pupil can be enlarged by the lysis of synechia at the pupillary margin and between posterior surface of the iris and anterior capsule. Sometimes the surgeon may also need to remove the fibrosis from the pupillary margin. If there is no synechia or the pupil may remain too small even after the lysis, the pupil may be stretched using two hooks. Surgeon may also use iris retractors to enlarge the pupil at four positions. Surgeon may decide to perform sphincterectomy. The undilated pupil usually remained 3 - 4 mm post-operatively after spincterectomy. This is usually adequate for fundus examination or laser treatments. Since patients with small pupil may require frequent examination of the retina, this slightly enlarged pupil should be considered beneficial. Surgeon performs the largest possible capsulorhexis after enlarging the pupil. Occasionally, to achieve adequate capsulorhexis, the surgeon needs to visualize the unseen position of the capsular flap underneath the iris.



Pupil Stretching



Sphincterectomy-sphincterotomy



Post-op sphincterectomy-sphincterotomy

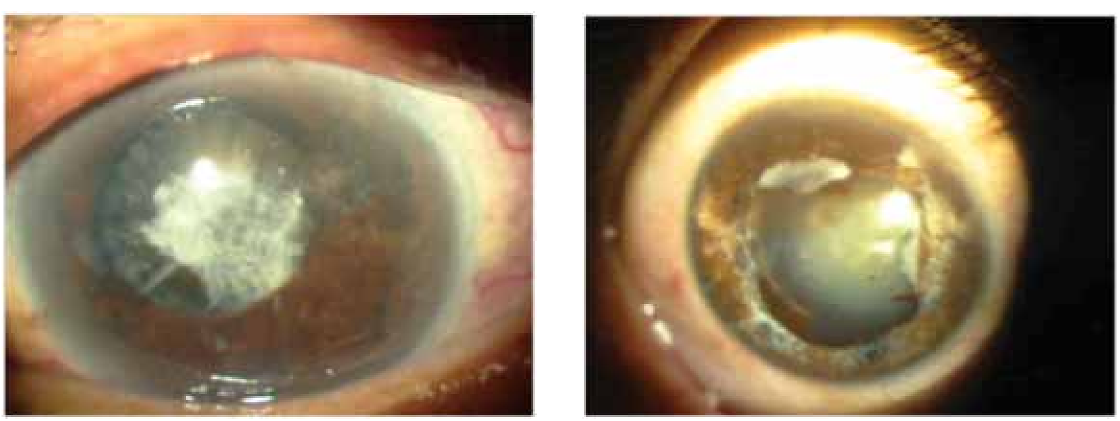
8.6. Posterior Polar Cataract: This type of cataract is usually caused by a congenital defect in the posterior capsule. But it may also be the result of thinning or true defect in the posterior capsule that develops after birth. The capsular defect leads to localized fibrosis and cataract. A thick plaque at the center of the posterior capsule characterizes this cataract. There may be a radiating opacity at the edge of the plaque. Posterior polar cataract may develop in one or both eyes. For younger patient, surgeon needs to anticipate that the defect may be more severe causing the rapid development of cataract.

The surgeon must avoid hydrodissection since the defect posts risk for posterior hydro rupture. Instead, the surgeon performs a hydrodelineation by injecting the BSS into the epinucleus until the golden ring sign is observed. The resulting epinuclear shell will help protect the capsular bag while the nucleus is disassembled using the technique appropriate to the nucleus density.

Since the posterior pressure from the vitreous may cause PC tear from the defect, it is essential to avoid flat AC through out the procedure. The surgeon must fill the anterior chamber by injecting the viscoelastic through the side port before removing the phaco or I/A hand pieces. Surgeon should not polish posterior capsule to avoid the risk of tear. After the IOL placement, the surgeon may form the anterior chamber with air bubble.

Posterior Polar Cataract

8.7. Traumatic Cataract: Surgeon must exercise caution in the case with rupture of the lens capsule since there may be associate posterior capsule rupture. In blunt trauma, there may be subcapsular fibrosis in the anterior or posterior capsule. Trauma may or may not lead to zonular rupture. Whenever possible a careful gonioscopic and fundus examination should be performed before surgery to rule out angle recession, choroidal rupture, retinal detachment, and optic atrophy. The surgical technique must be adjusted, as discussed in previous sections, to cope with damages from the trauma such as weak zonule or lens dislocation.



Traumatic Cataract