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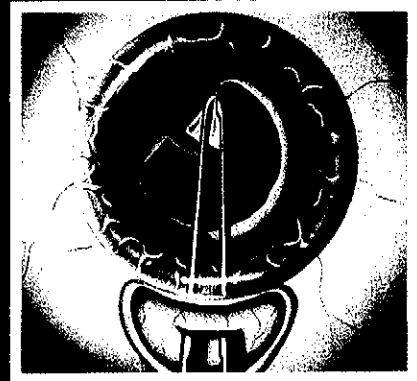
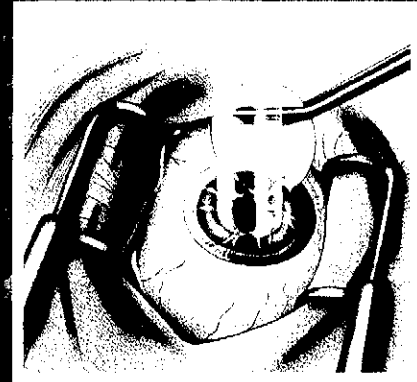
June 1998

# Operative Techniques in Cataract and Refractive Surgery

Editor Richard Elander, MD

Phacoemulsification  
Techniques

I. Howard Fine, MD  
Guest Editor



# Operative Techniques in Cataract and Refractive Surgery

**Editor:**

Richard Elander, MD

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**Editorial Correspondence** should be addressed to Richard Elander, MD, Elander Eye Medical Group, 242 26th Street, Santa Monica, CA 90402.

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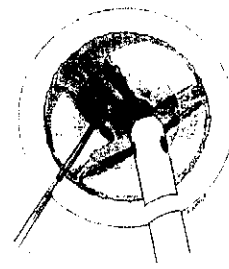
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# Operative Techniques in Cataract and Refractive Surgery

Vol 1, No 2

June 1998

## Introduction

**T**his edition of *Operative Techniques in Cataract and Refractive Surgery* focuses on phacoemulsification techniques. There has been a rapid evolution in phaco techniques over the past 5 years, due in large part to the enormous advances in phacoemulsification technology that have become available to cataract surgeons.

Charles Kelman was the first surgeon to actually do endolenticular phacoemulsification by grooving the nucleus in the posterior chamber in the meridian of the incision, cracking it with a Ringberg ENT forceps, and then bringing each of the hemi-nuclei up into the anterior chamber for consumption. Dr Kelman believed that this technique was too difficult for most of the surgeons he was training in transition to phacoemulsification because they were also untrained in the use of the operating microscope. He therefore emphasized anterior chamber techniques, which were really the most commonly used techniques during the first decade of phacoemulsification. These nuclei were essentially consumed by ultrasound energy by removing nuclear material from outside-in.

In the second decade of phacoemulsification, the initial emphasis was on posterior chamber phaco as introduced by Bob Sinskey and Dick Kratz. Later, Kratz's technique of two-hand pupillary plane phacoemulsification became the predominant technique, having been popularized by Bill Maloney in his "Three Steps to Phaco" courses.

In the beginning of the third decade of phacoemulsification, because of the enormous advantages of continuous curvilinear capsulorhexis for early and late centration of intraocular lenses, surgeons turned to endocapsular phacoemulsification. Initially surgeons tried sculpting through the small circular capsulorhexis, within the substance of the nucleus, down to a posterior plate, which then was difficult to mobilize and remove. Howard Gimbel was the first to systematize endolenticular phacoemulsification techniques using the nucleofractis techniques of crater and trench divide and conquer, which essentially were cracking techniques. These were refined by John Shepherd in his phacoemulsification in situ technique with cruciate grooving and cracking into quadratic segments, which were initially removed by tumbling. Subsequently, I introduced chip and flip phacoemulsification, a method of circumferential division of the nucleus into a central endo-

nucleus and a soft outer epinuclear shell. Bill Maloney, David Dillman, and I then introduced crack and flip phacoemulsification, which combined the safety of working within an epinuclear shell with the efficiency of cracking techniques.

A new innovative technique for disassembling the nucleus and removing it from inside-out, as all of the endolenticular techniques were designed to do, was introduced in 1993 at the ASCRS meeting in Seattle by Kunihiro Nagahara, who showed us chopping. However, in his initial demonstration and video, the large segments of nuclear material were brought up into the anterior chamber after chopping. This seemed to be enough of a disadvantage that few surgeons adopted this technique. Independently, Paul Koch and Roger Steinert developed methods of combining some sculpting with chopping in a technique now known as stop and chop. This was essentially a combination of cracking and chopping.

All of the endolenticular techniques benefited from some of the new and improved technology introduced in the early 1990s, which included better cutting systems, higher vacuum capabilities, and much more stable fluidics. The introduction of microprocessor control of these different functions added additional capabilities for control and safety.

In the mid-1990s, we have seen most systems develop along the lines of higher-vacuum cassettes, downsized phaco tips, new tip configurations, and most importantly power modulations. These have led to a major interest in chopping techniques and, for some, a return to pupillary plane techniques. In this issue, we will see several ways of hydroexpressing the nucleus into the plane of the pupil for consumption, again from outside-in, as in the articles by David Brown and Dick Lindstrom. Most of the other articles represent variations of chopping techniques using some aspect of the newer technology available in the mid-1990s.

I think that readers will enjoy seeing the variety of possibilities for nuclear removal as described by authors who are all excellent technicians as well as experienced teachers. It is hard to imagine anyone reading this issue and not finding some way to modify and improve his or her technique.

I. Howard Fine, MD  
Guest Editor

# Slow-Motion Phacoemulsification

Robert H. Osher, MD

Slow-motion phacoemulsification is the name of the technique that I developed in 1984 for safe emulsification of the nucleus. By reducing the aspiration rate, the vacuum, the infusion, and the ultrasonic power to unprecedented low levels, the most precise control of the nucleus is possible. Although this technique is highly effective in routine cataract surgery, it has its greatest benefit in challenging cases such as loose lenses, small pupils, positive pressure, mature cataracts, and when coexisting endothelial dystrophy is present. Although not the fastest technique, the lack of trauma to the cornea and lack of movement of the posterior capsule and iris make slow-motion phacoemulsification among the safest of all current techniques.

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## Anesthesia

I have worked with one nurse anesthetist for more than a decade, and she gives a wonderful retrobulbar block. Because I have not encountered any problems with her technique or complications related to her injection, there has been little motivation to change to a different method of anesthesia. In cases with a high risk of bleeding, topical anesthesia is my preference.

## Incision

The incision that I prefer is a mid-limbal approach in most cases. This incision is usually placed in the superotemporal quadrant, where the access to the globe is optimal and independent of the anatomy of the bony orbit. Of secondary importance is the axis of the steepest meridian of curvature, although I routinely perform astigmatic keratotomy for more than 2 diopters of preexisting cylinder. Yet I am comfortable with the clear corneal incision if the patient has a preexisting filtering bleb, scleromalacia with rheumatoid arthritis, ocular

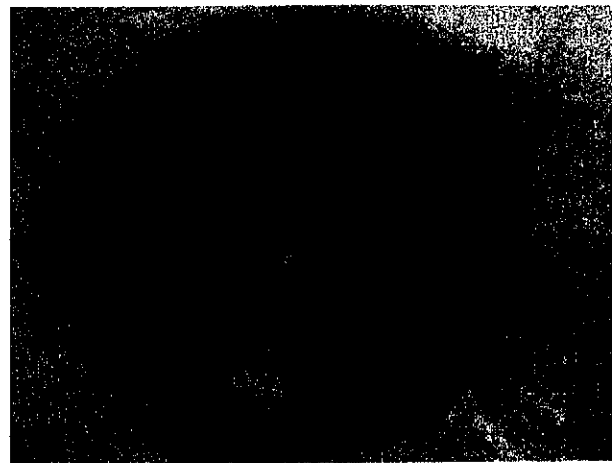


Figure 1. The central trough.

cicatricial pemphigoid, or is on anticoagulant therapy. The incision is constructed with an initial vertical groove using a guarded diamond knife (Duckworth & Kent 5-600; Duckworth & Kent USA Ltd, St Louis, MO) followed by anterior dissection into clear cornea with a trifaceted diamond knife (Storz E0108; Storz Ophthalmics, St Louis, MO). The incision length varies between 3.5 and 6.0 mm, depending on whether an acrylic, silicone hydrogel, or polymethylmethacrylate (PMMA) lens insertion is planned.

## Capsulotomy

After the anterior chamber has been entered, Healon GV (Pharmacia & Upjohn Inc, Kalamazoo, MI) is injected into the eye. This viscoelastic agent is my first choice because of its excellent chamber-deepening characteristics and its bubble-free visibility. The capsulorhexis is performed with a 22-gauge needle and is between 5.5 and 6.5 mm in diameter. Although more difficult to perform, I believe that a larger rhexis is safer and facilitates the surgical procedure while minimizing the likelihood of postoperative problems. The diameter of the

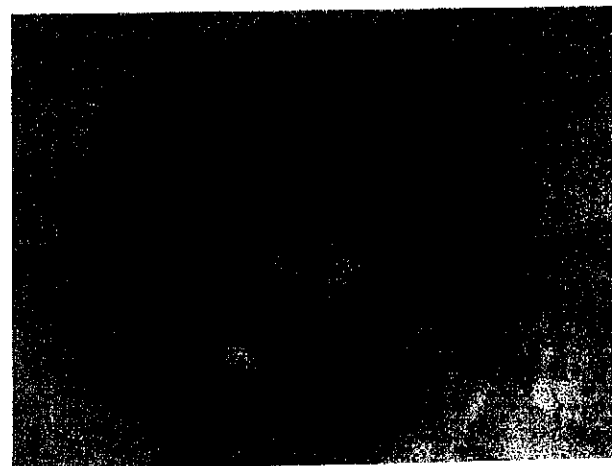


Figure 2. The nuclear split into hemispheres.

From the Cincinnati Eye Institute, Cincinnati, OH.

Address reprint requests to Robert H. Osher, MD, Cincinnati Eye Institute, 10494 Montgomery Rd, Cincinnati, OH 45242.

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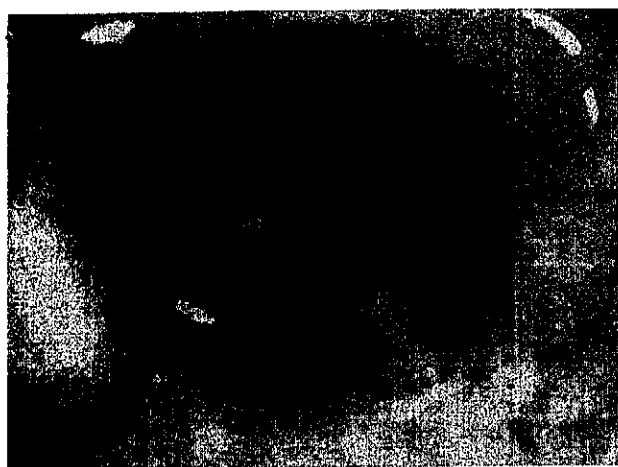


Figure 3. The chop into two quadrants.

rhesis is deliberately reduced in the pediatric eye, however, because the elasticity of the capsule encourages the edge to run toward the periphery. A smaller rhesis is also helpful in cases with preexisting zonular dialysis. The rhesis is initiated approximately 120 degrees opposite the incision entry, more centrally to ensure finishing outside of the starting point. The continuous tear is only modified in a white cataract, where the initial puncture is even more central. If the lens is white and firm, I try to complete the rhesis with minimal disengagement of the capsule but may need to switch to either a forceps or a mini can opener, which will be enlarged and converted to a continuous tear at a later point in the procedure. If the lens is white and intumescent, I aspirate the soft cortex through the initial puncture to lower the intralenticular pressure, reducing the tendency for the rhesis to run. If the lens is white and Morgagnian, the liquefied cortex is aspirated, and the lens bag is refilled with Healon GV. Occasionally a scissors is necessary to complete the capsulotomy in this type of cataract, but the initial puncture should be placed near the incision because introducing the scissors allows cutting away from (not toward) the incision site. The same rules apply to the leathery fibrotic capsule.

### Hydrodissection

The hydrodissection is accomplished with a 27-gauge cannula (safer than a 30-gauge) on a 3-cc plastic syringe placed under the edge of the capsule in several locations. The injected stream



Figure 5. Rotating the remaining hemispheres.

of BSS is gentle while applying intermittent downward pressure on the lens to facilitate the posterior fluid wave while preventing the endocapsular pressure from rising too high. Very limited hydrodissection is recommended in cases with zonular dialysis or posterior polar cataract when there is a risk of either posterior misdirection of balanced salt solution (BSS) or capsular rupture.

### Phacoemulsification Technique

In 1984, I introduced the phacoemulsification technique, known as "slow-motion phaco," which takes advantage of the reduction of all parameters. Initially the machine manufactured by United Surgical Corporation was the only one that offered this versatility. Although most of the manufacturers have since modified their machines to permit reduced parameters, I prefer the Alcon Legacy Series 20,000 (Alcon Surgical Inc, Ft Worth, TX). This machine has been in each of our four operating rooms for the past 3 years, with a stellar track record for performance and reliability. The tip selection depends on the type of cataract, 30-degree round (30R+ Alcon) in routine cases and a 30-degree Kelman tip (30KT) for the yellow or brunescient nucleus. The aspiration rate is set between 20 and 25 cc/min, the vacuum is reduced to 10 mm Hg, and the phaco power is surgeon-controlled with a maximum of 60%. The infusion is continuous, and the bottle height, which is adjusted with an automated foot switch, is set so that a single stream projects from the limbus to the mid pupil as the handpiece is





Figure 7. Last quadrant emulsified.

held parallel to the iris just above the incision. The reduced infusion minimizes the turbulence inside the eye, which allows the Healon GV to remain in the anterior chamber throughout most if not all of the emulsification. The surgeon must remember to check the phaco functions before entering the eye and then to remove a small quantity of viscoelastic material just above the surface of the lens to ensure good fluid exchange at the tip to avoid the possibility of a thermal burn. The main benefit of slow motion phaco is maximum safety because neither the iris nor the posterior capsule moves toward the tip. Moreover, the corneas appear crystal clear in most eyes on the first postoperative day.

The specific technique depends on the hardness of the nucleus. If relatively soft, a one-handed rotational technique is easily performed whereby the peripheral nucleus is removed 360 degrees and the remaining posterior plate is tilted and emulsified. If the nucleus is hard enough to crack, a layer of anterior cortex is cleared to both mark the anterior capsular edge and to get the phaco tip below the level of the capsulorhexis. Then a long deep central groove is sculpted (Fig 1), and the nucleus is divided into hemispheres (Fig 2) with the Osher nucleus chopper (Storz E612). After rotating the nucleus 90 degrees, the preset vacuum is increased to 25 mm Hg. (Memory 2) and the hemisphere is either chopped or divided into quadrants (Fig 3). The apex of each quadrant is tipped anteriorly and emulsified (Fig 4). The remaining nuclear hemisphere is rotated 180° (Fig 5), chopped (Fig 6), and

removed in the same fashion (Fig 7). If the nucleus is hard, the more efficient cutting Kelman tip is used, and quadrant removal is accomplished by raising the vacuum level to 50 mm Hg (Memory 3) with a concomitant slight elevation in the bottle height. If an epinucleus remains, it is aspirated with the phaco tip. There are many variations in the overall theme, but this technique allows safe and efficient emulsification regardless of the pupil size, zonular integrity, or cataract type.

### Cortical Aspiration

The cortex is removed with a 0.3-mm irrigation and aspiration (I&A) tip with an aspiration rate of 16 cc and a vacuum ceiling of 400 mm Hg. The rise time is surgeon-controlled by the footswitch accelerator. The fundamental principles include grasping only the most proximal portion of the anterior cortex, stripping as the vacuum builds, and rotating the port away from the posterior capsule as the cortex is aspirated. I strongly recommend that the cortex be initially removed closest to the incision. By doing so, the cortical bowl serves to keep the capsular bag open during the removal of the most difficult cortex. By contrast, if the subincisional cortex is left until last, the capsular bag will have its greatest tendency to close, further adding to the difficulty of this task. If the subincisional cortex cannot be safely removed, a J-shaped 27-gauge cannula (Storz E-4420) is used to remove the cortex after the capsular bag has been filled with Healon GV in preparation for the lens

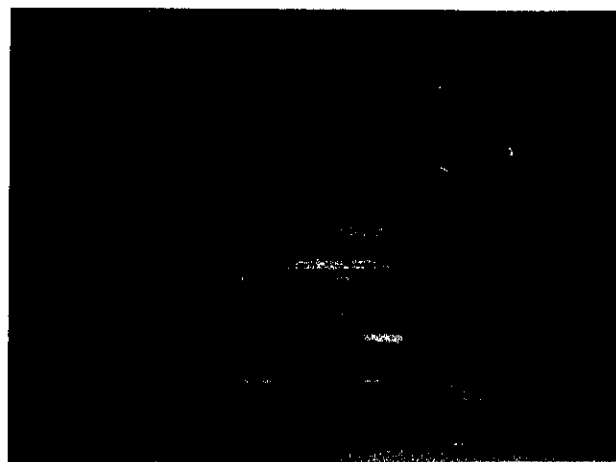


Figure 9. IOL is irrigated with warm BSS.

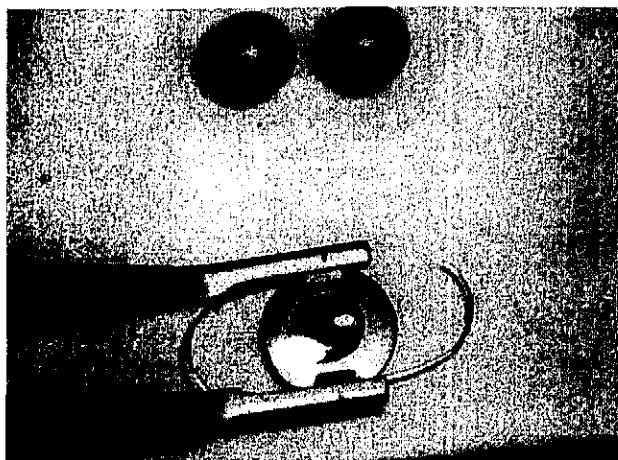


Figure 8. Folding forceps lift acrylic IOL off post.



Figure 10. IOL is folded over two mushrooms.



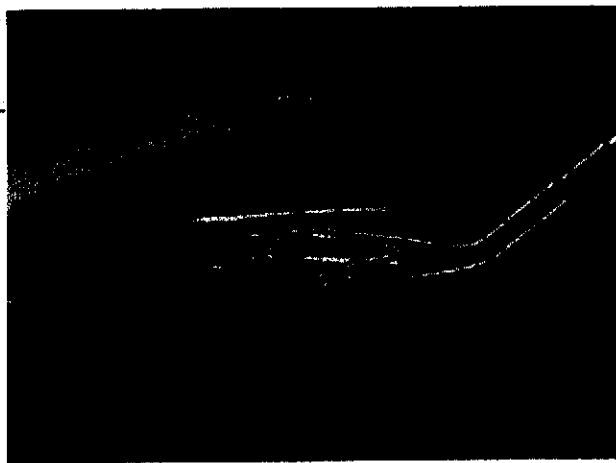


Figure 11. IOL is transferred to insertion forceps.

implantation. A dry cortical removal with the chamber filled with Healon GV is occasionally necessary if there is a capsular tear, zonular dialysis, or extensive positive pressure. The optimal size of the cannula varies, depending on which viscoelastic agent is used. Residual wispy ribbons of cortex are best removed with a smaller-gauge cannula, which allows better occlusion of the tip.

### Cleaning of the Posterior Capsule

Once the cortex has been completely removed, I prefer to vacuum the posterior capsule unless the capsule is extremely thin (posterior polar cataract) or inordinately loose. The aspiration rate is set at 5 cc/min, and the vacuum is set at 11 mm Hg, increasing to 13 or 15 mm Hg if a capsular plaque is present. The central capsule is always vacuumed first to prevent an uncontrolled capsular tear were it to occur, as in the rare instance of a burred tip. Occasionally I fill the anterior segment with Healon GV and use a 27- or 30-gauge cannula to vacuum off a dense plaque. Another trick called the minimal aspiration technique is useful when the posterior capsule is especially fragile or spidery. I will vacuum during a staccato depression and release of the foot peddle, preventing the vacuum from building up too high as the tip is moved back and forth quickly across the posterior capsule.



Figure 12. Leading haptic placed into bag as IOL unfolded by supination.

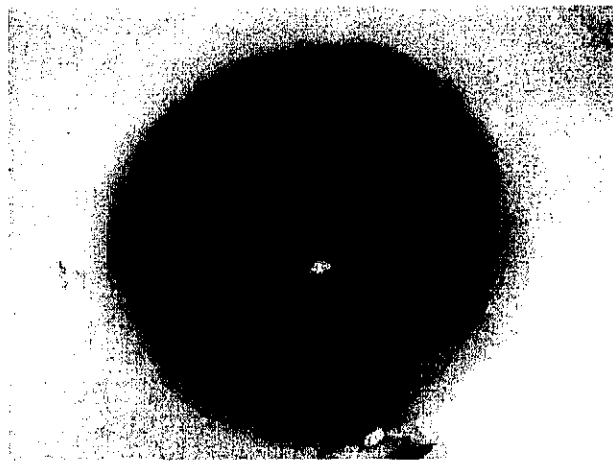


Figure 13. Trailing haptic is placed into capsular bag with Y-hook.

### Implantation of the IOL

After filling the capsular bag with Healon GV, the wound is enlarged to 3.5 mm with a diamond keratome if a 6.0-mm hydrogel or acrylic optic is to be implanted. I prefer a foldable intraocular lens (IOL) with PMMA haptics in most of my cases. The acrylic lens is grasped with the Seibel-Osher folding forceps (Storz E2976) from the 6- to the 12-o'clock positions (Fig 8), irrigated with warm BSS (approximately 100°F) (Fig 9) and folded over the titanium mushrooms on the Osher Platform (Duckworth & Kent) (Fig 10). The lens is transferred to the titanium Osher lens forceps (Duckworth & Kent) (Fig 11) and inserted in a supinating motion (Fig 12). Once the leading haptic and the optic are within the capsular bag, an Osher Y-hook (Storz E0577) is placed into the crotch of the trailing haptic/optic junction and rotated into the bag (Fig 13). If a larger 6.0-mm PMMA optic has been selected for any number of reasons, the wound is enlarged with the trifaceted diamond knife, and the incision size is confirmed with the Osher internal caliper (Storz #E2419). The single-piece PMMA lens is implanted by controlling the trailing haptic with an Osher biangle hook (Storz E0573MNI) that is placed into the eyelet and released in the bag. Regardless of the IOL type, the optic is rotated until the lens appears to be best-centered (Fig 14).

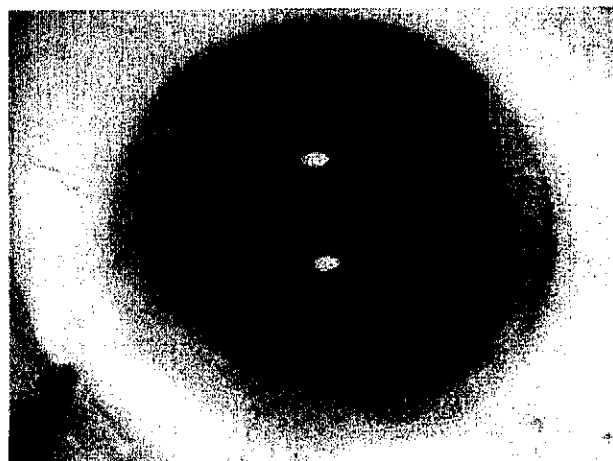


Figure 14. IOL well-centered.

### Viscoelastic Removal and Closure

Complete removal of the viscoelastic is especially easy with Healon GV. I place a 27-gauge cannula on a 3-cc plastic syringe filled with 1 cc BSS solution behind the optic and aspirate the Healon GV, which readily follows itself into the cannula until all is gone. I reinject a portion of the viscoelastic in front of the optic to deepen the anterior chamber before withdrawing the cannula. Miochol (CibaVision, Atlanta, GA) is instilled to constrict the pupil and confirm optimal centration of the IOL. The water tightness of the 3.5-mm wound is confirmed, and the incision is left sutureless. If a 6-mm incision has been made for a rigid PMMA IOL, a single horizontal 10-0 nylon suture is

passed to assure a watertight closure. A miniature I&A tip (Storz E4973) is placed into the anterior chamber, and the remaining Healon GV is completely removed and exchanged for BSS solution. The conjunctiva is reapproximated with the coaptation cautery completely covering the incision, and any elevated tissue is trimmed flush to prevent a foreign body sensation on the first postoperative day.

In conclusion, my practice is limited to cataract surgery by referral, and I have a high percentage of one-eyed and challenging patients. I believe that the procedure described offers the patient an extremely safe, modern, yet time-tested operation.

# "Phaco-Chop" or "Divide and Conquer"

Samuel Masket, MD

New phacoemulsification methods and equipment offer the opportunity to obtain uniformly good results in most case types. Certain principles should guide the surgeon to avoid complications when adapting to new methods. Safe nuclear chopping is best accomplished with high-vacuum systems designed to pull the nucleus away from the capsule for chopping under direct visualization. I have developed a "Half-Stop and Chop" method that can be used in most cases. This technique allows reduced sculpting time, easy lens division, and the ability to chop in direct view. However, for a minority of cases, in particular those with small pupils or very dense nuclear cataracts, I continue the use of a traditional divide and conquer method, because this appears safer for eyes in these categories. Very soft cataracts may be simply aspirated. Surgical flexibility is greatly aided by new phacoemulsification devices, such as the AMO Diplomax (Allergan, Inc, Irvine, CA), which I routinely employ. It offers software and hardware innovations that allow the surgeon to harness the positive aspects of vacuum achieved by tip occlusion, presents a menu with a variety of cutting modes, and is equipped with side switches in the foot pedal that allow the surgeon to shift memory modes as desired. Given the tremendous advantage and flexibility of new hardware and software technology, I can adapt to the demands of each case while retaining the principle of safety first and achieve reliable and reproducible results for virtually all patients.

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**E**volving techniques in cataract surgery have, as a rule improved on previous methods with respect to reduced rates of complications and acceleration of visual recovery. Recently, there has been an interest in nuclear chopping after the introduction of the method in 1992 by Nagahara.<sup>1</sup> The purported advantages of nuclear chopping include reduced phacoemulsification time, reduced surgical time, and lessened stress on the zonules. Other methods for nuclear disassembly require significant sculpting to create a series of grooves in the nucleus before fracturing, whereas chop techniques use natural "fault lines" in the nucleus for mechanical, rather than ultrasonic, disassembly. As a result, the corneal endothelium is exposed to less turbulence because ultrasound sculpting time is reduced. Nuclear chop also relies on higher vacuum levels than previous sculpting methods.

Nevertheless, it must be recognized that the nuclear chopping methods may not be ideal for all cases. As an example, eyes with small pupils make it impossible to view the end of the chopping device after it is placed under the iris and capsule to reach the nuclear equator. This violates a basic cataract surgical procedure that dictates that sharp instruments should never be used out of the surgeon's line of sight. Indeed, in

viewing many surgeons' videos of phaco chop, one can note that the sharp end of the chopper is passed out of view in many routine cases. Although no data have been presented or published, I am suspicious that both anterior and posterior peripheral capsule rupture are more common with phaco chop than with divide and conquer. Given that new surgical methods should not increase the risks for significant complications, divide and conquer phacoemulsification may be safer in small pupil cases and other conditions because it is a very reproducible and safe form of nuclear removal.

## Technological Advances Allow Flexibility

My current approach is a continuum of styles, afforded by the unique hardware and software of the AMO Diplomax phacoemulsification system (Allergan, Inc, Irvine, CA). As noted elsewhere,<sup>2</sup> the Diplomax offers innovative software that senses tip occlusion and allows the unit to vary both fluidic and cutting (phaco energy) behaviors according to customized and preprogrammed parameters. Once the tip is occluded with lens tissue and a preset vacuum threshold level is achieved for each of the three multimodulation memory positions (Memory 1, 2, or 3), the unit automatically changes the aspiration flow rate, hence vacuum rise time, and cutting mode to the desired format. Furthermore, the hardware incorporates side switches in the footpedal that allow the surgeon to shift up or down through memory positions, without the need for assistance.

Approximately 80% of cases in my practice are applicable to chopping methods; the remaining have either small pupils, soft cataracts, or advanced brunescant cataracts.

## Half-Stop and Chop

My preferred surgical method may be referred to as "half-stop and chop phacoemulsification." What has become the traditional nuclear chopping method avoids sculpting because the phaco tip is buried into the nucleus and the chopper employed to score the lens until cracks are created in the naturally occurring lens fault lines, the nucleus is disassembled, and the pieces removed. However, some surgeons note that it is difficult to break the nucleus apart, because there is little room to maneuver the lens.

Paul Koch,<sup>3</sup> in recognition of this dilemma, originated the concept of stop and chop, wherein a central 180-degree nuclear trough is sculpted and the nucleus is cracked only into hemisections, "stopping" the sculpting process. Each hemi-nucleus is then chopped, rather than sculpted, into any number of pieces according to the dictates of the lens and the style of the surgeon. Emulsification times are reduced when compared with traditional four-quadrant divide and conquer nuclear removal.

My preference is to further reduce sculpting time but to maintain the concept of cracking the lens into two pieces. This may be accomplished with a "half-stop" maneuver. The technique depends on the use of high vacuum and is well suited to

From the Jules Stein Eye Institute, University of California, Los Angeles, CA.

Address reprint requests to Samuel Masket, MD, Advanced Vision Care, 7320 Woodlake Ave, Suite 380, West Hills, CA 91307.

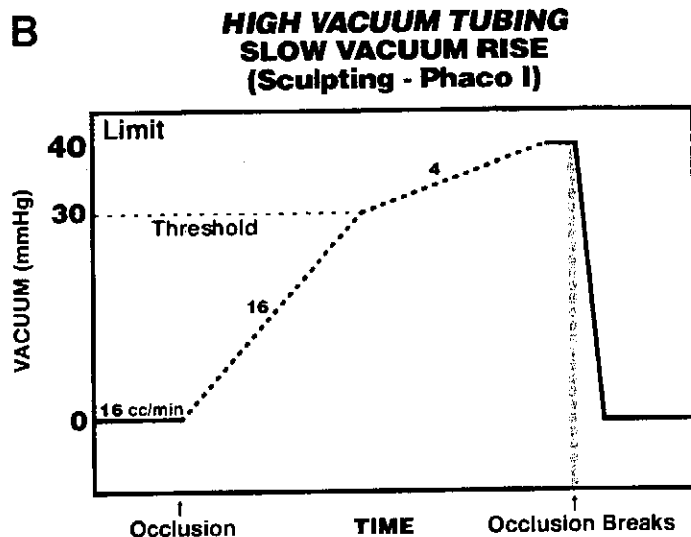
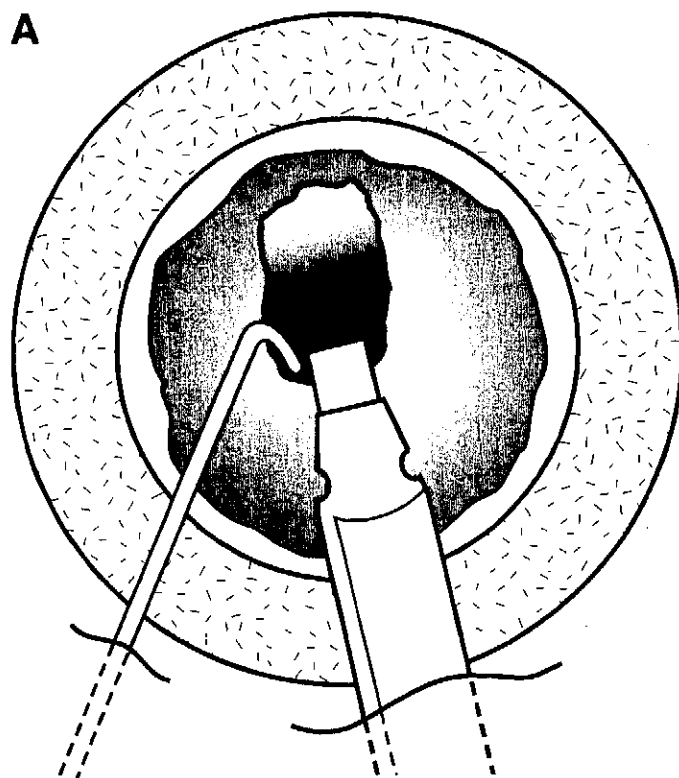
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the preprogrammable custom fluidics of the AMO Diplomax. After traditional capsulorhexis, adequate hydrodissection for lens rotation and cortex loosening, and hydrodelineation to define an epinucleus, a half groove is sculpted from the middle of the lens toward the periphery (Fig 1A) employing Memory 1 occlusion mode parameters for sculpting (Fig 1B, Table 1).

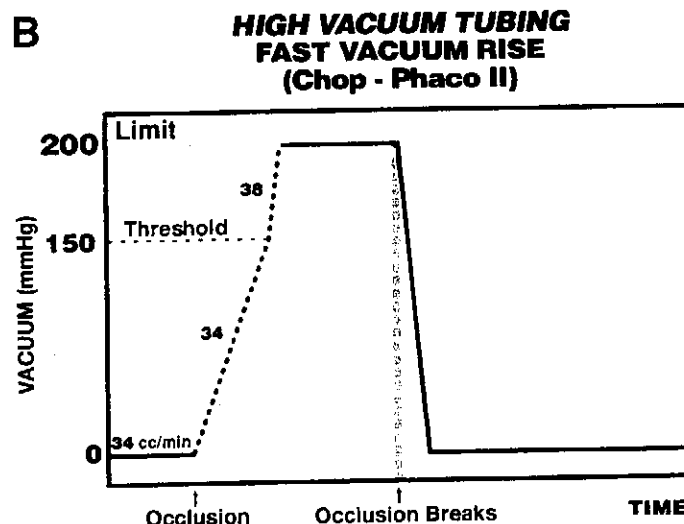
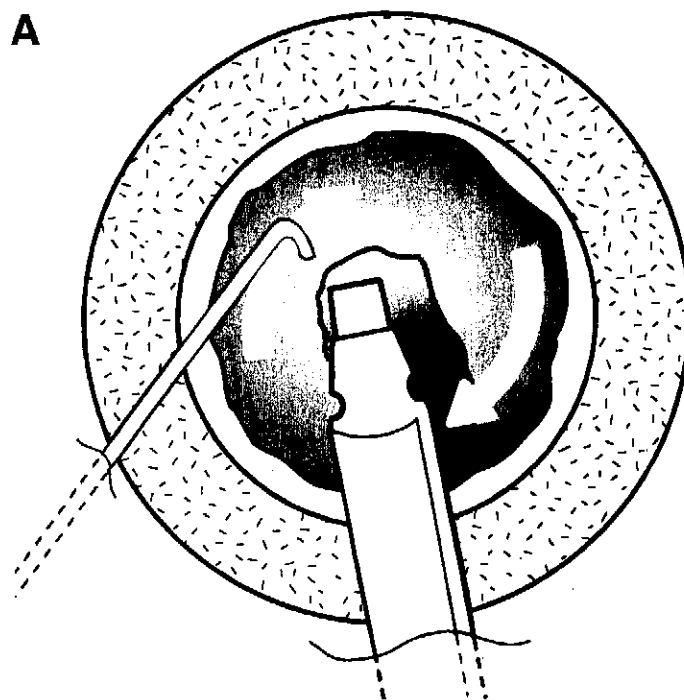
The nucleus is rotated 180 degrees, the unit shifted to the Memory 2 position with the side switch in the footpedal, and the phaco tip is embedded into the center of the endonucleus (Fig 2A), employing single 120-microsecond bursts of phaco energy in burst mode (Fig 2B, Table 2). It may be necessary to use several bursts or as few as one to achieve tip occlusion, varying with the density of the lens; I prefer to control the number of bursts with action on the footpedal rather than use

**TABLE 1. Memory Mode 1 Slow Vacuum Rise Parameters for Sculpting**

Unoccluded	Occluded
<b>Continuous</b>	Continuous
Pulse 40 ms	<b>Pulse 40 ms</b>
Pulse 60 ms	Pulse 60 ms
Pulse 80 ms	Pulse 80 ms
Power pulse	Power pulse
Single burst	Single burst
Multi burst	Multi burst
Burst continuous	Burst continuous
Power off	Power off



**Figure 1.** (A) A half groove is sculpted from the middle of the lens toward the periphery using Memory Mode 1. (B) Slow vacuum rise using Memory Mode 1 "Occlusion Mode" for sculpting (see Table 1 for parameters).



**Figure 2.** (A) The nucleus is rotated 180 degrees and the phaco tip embedded into the center of the endonucleus using Memory Mode 2. (B) Fast vacuum rise using Memory Mode 2 "Burst Mode" for tip occlusion (see Table 2 for parameters).

**TABLE 2. Memory Mode 2 Fast Vacuum Rise Parameters for Tip Occlusion and Chopping**

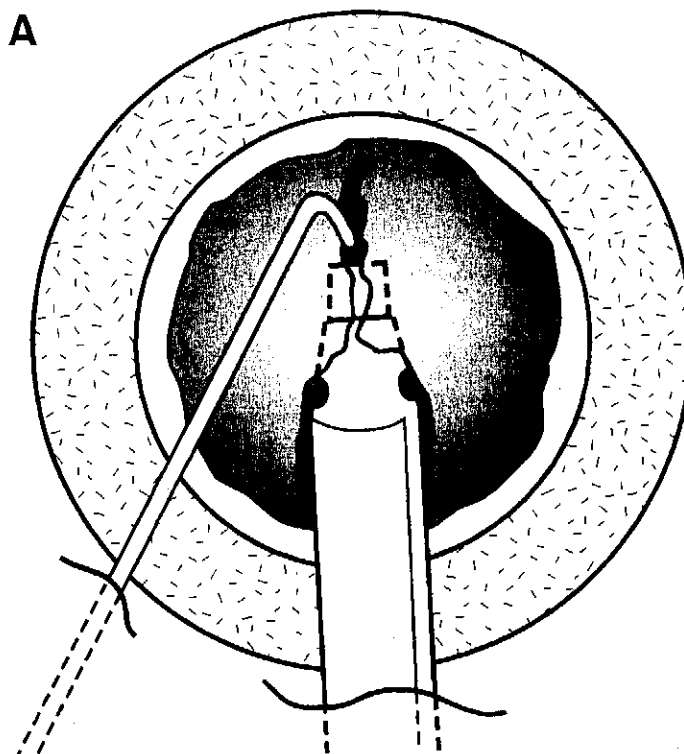
Unoccluded	Occluded
Continuous	Continuous
Pulse 40 ms	Pulse 40 ms
Pulse 60 ms	Pulse 60 ms
Pulse 80 ms	<b>Pulse 80 ms</b>
Power pulse	Power pulse
<b>Single burst</b>	Single burst
Multi burst	Multi burst
Burst continuous	Burst continuous
Power off	Power off

automated multiple bursts. (Once occlusion is reached, the power is preprogrammed to shift to pulse mode and will not return to burst mode unless the footpedal is first raised to irrigation-aspiration before it can reactivate phaco energy by depressing the pedal. This safety feature prevents the machine from activating an undesired energy burst after an occlusion break.)

With occlusion reached, I pause slightly to allow vacuum to build (the preprogrammed fluidics increase the pump speed to shorten vacuum rise time) and I draw the endonucleus away from the epinuclear shell. The edge of the endonucleus is pulled centrally, and a chopping instrument, held in the nondominant hand, can be used to score the nucleus under direct visualization, avoiding damage to the zonules, the anterior capsulorhexis, or the peripheral capsule (Fig 3A). Because half of a groove has already been sculpted, the nuclear scoring generally will result in a hemisection of the lens. The heminuclei are further subdivided with similar burst-occlusion-vacuum-chop sequences. Each chopped piece is removed by shifting the unit to Memory 3 (with the footpedal side switch; Fig 3B, Table 3), where less vacuum is beneficial (to prevent small nuclear pieces from breaking free), and pulsed energy mode assures egress of the nuclear segments with little expended phaco power. I generally chop and remove each fragment and then return the unit to Memory 2, chop another segment and again return to Memory 3 with the foot switch until the endonucleus has been removed. The epinucleus is removed in Memory 3; however, little to no phaco energy is required, because high flow brings the epinucleus into the tip, and I use a blunted second instrument, different from the chopper, to help feed in the material.

Should the initial half-chop method fail to subdivide the nucleus, or if the nucleus is either too firm (4+/4+) or too soft, I return the module to Memory 1 with the footswitch and sculpt a traditional full-length nuclear groove after 180-degree nuclear rotation. Nuclear cracking into hemisections is completed before returning to either a chopping sequence in Memory 2, further groove dissection for very firm lenses in Memory 1, or soft nuclear aspiration in Memory 3. For cases with small (3- to 4.5-mm) pupils, I generally hemidivide the nucleus, further sculpt and divide the first heminucleus into quadrants that are emulsified, and then chop the remaining heminuclear portion, because room is then sufficient to bring the nuclear half centrally and chop under direct visualization. Therefore, my surgical philosophy is to employ the safest and most efficacious means of nuclear removal in each case type. On occasion, the presurgical examination belies the nature of the nucleus; flexibility in the surgical plan is useful, as is the adaptability of the hardware and software of the AMO Diplomat unit.

A



B

**HIGH VACUUM TUBING  
CONTROLLED VACUUM RISE  
(Remove Quadrants/Epinucleus - Phaco III)**

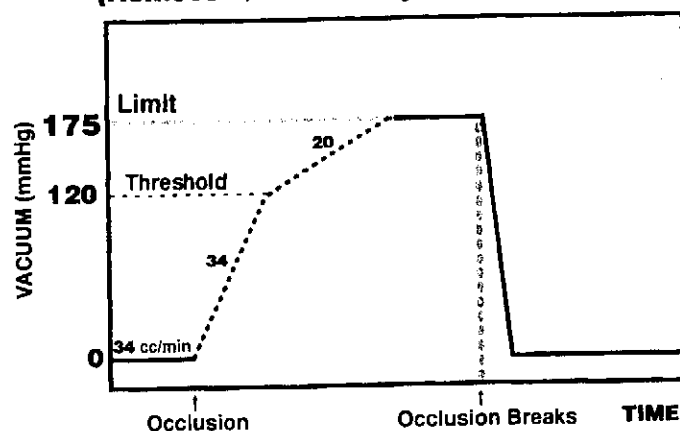


Figure 3. (A) The end of the endonucleus is pulled centrally, and the chopping instrument is used to score the nucleus under direct visualization using Memory Mode 3. (B) Controlled vacuum rise using Memory Mode 3 (see Table 3 for parameters).

**TABLE 3. Memory Mode 3 Parameters for Removing Quadrants and Epinucleus**

Unoccluded	Occluded
<b>Continuous</b>	Continuous
Pulse 40 ms	Pulse 40 ms
Pulse 60 ms	Pulse 60 ms
Pulse 80 ms	<b>Pulse 80 ms</b>
Power pulse	Power pulse
Single burst	Single burst
Multi burst	Multi burst
Burst continuous	Burst continuous
Power off	Power off

Given that safety is paramount in my agenda, I do not chop nuclei that are too firm to allow for hydrodelineation of the nucleus, because the absence of an epinuclear shell makes capsule rupture more likely during manipulations, and because space is greatly compromised with a large, rock-hard lens. Furthermore, sharp, long chopping instruments are required to cut through dense cataracts; as such they also pose a greater risk for capsule rupture. For cases of this nature I use a traditional divide and conquer method, sculpt with a 45-degree tip for cutting efficiency, crack the nucleus into four or more pieces, and then chop the individual segments only after elevating them away from the posterior capsule.

Cortex removal is accomplished with a curved I/A handpiece tip. Although I perform copious hydrodissection and also use subincisional hydrodissection thorough the sideport, I do not routinely use Fine's cortical cleaving hydrodissection<sup>4</sup> because it may cause the cortex to exit the capsular bag during nuclear removal, hindering my view while eliminating a capsular protective cushion; the latter may be important during epinuclear removal. Earlier, I had used a bimanual I/A system as described by Brauweiler et al,<sup>5</sup> but found it generally unnecessary with adequate hydrodissection. Furthermore, the enlarged sideport incisions necessary to admit the instruments may tend to leak at the close of surgery.

In addition to the current study, I performed a retrospective study<sup>6</sup> to determine the safety of intracameral anesthetic. Using corneal edema on the first postoperative day as the test parameter, I sought to determine whether the use of intraocular nonpreserved lidocaine induced a greater degree of corneal edema than topical lidocaine alone. Two patient groups were compared. The earlier group had only topical anesthesia, and the latter patients received both topical and intracameral agents. The results of the investigation showed a decreased likelihood for corneal edema in the latter group (Table 4). One might conclude from the data that nonpreserved lidocaine reduces corneal swelling, but a much more likely explanation is that, concurrent with the addition of intracameral anesthesia to my surgical regimen, I introduced high-vacuum phaco methods and converted gradually to nuclear chopping from

**TABLE 4. Safety of Intracameral 1% Lidocaine Hydrochloride One Day Postoperatively for Corneal Edema**

Edema	Topical Alone (N = 352)	Topical Plus Intracameral (N = 279)	Difference P
0	76.7	88.2	<.001
0.5+	14.6	6.2	<.005
1.0+	4.7	4.1	<.59
>1+	3.7	1.3	<.08

traditional divide and conquer for most patients. Although the purpose of that investigation was to evaluate anesthetics, the data strongly suggest that the cornea is better protected with nuclear chopping combined with high-vacuum fragment removal.

And so, the answer to the title question of phaco chop or divide and conquer remains "both" for me. I use half-stop and chop for approximately 80% of cases, depending on the condition of the eye. Given the tremendous advantage and flexibility of new hardware and software technology, I can adapt to the demands of each case while retaining the principle of safety first and achieve reliable and reproducible results for virtually all patients.

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# "The Snap and Split" and "Phaco Burst" Technique

Hideharu Fukasaku, MD

Numerous nucleus dividing techniques exist. I have developed the snap and split technique as a safe and effective alternative to other, more risk-prone, techniques. The keys to success with snap and split are use of the specially designed snapper hook, deep sculpting and fixation of the phaco tip to create a fulcrum for snapping and visualization of the meridional stress lines of the lens. I have recently added phaco burst to the snap and split technique for even more effective nucleus division.

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Numerous nucleus-dividing techniques exist. I believe my original snap and split technique is one of the best for dividing the nucleus with mechanical force using the phaco tip and Fukasaku snapper hook.

The divide and conquer and phaco chop techniques are useful. However, they must be performed under the continuous curvilinear capsulorhexis (CCC) edge or in the peripheral lens. Serious complications, such as rupture of the posterior capsule with the hook and rents in the CCC edge with the phaco tip, can occur (Fig 1).

I developed the "snap and split technique" to overcome these potential complications and make a faster and more effective procedure. This technique uses the energy released by snapping to easily and safely crack the nucleus. There is a release of concentrated potential energy similar to the snapping action of the fingers, hence the name "snap and split." I use the snapper hook for the snap and split technique because it is much shorter and safer than the long phaco chop hook (Fig 2). The snapper hook is available through Katena Products, Inc (Denver, NJ).

## Snap and Split Technique

The key to the snap and split is concentrated energy along the meridional stress lines created by the lens fibers. The lens fibers are formed by the differentiation and elongation of the lens epithelium at the equator. These lens fibers run meridionally around the equator of the lens from the posterior to the anterior lens surface (Fig 3). The junctures of these fibers form the Y-sutures. It is important to mentally visualize these meridional fibers because these are the stress lines along which the vector forces created by snapping will travel and along which the subsequent splitting will occur (Fig 4).

The epinucleus is first removed by aspiration. This allows visualization of the nucleus (Fig 5). Next, the nucleus is sculpted deeply adjacent to the center of the nucleus (Fig 6). The snapper hook is placed adjacent to the phaco tip at the stress lines created by the lens fibers. The phaco tip is then

buried into the nucleus with slight phacoemulsification and the nucleus fixated using high-vacuum aspiration at 125, 175, or 300 mm Hg, depending on the hardness of the nucleus (Fig 7). The key is concentrating energy along the meridional stress lines of the lens.

The snapper hook and phaco tip are then moved in opposite, arclike motions, with the snapper hook pulling and the phaco tip pushing (Fig 8). The snapper hook and the phaco tip create concentrated energy at the meridional stress lines of the lens, and the opposite, arclike motions of the snapper hook and the phaco tip snap the nucleus in half (Fig 9).

I routinely use a high-vacuum phaco technique. The surgeon needs to grasp the center of the nucleus firmly with high vacuum to concentrate phaco energy efficiently. I use the Nidek CV 12000 phaco unit (Nidek Inc, Fremont, CA) and, depending on the hardness of the nucleus, set the vacuum at 125, 175, or 300 mm Hg, with ultrasound power at 70%, 80%, or 90% and flow rate at 27, 28, or 28 cc/min. High vacuum enables one to concentrate phaco energy in a discrete zone where it is most effective. With the snap and split technique, the phaco tip and the snapper hook are rotated tangentially past each other. The phaco tip moves forward with an arclike tangential force, pushing the cracked portion away. The snapper hook is then moved around the phaco tip, hooking the half-portion away.

Next, the nucleus is rotated for quartering. The phaco tip is buried into the nucleus at the center with slight phacoemulsification, and the snapper hook is placed adjacent to the phaco tip at the stress lines of the lens. Phaco power is magnified between the phaco tip and the snapper hook (Fig 10). The snapper hook is then pressed into the nucleus. The snapper hook and the phaco tip are tangentially rotated past each other and the nucleus half snapped into quarters (Fig 11). Phacoemulsification and aspiration of the quartered fragments then proceeds with ease within the central safe zone. All manipulation occurs within the central 5-mm safe zone.

## Phaco Burst

Although my original snap and split technique is very good for dividing the nucleus of most lenses using mechanical force alone, I have refined this technique to use concentrated phaco energy to literally burst the hard nucleus. This refinement is called phaco burst.

This phaco burst technique uses the concentrated phaco energy magnified between the snapper hook and the phaco tip to augment the mechanical energy applied with the snap and split technique in a contra-coup fashion (Fig 12). The energy release is magnified within the confined nucleus tunnel, literally creating a burst of energy that easily splits the hard nucleus. This phaco burst is an addition to the original snap and split technique, and I call this refinement phaco burst and snap.

From the Fukasaku Eye Center, Yokohama, Japan.

Address reprint requests to Hideharu Fukasaku, MD, Fukasaku Eye Center, 1-11-15 Kitasaiwai, Nishi-ku, Yokohama, Japan 220.

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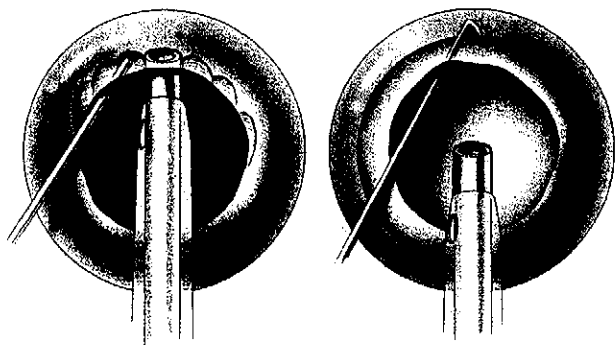


Figure 1

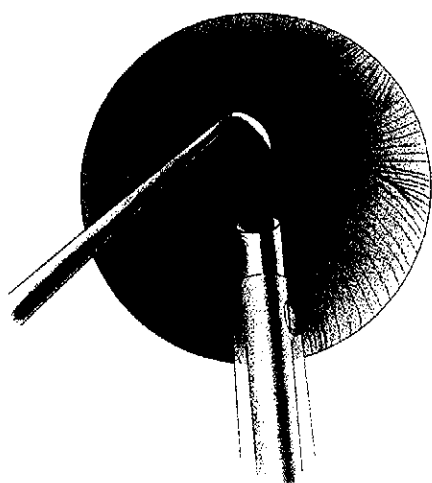


Figure 4

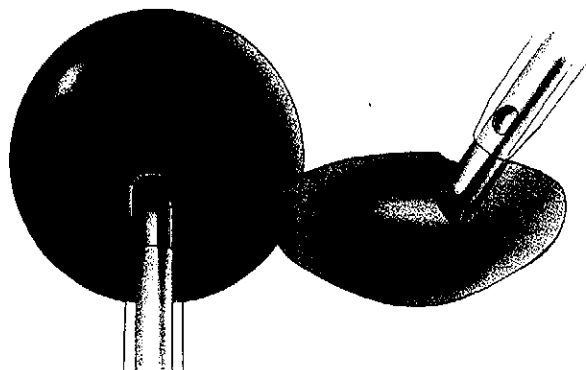


Figure 6



Figure 3

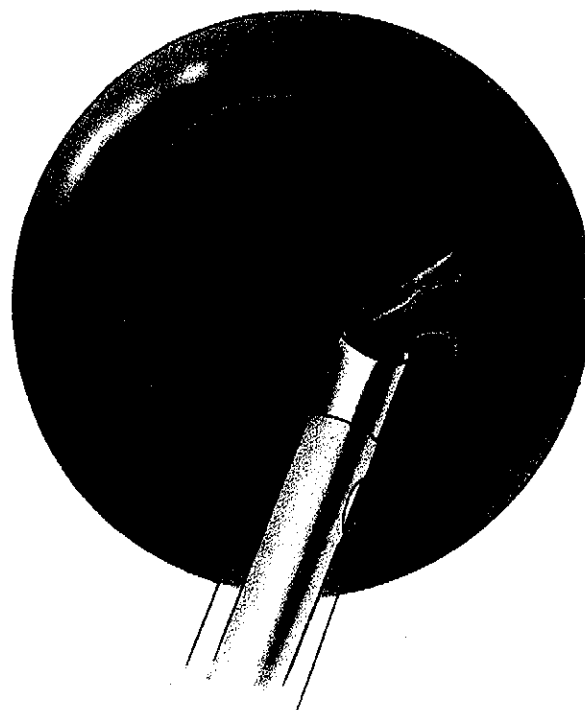


Figure 5

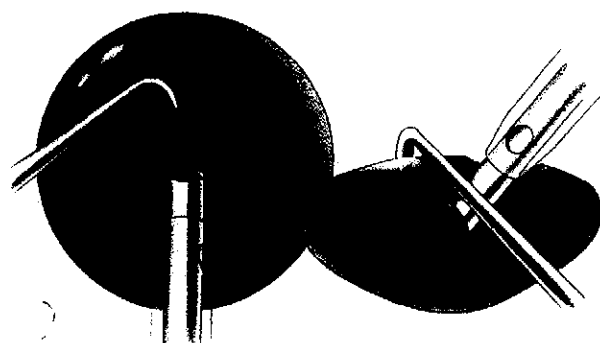


Figure 7

Figure 1. Divide and conquer and phaco chop techniques.  
 Figure 4. Meridional lens fibers. The stress lines for vector forces.  
 Figure 6. Deep sculpting and fixation of the nucleus.

Figure 3. Meridional lens fibers.  
 Figure 5. Sculpting the epinucleus.  
 Figure 7. Nucleus fixation using high-vacuum aspiration.



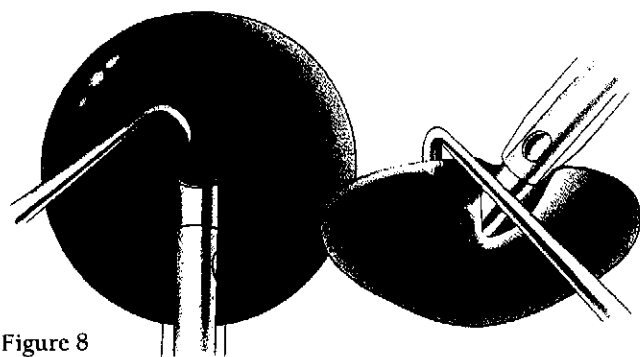


Figure 8

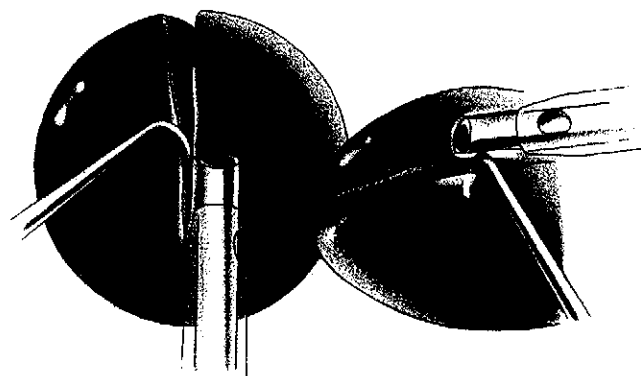


Figure 9

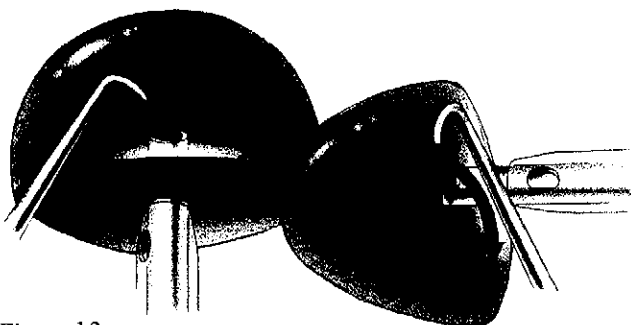


Figure 10

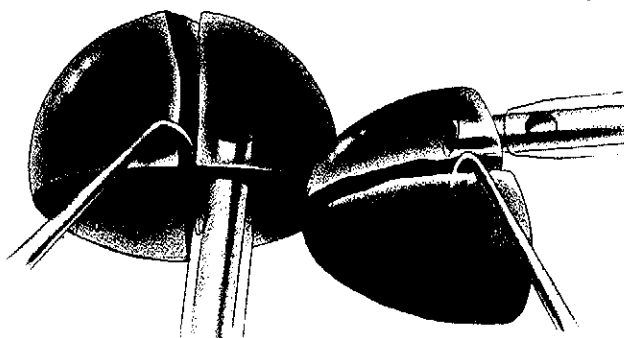


Figure 11

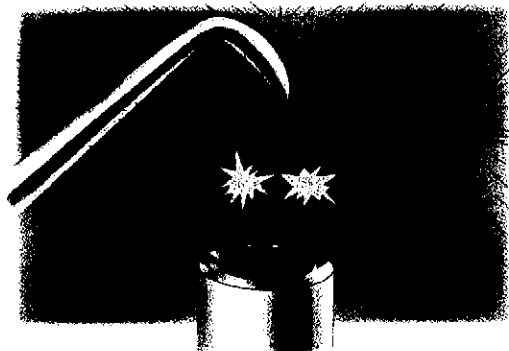


Figure 12

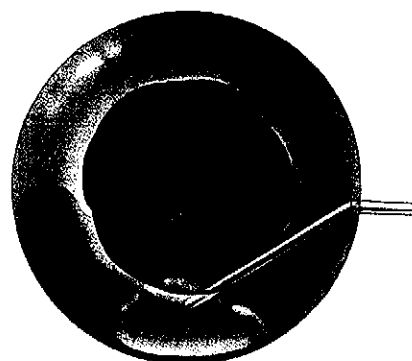


Figure 13

Figure 8. Snapping the nucleus with opposite arc-like motions.

Figure 10. Deep sculpting and fixation of the half nucleus.

Figure 12. The contra-coup forces of phaco burst.

Figure 9. Splitting the nucleus with the snapper hook and phaco tip.

Figure 11. Quartering the nucleus.

Figure 13. Visco-dissection of retained epinucleus.



Figure 2. Short snapper hook and long phaco chop hook.

### Visco-dissection

After extraction of the medium hard nucleus, the epinucleus often remains. If there is residual epinucleus, visco-dissection of the epinucleus is very important. Rupture of the posterior capsule can easily occur, especially when removing the epinucleus at the incision site. However, viscoelastic material can be used to lift the epinucleus with ease and safety.

After lifting the epinucleus with viscoelastic at the incision site, the epinucleus can be phacoemulsified safely (Fig 13). All manipulation occurs within the iris plane and central safe zone. This visco-dissection technique is both effective and very safe.

### Snap and Split for the Small Pupil

The snap and split technique is ideal for the small pupil. Because all manipulation is performed in the 5-mm central safe zone, the surgeon can always see the instruments, and blind maneuvering beneath the iris is not necessary. Some surgeons use the iris retractor to enlarge the pupil. However, this can



Figure 14. Small-pupil snapper hook.

traumatize the iris and lead to inflammation. Removal of the nucleus using snap and split does not require an iris retractor even with small pupils, because one always works in the central zone. It is minimally traumatic with less postoperative inflammation and is very fast.

I have developed a new, small-pupil snapper hook (Katena Products Inc.). This hook has two important features (Fig 14): The outside of the hook can be used to push the iris aside nontraumatically while the inside surface of the hook is used to snap the nucleus. This new feature is especially useful during cortical aspiration, in which the surgeon can push the iris away with one hand while aspirating with the handpiece using the other hand. Also, implantation of the intraocular lens in the bag can be ensured by pushing aside the iris with two snapper hooks.

Many glaucomatous eyes have small pupils because of age and the chronic use of miotic agents. For such small pupil cataract surgery, some surgeons use an iris retractor to enlarge the pupil. However, this can traumatize the iris, leading to inflammation and damage to the filtering site. Because this snap and split small pupil phaco technique is minimally traumatic with less postoperative inflammation, there is less chance of filter failure. This is especially true when it is combined with a filtering procedure.

### Three Keys to Success

I believe the three keys to success with the snap and split technique are:

1. Using the specially designed snapper hook. This hook is designed to be both safe and effective, with a short hook arm that will not damage the posterior capsule or the edge of the CCC.
2. Deeply sculpting the nucleus and burying the phaco tip into the nucleus and fixating it with high vacuum. This effectively creates a fulcrum around which the tangential vector forces created by snapping are magnified.
3. Pressing the snapper hook into the nucleus next to the phaco tip and cracking the nucleus with opposite arclike forces. Visualizing the meridional stress lines of the lens helps ensure the correct arclike, tangential motion.

### Conclusion

I believe the snap and split technique has distinct advantages over other methods of nucleus extraction. It is fast, effective, and most importantly, it is safe.

I have refined my original snap and split technique to include phaco burst technique as a further improvement. I call this the phaco burst and snap technique. The phaco burst and snap technique is safe and effective even with the hardest nucleus and small pupil. The key to the phaco burst and snap technique is the phaco energy created deep in the nuclear tunnel between the snapper hook and phaco tip that results in a burst of released energy and nuclear cracking in a contracoup fashion.

Snap and split and phaco burst techniques significantly shorten operating time. Our cases average 5 to 6 minutes. There is a significant learning curve associated with the phaco burst and snap technique. This should not, however, be difficult to overcome for surgeons already experienced with the divide and conquer or phaco chop techniques.

# Phaco Quick Chop

David M. Dillman, MD

Traditional phaco chop can be challenging because of the maneuver of placing the chopper *under* the anterior capsule and then peripherally out to the equator of the lens. Phaco quick chop circumvents all that by placing the chopper either directly on top of, or directly to the side of, the buried phaco tip. As a result, I believe phaco quick chop has the efficiency of traditional phaco chop but adds safety, and thus is both safer and more efficient than traditional divide and conquer techniques.

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**L**ike so many of you who attended the 1993 American Society of Cataract and Refractive Surgery (ASCRS) meeting in Seattle, I saw for the first time Dr Kunihiro Nagahara's videotape on the phacoemulsification technique he called "phaco chop." "Wow!" I thought to myself, "that looks wonderful, and so easy too! I'm going straight home to Danville and try that immediately." And I did . . . and I wasn't worth a hoot at it. And so, like January's diet, I quickly abandoned it. I resigned myself to the belief that I simply did not have the necessary skills to phaco chop and decided to stick with ol' faithful, a divide and conquer, four-quadrant-type technique.

Fast forward to the 1996 ASCRS Seattle meeting. By now I have seen at least a gazillion phaco chop videos and they all look pretty much the same to me. That is, until I see Dr Vladimir Pfeifer's from Slovenia. He calls his chopping technique "phaco crack." "Wow!" I thought to myself, "that looks wonderful, and so easy too! I'm going straight home to Danville and try that immediately." And I did . . . and I could do it! It was (pretty) easy! And it was safe! And it was efficient!

Now, some years later, I enjoy it more and more with each surgical day. I have taken the liberty of changing the name "phaco crack" to "phaco quick chop," because I think it better describes what actually transpires.

## Phaco Chop Versus Phaco Quick Chop

The main difference between phaco chop and phaco quick chop is subtle, yet it makes all the difference in the world. It simply deals with the placement of the chopper itself. With traditional phaco chop, once the phaco tip is buried into the center of the lens, the chopper is placed under the inferior anterior capsule and then advanced peripherally until it reaches the equator of the lens (Figs 1 and 2). The chopper is then pulled toward the buried phaco tip in a nearly horizontal movement (Fig 3). At least, that is the theory. Unfortunately, for me, it is too much like my golf game. I understand the theory just fine; it is the execution part that has stifled me. On at least two occasions that I recall, I thought I had the chopper

under the anterior capsule when, in fact, it was on top of the anterior capsule. When I attempted the actual chop, I succeeded only in creating a huge rent in the anterior capsule, which quickly wrapped around to include the posterior capsule early in the case.

You can imagine how happy I was to see Dr Pfeifer ignore the anterior capsule altogether. He simply placed the chopper basically on top of the buried phaco tip, pretty much at the center of the lens (well away from the anterior capsule) and initiated the chop with a nearly vertical movement (Fig 4). His technique had the efficiency of phaco chop but with what I perceived to be considerably greater safety.

## Technique

Phaco quick chop should be preceded by a good capsulorhexis and excellent hydrodissection. By excellent hydrodissection I am referring to the absolute, unquestionable ability to easily rotate the lens within the confines of the capsular bag with your hydrodissection cannula.

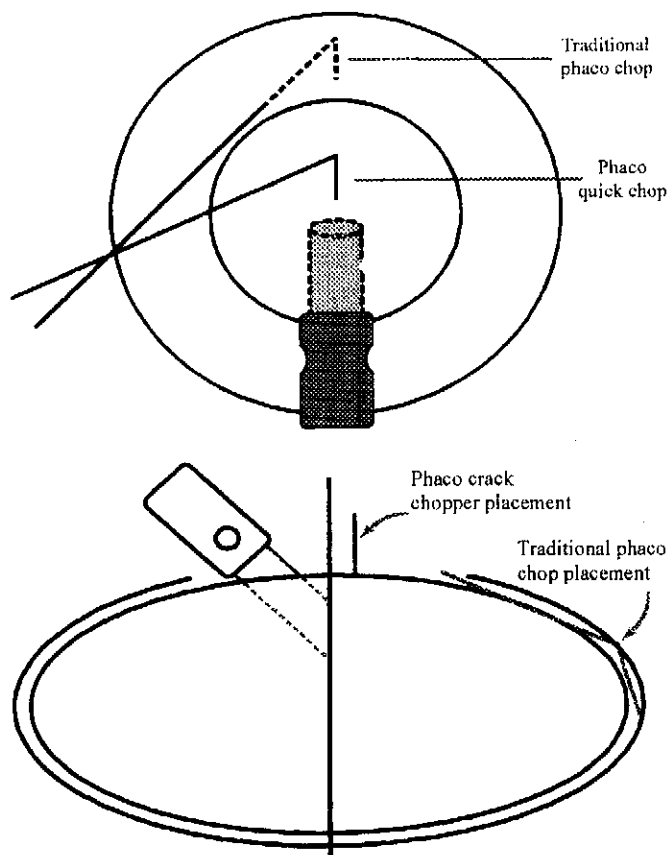
After capsulorhexis and hydrodissection, the phaco needle is introduced into the eye through the phaco incision, and then the chopper is introduced into the eye through the side port incision. It is important to get the chopper into the eye before burying the phaco tip. There is a strong natural tendency to retract the phaco tip if it is buried with the chopper external to the eye and then the chopper introduced secondarily. The phaco needle is placed on the surface of the lens just in front of the edge of the capsulorhexis nearest you (Fig 5). The phaco needle is then buried, aiming it toward the center of the lens (Fig 6). Because this means you will be very quickly working with a totally occluded phaco needle, and because a totally occluded phaco needle is a prime setup for a corneal/scleral burn, I strongly suggest that this burying process be done with three to four short (foot-pulsed) bursts of phaco (foot position 3) as opposed to a single continuous, uninterrupted one. Once buried, remain in foot position 2 (aspiration).

The chopper is now lightly placed on the surface of the lens either directly above the end of the buried phaco needle or as much as a millimeter or 2 in front of it (Fig 7). You are now ready to make the first chop. Simultaneously, the chopper is moved downward while the buried phaco needle is moved upward (Fig 8). For a long time, I thought this was an "equal opportunity" type of a maneuver, with 50% of the effort devoted to the downward movement of the chopper and 50% of the effort devoted to the upward movement of the buried phaco needle. More recently, I have convinced myself that the chopper is doing most of the work; probably a more accurate ratio would be 90% chopper/10% buried phaco tip. This "vertical" maneuver initiates the division of the lens centrally. However, the peripheral propagation of the division is accomplished by yet a third maneuver that virtually follows on the heels of the first two. Once the chopper and buried phaco needle have come into very near contact (or they can even come into contact), they are laterally separated (Fig 9). This

From Dillman Eye Care Associates and the Institute of Refractive Eye Surgery at Dillman Eye Care, Danville, IL.

Address reprint requests to David M. Dillman, MD, Dillman Eye Care Associates, 600 N Logan Ave, Danville, IL 61832.

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Figures 1 and 2. Figure 1 shows the top view and Figure 2 shows the side view of the contrasting locations for the placement of the chopping instrument for phaco quick chop versus traditional phaco chop.

triad of maneuvers—(1) chopper down, (2) buried phaco needle up, and (3) lateral separation—when properly done, smoothly flow into what might well be perceived as a single movement by a first-time observer.

Because excellent hydrodissection precedes this initial chop (and, therefore, good mobility of the lens within the capsular bag is an unquestionable given), the lateral separation maneuver might well be accompanied by a spinning of the lens within the bag. The next intended maneuver is to spin it, anyway. Rotate the lens (clockwise or counterclockwise) so that the split in the lens is in the horizontal position from your

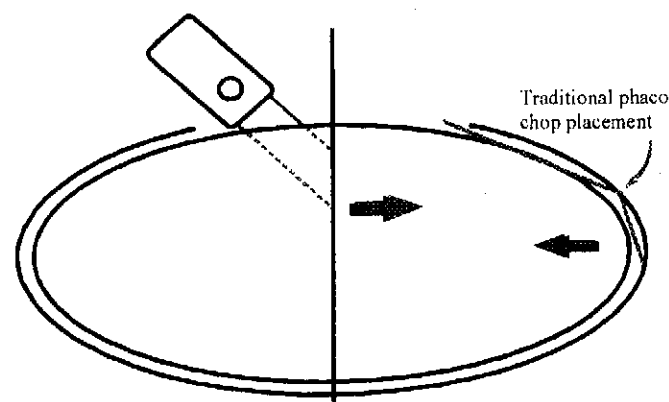


Figure 3. In traditional phaco chop, the chopper is pulled toward the buried phaco needle in a near horizontal fashion.

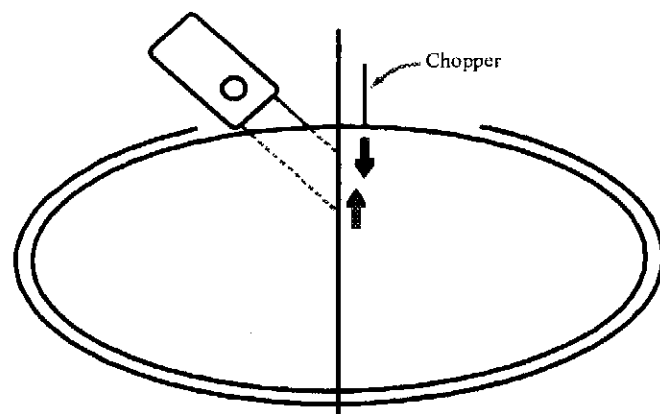


Figure 4. In phaco quick chop, the chopper is moved straight downward and the buried phaco tip is moved straight upward, resulting in a "vertical" chopping maneuver. Contrast this to the "horizontal" chopping maneuver of traditional phaco chop (Fig 3).

perspective (Fig 10). (Another way of couching that would be so that the split in the lens is parallel to the phaco incision.)

It is prudent at this point to take a moment to ensure that this first chop is truly complete; that is, both posterior and peripheral nuclear plates are completely severed. This is easily accomplished by placing both the phaco needle (you are now in foot position 1, irrigation only) and chopper within the split and then pushing the inferior half of the lens away from you with the phaco needle while simultaneously pulling the superior one half toward you with the chopper (Fig 11).

Now that you have two completely separated halves, there are a variety of ways in which to proceed but, for sake of simplicity, I am going to follow the quartering approach in this description. The phaco needle is now buried into the center of the inferior one half (foot position 3). Once again, I would recommend doing this in two or three short bursts of ultrasound as opposed to one continuous burst. The chopping of this half into quarters is accomplished in exactly the same fashion as the initial chop. The chopper is lightly placed on the surface of the lens, essentially on top of the end of the buried phaco needle (which is now in foot position 2) and in front of

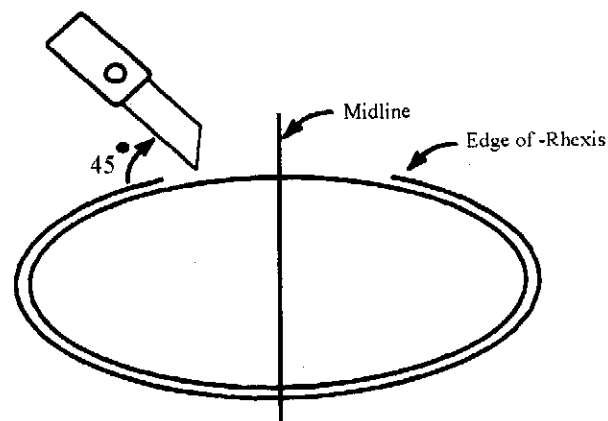


Figure 5. The angle with which the phaco needle contacts the surface of the lens is determined by the size of the capsulorhexis. A smaller capsulorhexis will demand a steeper angle, and a larger capsulorhexis will allow for a flatter angle. In general, aim for approximately a 45-degree angle.

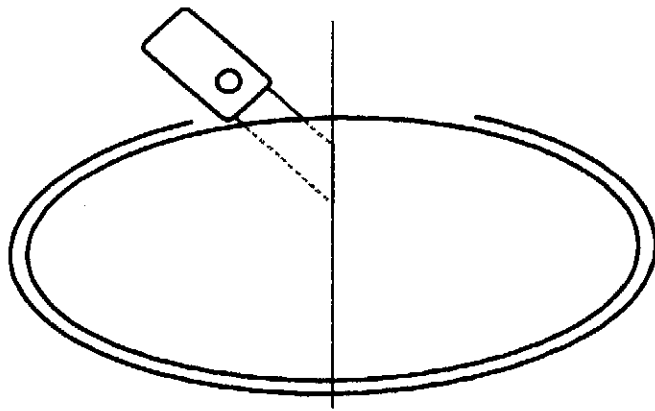


Figure 6. Using short, interrupted bursts of ultrasound, the phaco needle is buried into the center of the lens. Please note that the buried tip does not come anywhere close to the posterior capsule.

the edge of the capsulorhexis. The aforementioned triad of maneuvers is then performed: (1) chopper down (90% of the effort), (2) buried phaco tip up (10% of the effort), and (3) lateral separation (Fig 12).

Before advancing, I strongly recommend ensuring that this second chop is also complete both posteriorly and peripherally. Although there are a variety of ways to do this, my personal approach is to support the left, inferior quadrant with the phaco needle (foot position 1 or 2) and to push the right inferior quadrant away from it by bringing the chopper over the phaco needle and using it to push the right inferior quadrant away in a cross-action fashion (Fig 13).

With the first half nicely quartered, a whole myriad of options now present themselves. The density of the lens, plus your surgical personality, will likely dictate how you decide to proceed. But, by way of example, here would be a few roads you might choose to travel: (1) remove both quarters; (2) chop one quarter into eighths, remove each eighth, chop the second quarter into eighths, and remove them; (3) leaving both quarters alone, spin the lens 180 degrees so as to bring the other half into the inferior capsular bag, and chop it into quarters. As you read this, I'm sure you are already thinking of other options as well.

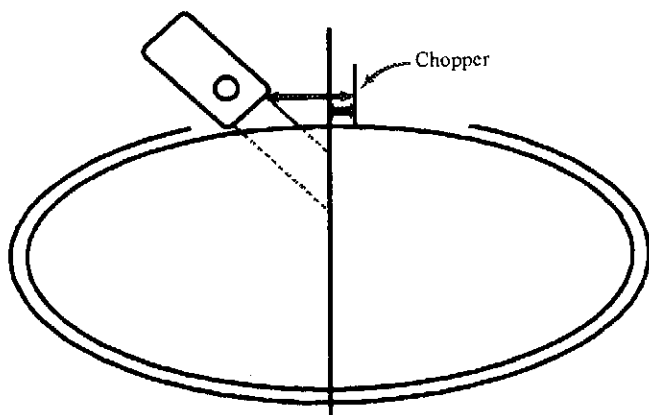


Figure 7. The chopper is placed anywhere from right on top of the end of the buried phaco needle to a millimeter in front of it.

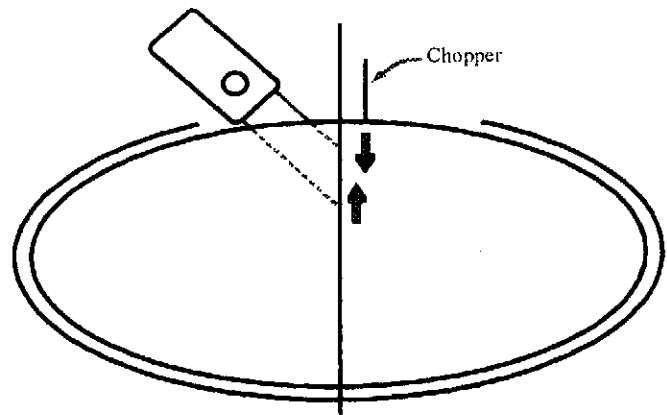


Figure 8. The first chop is initiated by vigorously moving the chopper in a downward fashion while gently moving the buried phaco tip in an upward fashion.

### Pearls

It would be unfair and inappropriate to deny that there is definitely a learning curve to phaco quick chop. That is the bad news. The good news is that it should be a fairly painless one. In an effort to smooth out some potential bumps along the way, let me now share with you a few observations regarding phaco quick chop that are not readily obvious at first.

The first two deal with the initial chop. The strong tendency is to be too tentative both with burying the tip and using the chopper. The phaco needle has to be well buried into the substance of the lens. To facilitate this, I retract the silicone sleeve approximately double the amount I would normally do for a divide and conquer technique (Fig 14). I am not concerned about breaking the posterior capsule with this extra exposure. The center thickness of the human lens is 3.5 to 4.0 mm. We have exposed 2 mm of the titanium tip. The silicone sleeve will act as a physical barrier to further advancement of the tip. If we approached the center of the lens at a 90-degree angle and went straight down, we would only reach the middle of the lens, well away from the central posterior capsule. But, in real phaco quick chop life, we are not going to approach the lens at a 90-degree angle; we are going to be much more at a 45-degree angle (Fig 5). As such, the actual penetration of the centrally buried tip will actually be less than 50%.

Once the phaco needle is well buried, keep in mind that it is

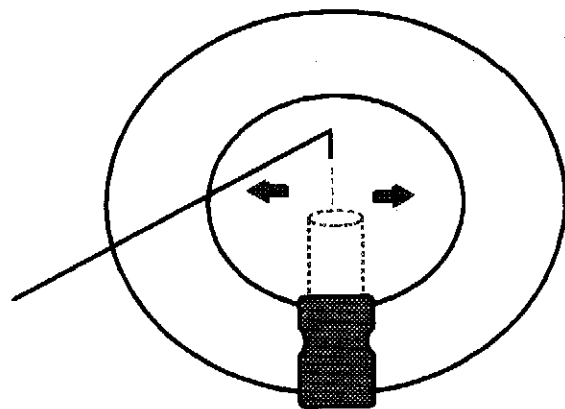


Figure 9. The central chop is propagated out to the periphery by laterally separating the buried chopper and buried phaco needle.

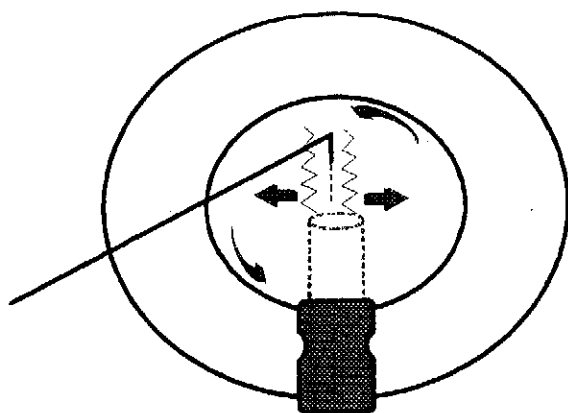


Figure 10. Because excellent hydrodissection is a quick chop prerequisite, it will be easy to rotate the lens into a position that puts the two halves in a "horizontal" position.

the action of the chopper that most determines the success or failure of the initial chop. Therefore, use the chopper with controlled aggression. Sink it into the substance of the lens and push down with authority.

Now, ready for some really good news? Say that, for whatever reason, that initial chop just does not happen successfully with the first effort. Fine, no harm done. You can either immediately abort phaco quick chop and covert to your divide and conquer technique, or you can spin the lens 90 degrees or so and try it again. Just be sure to pick a new place to bury the phaco needle, this time a little more peripherally than the first attempt. What if it does not work the second time? Fine, again, no harm done. At that point you could choose to convert to your fast ball technique, or you could spin it another 90 degrees or so and try it again (third time's a charm, they say!).

Also, please do not be frightened or concerned if your initial chop does not result in a lens split perfectly right down the middle. It might well be that you will not have two absolutely equal-sized halves. You might end up with a one-third-two-thirds type split. Fine, no harm done. The bigger piece will simply need more further chopping than the smaller piece.

This next little variation was taught to me by Bruce Wallace,

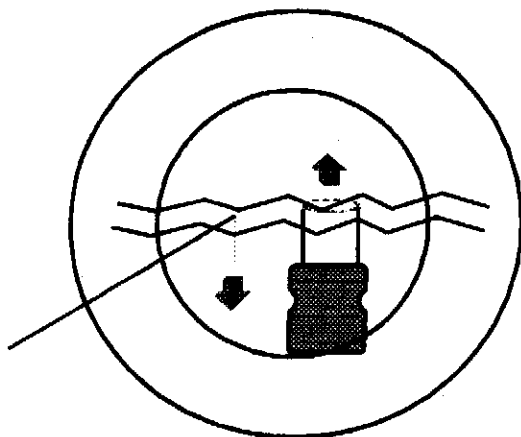


Figure 11. As with any chopping or cracking technique, it is crucial to ensure complete separation of individual pieces. Therefore, before proceeding beyond the initial chop, use the phaco needle and chopper to "work the split" until you are convinced of a through-and-through chop.

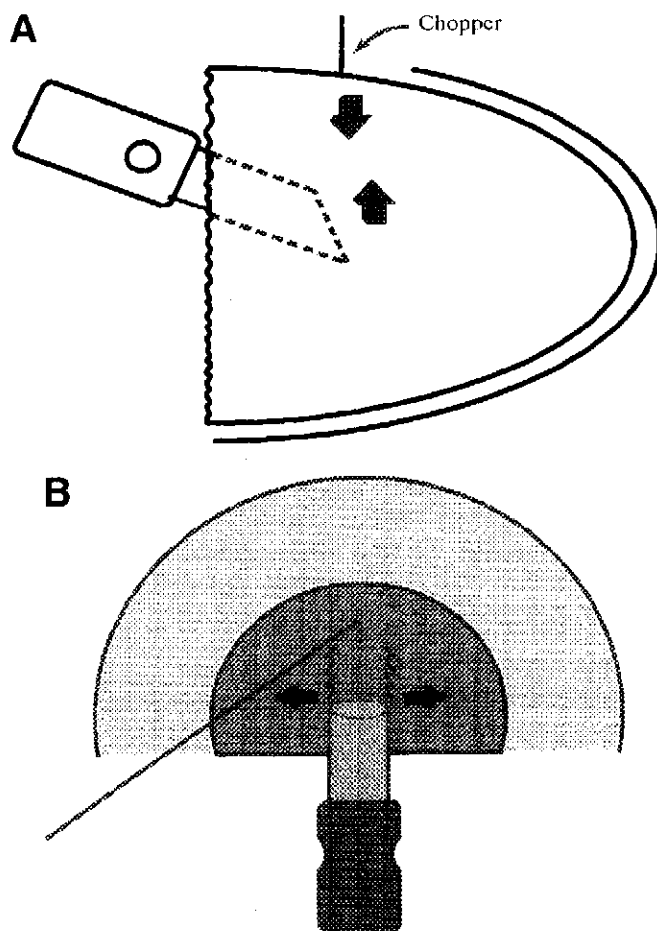


Figure 12. Further chops are made in a near identical fashion to the initial chop. (A) The phaco needle is buried into the lens, the chopper placed on top, and a vertical chopping maneuver is performed, followed by (B) lateral separation.

MD, from Alexandria, Louisiana, and it is well worth sticking in your bag of quick chop tricks. After the initial chop, if, for some reason (eg, the size of the pupil or capsulorhexis is smallish) there is little to no room in front of the buried phaco needle to place the chopper, simply place the chopper to the side (left side if you control the phaco handpiece with your

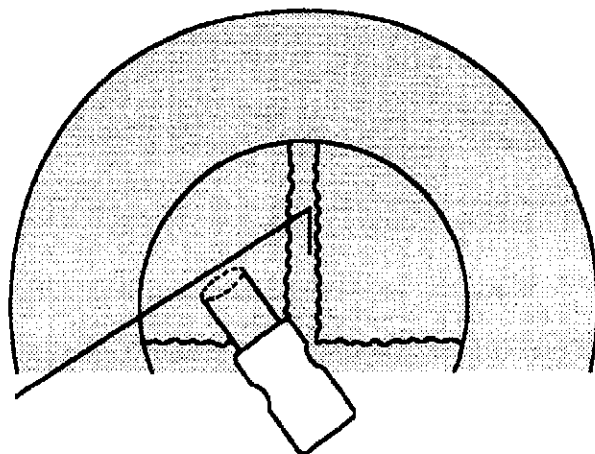


Figure 13. Use both instruments (phaco needle and chopper) to constantly "work the chops" to ensure they are through and through, both posteriorly and peripherally.

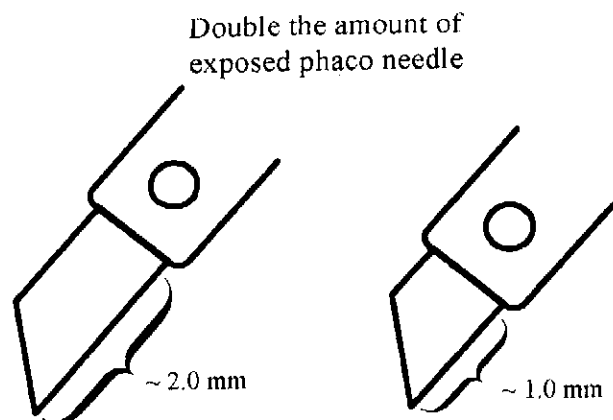


Figure 14. If you are like me, you will be too tentative burying the phaco tip at first. Exposing more of the titanium needle facilitates burying. Just be careful not to overdo it and have the irrigating sleeve out of the eye . . . bad form!

right hand) of the buried phaco needle and carry on exactly as if it were right on top of it. Remember, one of the aims of phaco quick chop is to avoid unintentional contact with the anterior capsule. This "side chopping" is great for that endeavor.

Here is a truly important pearl. I have actually already discussed it once, but it is worth re-emphasizing. Just because you see a chop, do not assume that it is a through-and-through chop. Be very active with both the chopper and the phaco needle. Use them to poke and pry, push and pull, rock and roll (Figs 11, 13). Incomplete chops in phaco quick chop are every bit as bothersome (and dangerous) as incomplete cracks in a divide and conquer technique.

Lastly, and it is a bit of a stretch to call this a pearl, here is a little something I do before the initial burying of the phaco needle. In foot position number 2 (aspiration), I use the phaco needle to vacuum away much of the central cortex and epinucleus. To my way of thinking, this "cleans things up a bit" and facilitates better visualization for the initial chop.

### Instruments

Hopefully, as more and more of us get involved with phaco quick chop, or some variation thereof, some folks who are a lot more clever than I am will devise chopping instruments and phaco needles that are better suited to phaco quick chop than traditional choppers and needles. (I admit to you that I have tried to design a couple of different choppers and needles and, the truth is, the prototypes worked no better than those already on the market. I am going to keep trying, though. Just think what would have happened if Charlie Kelman stopped after only a couple of attempts!).

Although Dr Pfeifer uses a Sinskey hook as a chopping device, I would advise against it if at all possible. A little more meat on the chopper's bones helps. As such, I would recommend at least starting out with a modified Sinskey hook-type device such as the Koch chopper (Storz # E0713) or the Nagahara chopper (STORZ # E0578) (Fig 15).

In addition, be aware that several of the choppers on the market have a rounded or bulbous ending. For traditional phaco chop, this facilitates getting under the anterior capsule. In addition, for traditional phaco chop, it is less likely to split the anterior capsule if, indeed, you are on top of it when you thought you were underneath it. However, a rounded or

bulbous ending is counterproductive to phaco quick chop, and I would advise against it (Fig 15).

At the time of this writing, I simply do not know which phaco needle is "best" for phaco quick chop. I have worked with several bevel angles: 0, 15, 30, and 45 degrees. I found no major advantage to any one of them, which truthfully caught me off guard. Going into it, I really thought the 0-degree tip would have the edge (or would that be lack of edge?), but not so. I have worked with several tip designs: round, oval, elliptical, square, and "Sleeping D." ("Sleeping D" was one of my failed ideas. It has a flat surface on the top with a rounded bottom surface . . . like the letter D lying down). Again, there was no significant advantage to any one of them.

With the traditional phaco needles (15-, 30-, 45-degree bevels), I have worked both bevel up and bevel down, and I cannot truthfully endorse one over the other.

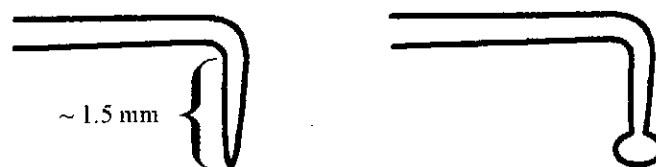
And so, at least at first, it probably makes sense for you to work with the phaco needle with which you are most comfortable. That is, unless your favorite phaco needle is a Kelman style. That downward bend nicely facilitates cutting and grooving, but phaco quick chop has no cutting or grooving. And, in fact, the Kelman downward bend is actually counterproductive to the vertical chopping maneuvers that are the backbone of phaco quick chop.

What about those downsized systems? The diameter of the internal lumen of a traditional phaco needle is 0.9 to 1.0 mm. Some of the systems on the market today have decreased this opening down to diameters that range from 0.8 to 0.6 mm depending on the manufacturer/designer. This definitely allows for safely employing smaller and smaller phaco incisions and has some theoretical cutting advantages as their thicker side walls improves cavitation. But, it significantly decreases the amount of cross-sectional areas available for occlusion and aspiration. Phaco quick chop is all about occlusion and aspiration and, thus, although it can be done with a downsized system, it is not quite as efficient as with traditional internal lumens.

I am about to start work with some prototype "upsized" phaco needles. I am going to see if increasing the internal lumen to 1.2 or 1.4 mm (and the corresponding increase in cross-sectional area) will better facilitate the phaco quick chop requirements.

### Machine Settings

Today's phaco machines are absolutely wonderful, but not perfect. And, because there are several outstanding models



### Chopping Instruments

Figure 15. Although phaco quick chop can be done with a Sinskey hook (Dr Pfeifer does so), I believe it is much easier to do with an instrument designed for chopping. I personally believe it should be at least 1.5 mm long and have a nonbulbous ending.

available, it is still imperative that you fully understand both the basics and nuances of your particular machine(s).

Is there a "best" phaco machine for phaco quick chop? No, but there are some important "phaco phacts" you need to keep in mind when converting to this technique. Phaco quick chop places emphasis on occlusion, aspiration, holdability, and followability. It ignores cutting, grooving, and sculpting. With that in mind, let us look at today's phaco machines by considering their pump mechanisms. In general, I believe it is acceptable to place pump mechanisms into one of two categories: (1) peristaltic and (2) on-demand systems. The "on-demand" nomenclature is a bit of a catch-all that includes three pump mechanisms: (1) rotary vane, (2) Venturi, and (3) diaphragm. And, although these three all work very differently from one another, clinically they behave with enough similarity to group them into a single entity for purposes of this discussion. (The new scroll pump should have the ability to swing back and forth, at the discretion of the surgeon, between the peristaltic and on-demand categories).

The on-demand systems are often referred to as "constant vacuum" systems. They create vacuum very quickly, have fast rise times, and tend to work at very high aspiration flow rates (30 to 50 cc/min). Because holdability and aspiration are functions of vacuum, and because followability is a function of aspiration flow rate, phaco quick chop and the on-demand systems marry very well. With the on-demand systems, I suggest setting the vacuum at  $100 \pm 25$  mm Hg. (Keep in mind that the aspiration flow rate is inseparably tied with these systems and with this vacuum range will be approximately  $40 \pm 10$  cc/min).

The peristaltic systems are known as "constant flow" systems. They tend to create vacuum more slowly, have slower rise times, and often function better at lower flow rates (15 to 25 cc/min.). Therefore, in general, their relationship with phaco quick chop is a bit more rocky. But take heart! The newer generations of peristaltic units have much improved electronics, collection systems, and venting abilities. Thus, they can better handle the demands of phaco quick chop. Because there is such a huge variety of peristaltic units active in the marketplace today, it is very difficult to be specific about peristaltic machine settings. I think the safest advice I can give is to work closely with your peristaltic machine representative. Tell him or her that you wish to work pretty much at the highest vacuum and highest aspiration flow rate your particular peristaltic machine can safely and predictably handle.

### Clinical Settings

Can you employ phaco quick chop with all types of cataracts and any size pupil? Well, of course not, but it might come

closer than you might think. If we simply categorize cataracts into a spectrum of densities, phaco quick chop, in its purest form, can handle most of them except for the two extremes, the very soft and the very hard. On the soft end, there has to be an identifiable endonucleus that has enough density to allow manipulation. On the hard end, and here I am talking about the grade 4+ + + +, "I-can't-believe-I'm-even-thinking-about-doing-phaco" kind of hard, phaco quick chop can still be employed with a simple variation. Because there is such a sheer mass of hard endonuclear material to deal with, I prefer to debulk the lens a significant amount using a phaco needle that is designed for efficient cutting, such as a 60-degree bevel, traditional needle, or a Kelman needle. This is obviously facilitated by the largest capsulorhexis I can safely make. Once debulked, I will then stop and change the needle to a 45-degree or 30-degree bevel and proceed with phaco quick chop. However, because I have done a substantial amount of central debulking, it is now conceivable that burying a phaco needle that has had the silicone sleeve significantly retracted could penetrate the lens and break the posterior capsule. As such, I am extra cautious in that setting and will retract the silicone sleeve only enough to expose no more than 1 mm of the titanium phaco needle.

Please do not get me wrong; I am not saying that phaco quick chop makes doing "the rocks" easy. It makes most of them doable with extra patience and caution. And, how about the small pupil? Phaco quick chop is by far the best small pupil technique I have ever come across. More than any other phaco technique with which I am personally familiar, phaco quick chop works in the center of the pupil, making pupil size less of an issue. There are several safe and effective ways of enlarging pupils (the Beehler pupil dilator being, by far, my personal favorite), and every effort should be made to work within a "reasonably sized" opening. Suffice it to say, however, that the reality is that some pupils are smaller than others, and the smaller the pupil, the more I appreciate phaco quick chop.

### Parting Thoughts

Safety and efficacy are my top two priorities when I perform cataract surgery in Danville, Illinois. Phaco quick chop, at least in my hands, is truly both the safest and most efficacious phaco technique I am aware of at the time of this writing.

I quite honestly do not know if it is an original concept from Dr Pfeifer or if he learned it from someone else. In addition, I strongly suspect that other cataract surgeons around the world have "originated" identical or very similar techniques, which they have either kept to themselves or shared via various modalities of communication. Phaco crack, phaco quick chop, or by any other name is, indeed, the real deal and I hope you'll "give it your best chop."



# The Choo-Choo Chop and Flip Phacoemulsification Technique

I. Howard Fine, MD

The choo-choo chop and flip phacoemulsification is a chopping technique that uses power modulations and high vacuum along with specific maneuvers to minimize the amount of ultrasound energy in the eye and maximize safety and control.

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**T**his technique is designed to take maximum advantage of various new technologies available through the Alcon 20,000 Legacy<sup>1</sup> (Alcon Surgical Inc, Ft Worth, TX) and the AMO Diplomax<sup>2</sup> (Allergan Medical Optics, Irvine, CA) Phacoemulsification Systems. These technologies include high-vacuum cassettes and tubing, multiple programmable features on both systems, as well as the Mackool Microtip (Alcon Surgical Inc) with the Legacy and burst mode and occlusion mode capabilities with the Diplomax (Table 1). The result is enhanced efficiency, control, and safety. The procedure is done as follows:

A side-port incision is made to the left with a 1-mm trifaceted diamond knife, after which the anterior chamber is irrigated with 0.5 mL preservative-free xylocaine. Using the soft-shell technique described by Steve Arshinoff, Viscoat (Alcon Surgical Inc) is placed into the anterior chamber angle distal to the side port, through the side-port incision. It fills the anterior chamber but allows the eye to remain relatively soft. Provisc (Alcon Surgical Inc) is instilled on top of the center of the lens capsule under the Viscoat. Provisc forces the Viscoat up against the cornea, creating a soft shell, which helps stabilize the anterior chamber and protect the endothelium. Additionally, Provisc, which is a cohesive viscoelastic, decreases any tendency for iris prolapse during the hydro steps. After clear corneal incision, cortical cleaving hydrodissection is performed in the two distal quadrants followed by hydrodelamination. After the two hydro steps, the nucleus should rotate easily within the capsular bag. The Mackool/Kelman microtip on the Legacy is introduced bevel down to aspirate the epinucleus uncovered by the capsulorhexis, and is then turned bevel up. With a Diplomax system, a 30° standard bevel-down tip is used throughout endonuclear removal. The Fine/Nagahara chopper (Rhein Medical, Tampa, FL) is placed in the golden ring and is used to stabilize the nucleus by lifting and pulling toward the incision slightly (Fig 1), after which the phaco tip lollipops the nucleus in either pulse mode at 2 pulses/second (Legacy) or 80-msec burst mode (Diplomax). With the energy set in this way, we minimize ultrasound energy into the eye and maximize our hold on the nucleus as the

vacuum builds between pulses or bursts. Because of the decrease in cavitation energy around the tip at this low pulse rate or in burst mode, the tunnel in the nucleus in which the tip is embedded fits the needle very tightly and gives us an excellent hold on the nucleus, thus maximizing control of the nucleus as we score and chop it (Fig 2) in foot position 2.

The Fine/Nagahara chop instrument is grooved on the horizontal arm close to the vertical "chop" element with the groove parallel to the direction of the sharp edge of the vertical element. In scoring the nucleus, the instrument is always moved in the direction the sharp edge of the wedge-shaped vertical element is facing (as indicated by the groove on the instrument), thus facilitating scoring. The nucleus is scored by bringing the chop instrument to the side of the phaco needle. It is chopped in half by pulling the chopper to the left and slightly down while moving the phaco needle, still in foot position 2, to the right and slightly up. Then the nuclear complex is rotated. The chop instrument is again brought into the golden ring (Fig 3), and the nucleus is again lollipopped, scored, and chopped, with the resulting pie-shaped segment now lollipopped on the phaco tip (Fig 4). The segment is then evacuated, using high vacuum and short bursts or pulse mode phaco at 2 pulses/second (Fig 5). The nucleus is continually rotated so that pie-shaped segments can be scored, chopped, and removed essentially by the high vacuum assisted by short bursts or pulses of phaco. The short bursts or pulses of ultrasound energy continuously reshape the pie-shaped segments that are kept at the tip, allowing for occlusion and extraction by the vacuum. The size of the pie-shaped segments is customized to the density of the nucleus, with smaller segments for denser nuclei. Phaco in burst mode or at this low pulse rate sounds like "choo-choo-choo-choo"; ergo the name of this technique. With burst mode or the low pulse rate, the nuclear material tends to stay at the tip rather than chatter as vacuum holds between pulses. The chop instrument is used to stuff the segment into the tip or keep it down in the nuclear shell.

After evacuation of the first hemi-nucleus, the second hemi-nucleus is rotated to the distal portion of the bag, and the chop instrument stabilizes it while it is lollipopped. It is then scored (Fig 6) and chopped. The pie-shaped segments can be chopped a second time to reduce their size (Fig 7) if they appear too large to easily evacuate.

There is little tendency for nuclear material to come up into the anterior chamber with this technique. Usually it stays down within the epinuclear shell, but the position of the endonuclear material can be controlled by the chop instrument. After evacuation of all endonuclear material (the Diplomax tip is turned bevel up) (Fig 8), the epinuclear rim is trimmed in each of the three quadrants, mobilizing cortex as well in the following way. As each quadrant of the epinuclear rim is trimmed, the cortex in the adjacent capsular fornix flows over the floor of the epinucleus and into the phaco tip. Then

From Oregon Health Sciences University, Portland; and the Oregon Eye Institute, Eugene, OR.

Address reprint requests to I. Howard Fine, MD, 1550 Oak St, Suite 5, Eugene, OR 97401.

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TABLE 1. Fine Phacoemulsification

Alcon Legacy				I & A	
MacKool System Hi-Vac "Choo-choo Chop and Flip"					
Memory Mode	Chop Mem 1 Pulse	Trim Mem 2 Pulse	Flip Mem 3 Pulp	Cortical Mem 1-3	Viscoat Mem 4
Power (%)	50	35	35	Surg vac	Surg as
Asp (mL/min)	28/33	20/18	22	38	60
Vac (mm Hg)	350	180	180	500+	500+
Mode	Pulse 2/sec	Pulse 7/sec	Pulse 7/sec	Cont irrig	Cont irrig
Bottle height (cm)	78	72	72	70	70
Fine AMO Diplomax				I & A Control Surg Vac Control	
Hi-Vac/Chop and Flip "Choo-choo Chop and Flip"					
	Chop Phaco 1	Trim Phaco 2	Flip Phaco 3	Cortical Clean-up	Viscoat Removal
Power (%)	60%	60	60		
Aspiration cont flow (mL/min)	26/30	32/26	32/16	10	30
Vacuum (mmHg)	50/250	40/90	70/150	500	500
Mode	Cont burst	Cont burst	Cont burst	Cont irrig	Cont irrig
Bottle height (in.)	32	32	32	28	28

the floor is pushed back to keep the bag on stretch until three of the four quadrants of epinuclear rim and forniceal cortex have been evacuated. It is important not to allow the epinucleus to flip too early, thus avoiding a large amount of residual cortex remaining after evacuation of the epinucleus.

The epinuclear rim of the fourth quadrant is then used as a handle to flip the epinucleus (Fig 9). As the remaining portion of the epinuclear floor and rim is evacuated from the eye, 80% to 90% of the time all of the cortex is evacuated with it (Fig 10). Continuing with the soft-shell technique, the capsular bag is filled with Provisc, and Viscoat is injected into the center of the capsular bag to help stabilize the anterior chamber and to blunt the movement of the foldable IOL as it is implanted into the eye. If the cortex was incompletely mobilized during epi-

nuclear removal, Viscoat (rather than Provisc) is instilled first to viscodissect the cortex into the capsular fornix and drape some of it on top of the capsulorhexis (Figs 11 and 12). Provisc is then injected into the bottom of the bag, forcing the Viscoat anteriorly. The foldable intraocular lense (IOL) is then implanted.

Residual cortex is evacuated with residual viscoelastic, the posterior capsule being protected by the optic of the IOL. Mobilization of Viscoat is greatly facilitated because it is encased within the much more highly cohesive Provisc and less time is necessary to evacuate residual viscoelastic.

The choo-choo chop and flip technique uses the same hydro

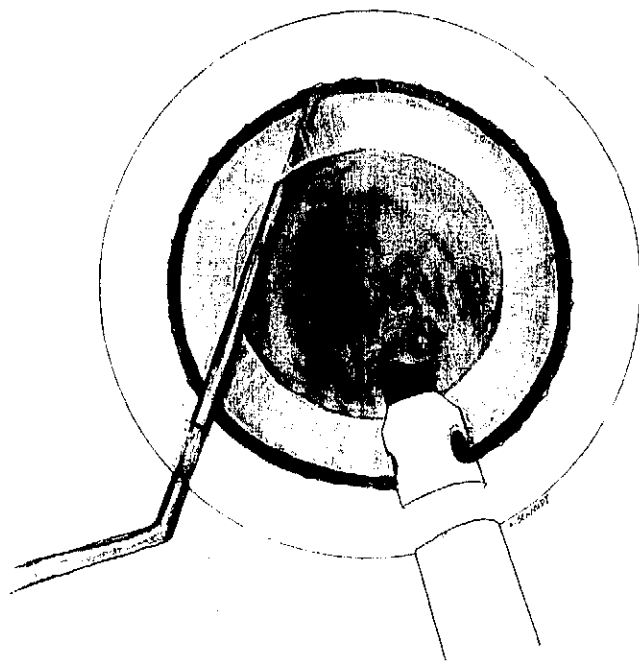


Figure 1. Stabilization of the nucleus during lollipoping for the initial chop.

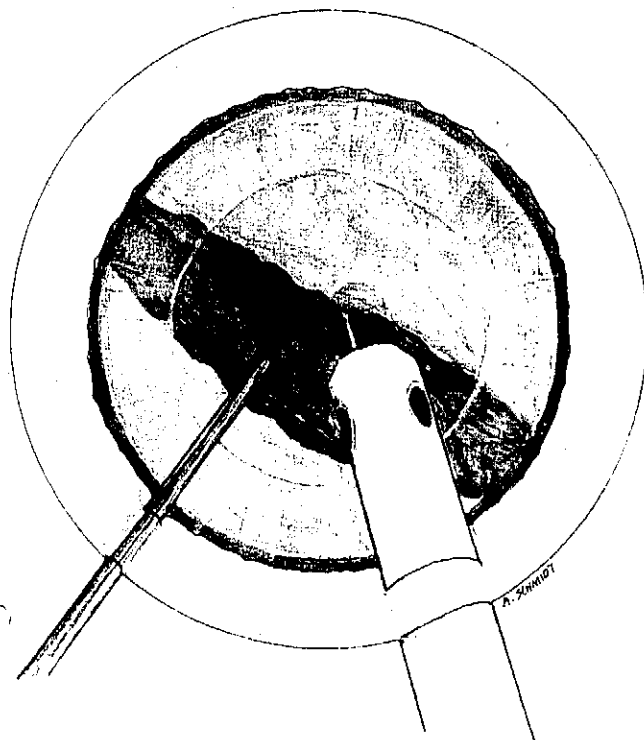


Figure 2. Completion of the initial chop.

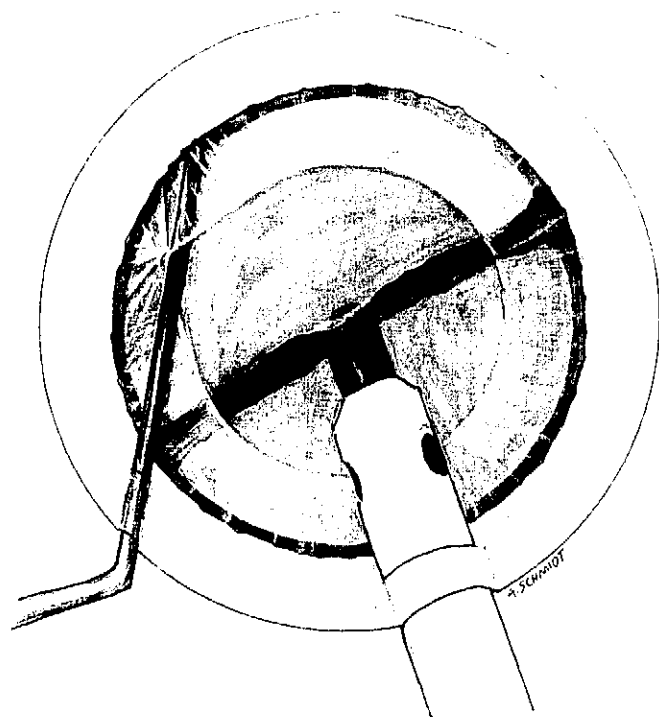


Figure 3. Stabilization of the nucleus before commencing the second chop.

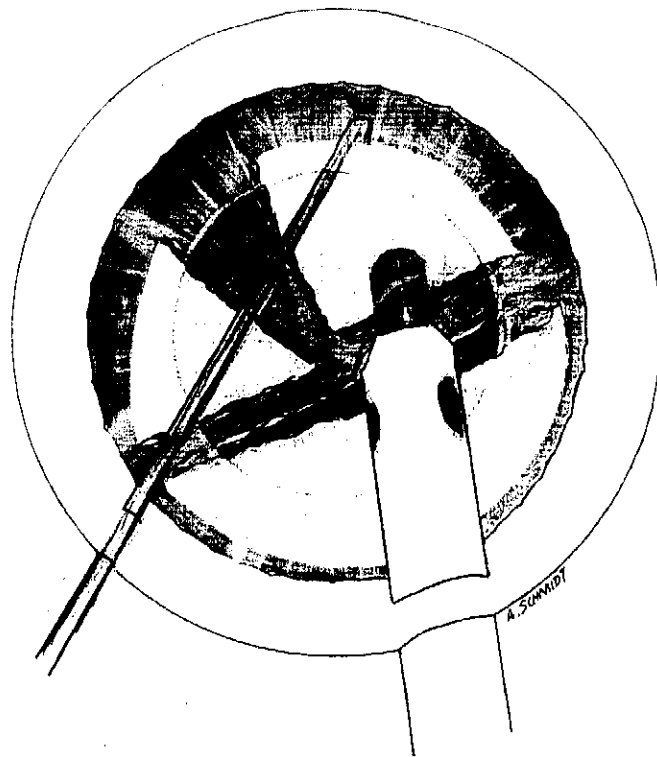


Figure 5. Mobilization of the first pie-shaped segment.

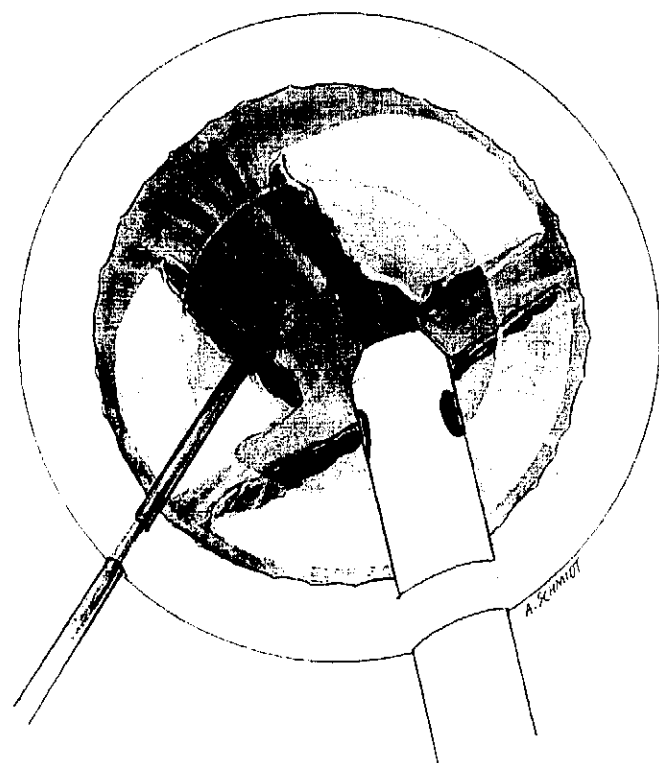


Figure 4. Pie-shaped segment adherent to the phaco tip after completion of the second chop.

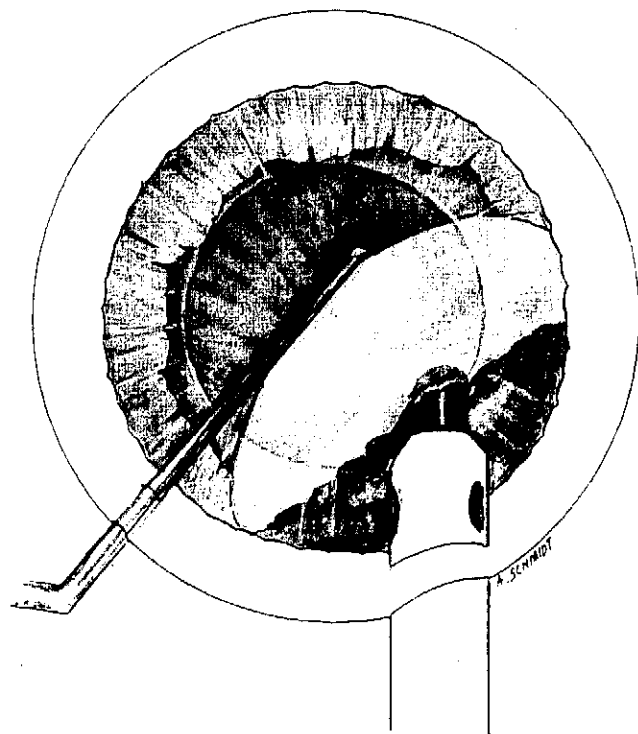


Figure 6. Scoring of the second hemi-nucleus.

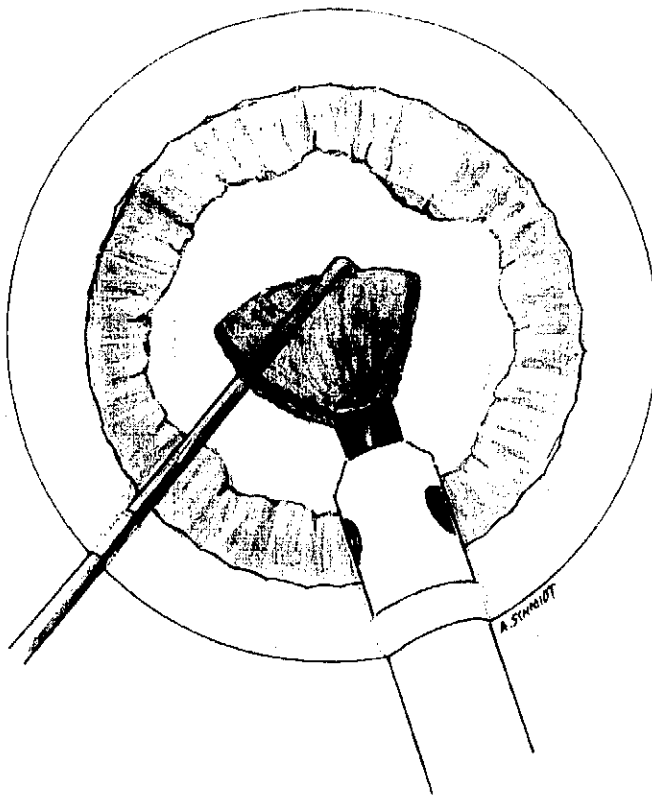


Figure 7. Mobilizing the final quadrant.

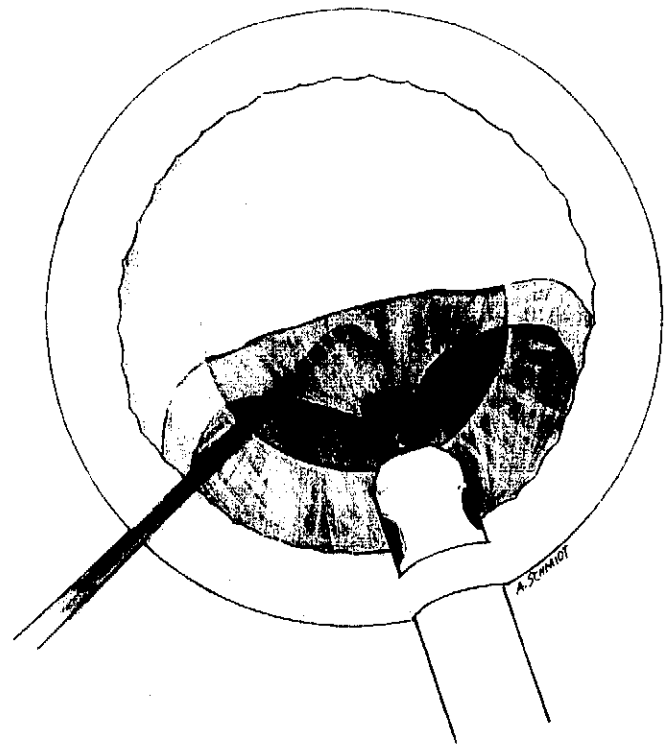


Figure 9. Flipping of the epinucleus.

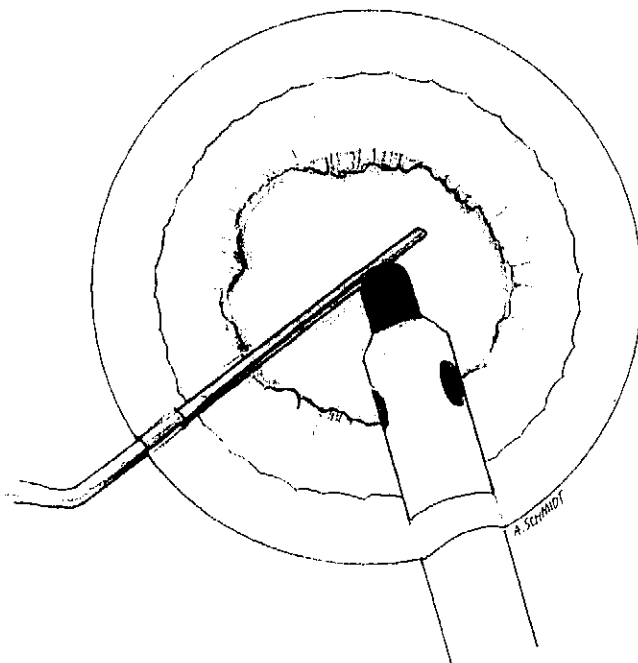


Figure 8. The epinuclear shell being rotated for trimming.

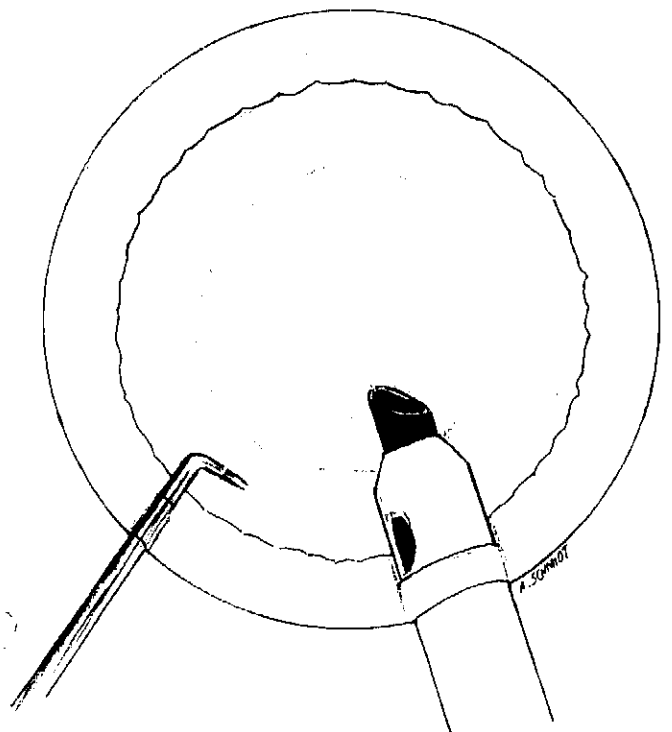


Figure 10. Empty capsular bag after flipping of the epinucleus.

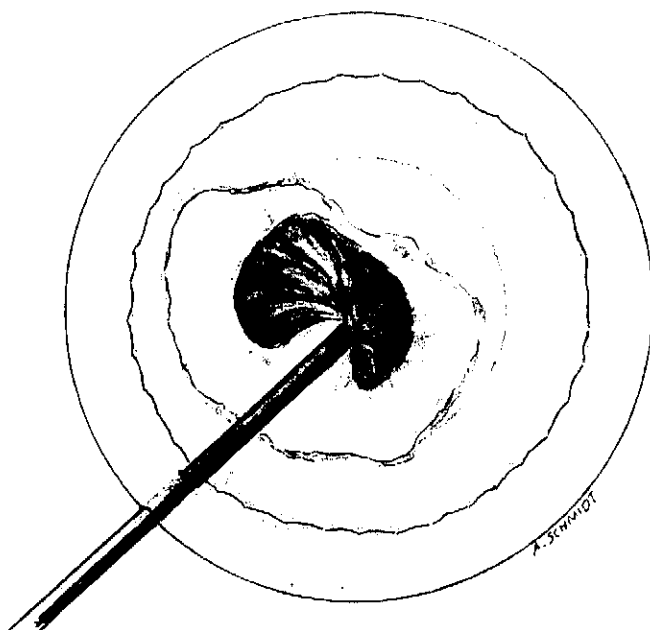


Figure 11. Viscodissection of residual cortex before IOL implantation.

forces to disassemble the nucleus but substitutes mechanical forces (chopping) for ultrasound energy (grooving) to further disassemble the nucleus. High vacuum is used as an extractive technique to remove nuclear material rather than using ultrasound energy to convert the nucleus to an emulsate that is evacuated by aspiration. This technique maximizes safety and control as well as efficiency in all cases, and allows for phaco of harder nuclei in the presence of a compromised endothelium. This technique facilitates the achievement of two goals: mini-

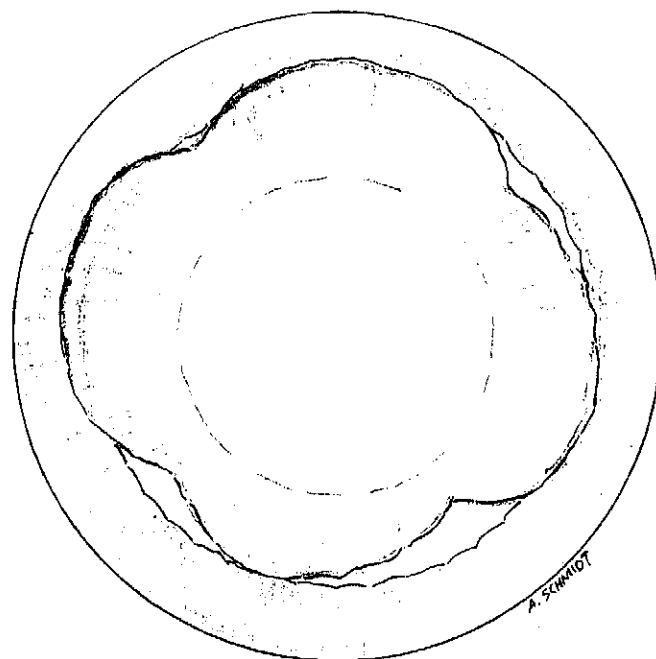


Figure 12. Viscodissection of residual cortex before IOL implantation.

mally invasive cataract surgery and maximally rapid visual rehabilitation.

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# Nuclear Chopping

Gavin G. Bahadur, MD and Jack M. Dodick, MD

We describe a technique of nuclear subdivision initially introduced by Dr Jochen Kammenn of Dortmund, Germany. Unlike other methods of nuclear fragmentation during phacoemulsification, such as cracking or conventional chopping techniques, this bimanual chopping maneuver divides the nucleus mechanically using no ultrasound energy nor aspiration to stabilize the fragments. We have noted a considerable decrease in the total ultrasound time and power needed for nuclear evacuation with this technique over four-quadrant divide and conquer using grooving and cracking.

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**W**e present a technique of chopping originally described by Jochen Kammenn of Dortmund, Germany, which offers significant advantages over many other commonly used methods of nucleofractis. In this technique, all of the nuclear fragmentation is performed mechanically, reducing the total ultrasound energy required for nucleus evacuation.

Total ultrasound energy during phacoemulsification has been shown to affect the extent of endothelial damage.<sup>1</sup> Because it minimizes ultrasound energy, this procedure is well suited for use in elderly patients with compromised endothelial function, patients with Fuch's endothelial dystrophy, or patients with corneal grafts. Furthermore, the direction of vector forces invoked during this technique places minimal stress on the lens capsule and zonules, making this procedure ideal for cases of pseudoexfoliation.

Two identical phaco choppers are used. Each instrument is 2.0 mm at its distal 90-degree bend, as shown (Fig 1, inset A'). The tips of the instruments are spherical and finely polished so as to be atraumatic to the lens capsule.

The technique may be performed equally well through a clear cornea (authors' preference) or scleral tunnel incision.

Hydrodissection is performed using balanced salt solution (BSS) through a 30-gauge blunt-tipped cannula. It is important to position the tip of the cannula at least 1 mm peripheral to the edge of the capsulorhexis to prevent the BSS from flowing centrally along the length of the cannula. The hydrodissection cannula should be used to tent the anterior capsule anteriorly to access the potential plane between the cortex and the lens capsule. Posterior pressure is gently applied with the cannula to decompress the capsular bag and to promote a complete fluid wave across the surface of the posterior capsule. Adequate hydrodissection is critical to the success of this procedure.

Hydrodelineation, the separation of central nucleus from peripheral epinucleus, is then performed by impaling the BSS cannula into the mid-periphery of the lens substance. Separating the concentric lamellae of the lens fibers permits clear

distinction between the soft epinuclear shell and the more dense central nucleus.

The capsulorhexis should be at least 5.0 mm in diameter to facilitate access to the anterior cortex. The next step is to use the phacoemulsification handpiece of the Legacy 20000 (Alcon Laboratories, Inc, Ft Worth, TX) to aspirate anterior lens cortex with a vacuum of 300 mm Hg and an aspiration rate of 25 cc/min in foot position 2 (using no phaco power). The phaco tip is kept bevel down and is swept in a circular motion within the capsular opening so as to remove as much anterior cortex as possible. Once this cortical material is removed, there is better visualization of the lens anatomy, and less cortical debris is loosened during the chopping maneuvers.

Next, the two choppers are inserted at 90-degree angles: one through the principal incision at the 11-o'clock position and the second through a clear corneal paracentesis at the 2-o'clock position. The instruments are inserted nearly parallel to the iris, between the anterior capsule and the lens. Each chopper is gently rotated and carefully positioned so that the blunt end faces the posterior capsule at the equatorial region of the lens (Fig 1A).

In a smooth, controlled motion with attention to the lens/capsule anatomy, the two choppers are drawn together toward the visual axis, exerting slight posterior pressure, thereby mechanically chopping the lens in half (Fig 1B). Next, the choppers are positioned on either side of the inferior heminucleus (at the 5-o'clock position and centrally) (Fig 1C) and are carefully drawn together, creating two distinct quadrants (Fig 1D). The choppers are then placed at the 11-o'clock position and centrally, and the superior heminucleus is fractured into two quadrants, as shown (Fig 1E, 1F).

Once quartered, the nuclear fragments are removed using vacuum settings of 300 to 400 mm Hg, aspiration flow rates of 35 to 45 cc/min, and maximum phaco power of 25% to 45%, depending on the density of the nucleus. A bottle height of 78 cm may be necessary to maintain anterior chamber depth. During phacoemulsification of the nuclear quadrants, a Sinskey hook may be used to feed nuclear fragments into the phaco tip.

With this technique, we require an average of 13% ultrasound power over an average of 2.11 minutes. These power and time parameters are a significant reduction from those routinely required in our cases in which we use phacoemulsification to groove the nucleus before cracking (24% phaco power over an average of 2.87 minutes).<sup>2</sup> Furthermore, according to Dr Kammenn in Germany, a 2+ brunescient nucleus can be evacuated using 600 mm Hg of vacuum, with no ultrasound power.

In our experience thus far, the procedure appears safe, and we have had no capsular ruptures during chopping. Nonetheless, the procedure requires fine motor control, mastery of the spatial relationships in the anterior segment, and substantial practice. The most significant potential risk of this procedure is to inadvertently place the choppers in the sulcus outside the lens capsule, thereby rupturing zonules and disinserting the

From The Sinskey Eye Institute, Santa Monica, CA.

Address reprint requests to Gavin G. Bahadur, MD, The Sinskey Eye Institute, 2232 Santa Monica Blvd, PO Box 4031, Santa Monica, CA 90411-4031.

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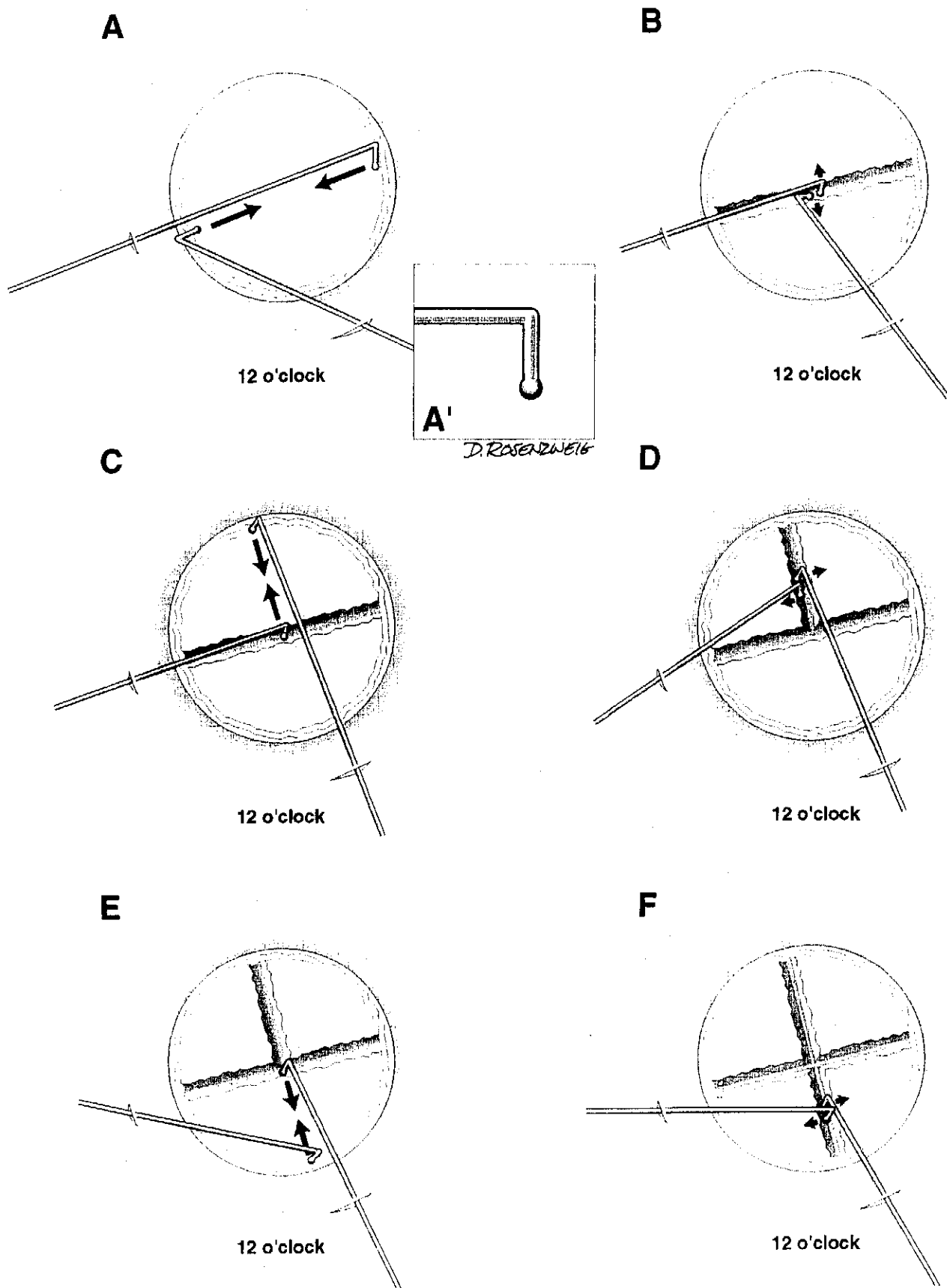


Figure 1. Proper placement and movement of choppers for effective nuclear division.

capsular bag during chopping. The 2-mm length of the chopper's distal end helps to ensure that the central posterior capsule will be untouched. Furthermore, we have consistently noted that the epinuclear shell is smooth and intact after nuclear chopping, underscoring avoidance of the posterior capsule during this procedure.

Using this technique of chopping and minimal phaco power, we have documented a high degree of corneal clarity and excellent visual results on the first postoperative day.

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# Phaco Prechop: Manual Nucleofracture Prior to Phacoemulsification

Takayuki Akahoshi, MD

Phaco prechop is a new surgical technique to make single-hand phacoemulsification easy and rapid. With this procedure, the nucleus is divided into pieces before the phacoemulsification and without grooving. The risk of posterior capsule rupture during grooving was diminished. Using a Phaco Prechopper, a special forceps designed for this technique, nuclei of any hardness can be divided easily. Harder nuclei or nuclei with weak ciliary zonules, however, should be prechopped especially carefully, supported with a nucleus sustainer to reduce the stress on the ciliary zonules. Phaco prechop also can be performed using two phaco-choppers or nucleus sustainers. High-flow and high-vacuum settings of the phaco machine are recommended for phacoemulsification of the prechopped nucleus, to control the nuclear fragments and protect the corneal endothelium. With the phaco prechop technique, ultrasound time was reduced to less than 50% of that required for the conventional grooving method. Because the nucleus was divided beforehand, the movement of the phaco tip was minimized. Mechanical and thermal damage to the wound was consequently reduced, and self-sealing of the clear corneal wound was easily attained without any stromal hydration. Thus, the phaco prechop technique is anticipated to provide novel advantages over the single-hand phaco technique. Copyright © 1998 by W.B. Saunders Company

**P**haco prechop is a new technique allowing division of the nucleus manually before phacoemulsification.<sup>1,2</sup> With this technique, the nucleus can be divided without grooving. With the conventional one-hand technique, grooving is indispensable for nuclear division. Making a groove of appropriate depth and length is the most important point in accomplishing single-hand phacoemulsification. However, this step is probably the most stressful for surgeons, because with shallow grooving, the nucleus is not divided completely, and a saucer-like nuclear plate remains, whereas excessively deep grooving results in rupture of the posterior capsule.

The efficacy of phacoemulsification is markedly improved by prechop of the nucleus. Even with a single-handed phaco procedure, the prechopped nuclear fragments can be emulsified quite easily and rapidly. The high-flow and high-vacuum setting of the phaco machine is recommended for phacoemulsification of the prechopped nucleus to control the nuclear fragments in the capsular bag and to protect the corneal endothelium.

With the phaco prechop technique, the ultrasound time is less than 50% of that required for the conventional grooving method. Division of the nucleus beforehand minimizes the movement of the phaco tip. Mechanical and thermal damage to

the wound is consequently reduced, facilitating self-sealing of the clear corneal wound without stromal hydration. The risk of rupturing the posterior capsule during the grooving process is diminished, and other complications are also reduced.

Furthermore, this technique is also applicable to the education of residents attempting to master phacoemulsification. Once the nucleus has been divided by the trainer, the following phacoemulsification is quite simple and can be safely performed by the trainee.

Since 1993, the author has performed this technique in nearly 9,000 cataract cases, thereby proving its safety and effectiveness. The phaco prechop technique is anticipated to provide novel advantages over the single-hand phaco technique.

## Indications and Contraindications

All types of nuclei are suitable for the phaco prechop technique, the only exceptions being the cases with severe zonular complications. In eyes suspected of having weakened ciliary zonules, this technique should not be done or should only be done with great care by a surgeon highly experienced in the technique. Such cases include subluxated lens in Marfan syndrome, eyes with a history of ocular trauma, eyes that have undergone intraocular surgery such as vitrectomy, eyes with pseudoexfoliation syndrome or advanced retinitis pigmentosa, and eyes with a history of acute glaucoma attack in patients with angle closure glaucoma and so on. In cases in which continuous curvilinear capsulorhexis (CCC) has not been completed, phaco prechop is possible, but it should be performed carefully so as to avoid enlarging the capsular tear. For nuclei harder than grade 4 or 5, the "counter prechop" technique or "double chopper prechop" technique should be chosen. Furthermore, these procedures should be attempted only after the surgeon has completely mastered the technique in relatively soft nuclei.

## Phaco Prechop Instruments

In soft nuclei, such as grade 1 or 2, phaco prechop can be performed with a capsulorhexis forceps. In harder nuclei, however, use of a capsulorhexis forceps is not recommended. The force necessary to drive the forceps into the nucleus may result in excessive stress on the ciliary zonules. To perform the phaco prechop technique easily and effectively, use of special instruments (Table 1) is recommended.

The phaco prechopper is a new cross-action forceps specially designed for the phaco prechop technique (Fig 52). The straight type (Fig 53) is suitable for clear corneal incisions, the angled type (Fig 54) for scleral tunnel incisions. The original phaco prechoppers produced by Duckworth & Kent (Baldock, Herts, England) are made of titanium (Fig 52), and those produced by American Surgical Instruments Corporation

From the Department of Ophthalmology, Mitsui Memorial Hospital, Tokyo, Japan.

Address reprint requests to Takayuki Akahoshi, MD, 1-11-7-2603, Tsukuda, Chuoku, Tokyo, 104-0051, Japan.

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**TABLE 1. Phaco Prechop Instruments**

Duckworth & Kent	
Akahoshi prechop forceps	
Straight type	2-815-1
Angled type	2-816-1
Akahoshi nucleus sustainer	
American Surgical Instruments Corporation (ASICO)	
Akahoshi prechopper	
Scleral model, angled	AE-4280
Clear corneal model, straight	AE-4281
Universal model	AE-4282
Akahoshi nucleus sustainer	AE-2525
Kammann prechopper	
Superior angled	AE-2521
Temporal straight	AE-2522
Katena	
Akahoshi phaco prechopper, angled	K5-7230
Brierley nucleus splitter	K3-2380
Rhein Medical	
Gillum nucleus splitters	8-14510

(ASICO) [Westmont, IL] are made of stainless steel (Figs 53, 54). These phaco prechoppers have a very fine, sharp tip that allows smooth insertion into the nucleus. The phaco prechoppers produced by Katena (Denville, NJ) (Fig 55) and ASICO (Fig 56) have a flat, sharp tip suitable for prechopping relatively soft nuclei.

The nucleus sustainer (Fig 57) is used to support the nucleus during insertion of the phaco prechopper into the core of the nucleus. To protect the posterior capsule, a microball is placed at the tip of the sustainer (Fig 58). Two nucleus sustainers can be used for the "double chopper prechop" technique. For this prechopping technique, special hooks with a blade were also designed by Dr Kammann and Dr Gillum.

### Surgical Procedure

After the application of topical anesthesia, that is, two drops of 0.4% oxybuprocaine hydrochloride (Benoxil Minims, Osaka, Japan), a 3.5-mm temporal clear corneal incision is made in two steps using a 3.5-mm diamond keratome. This size is adequate for insertion of an acrylic intraocular lens, AcrySof MA30BA (Alcon Laboratories, Fort Worth, TX), without enlarging the wound size. After filling the anterior chamber with viscoelastic material, continuous curvilinear capsulorhexis is performed using a capsulorhexis forceps. To perform phaco prechop safely, a complete CCC with no tears or notches should be made. Sufficient cortical cleavage hydrodissection is made until the nucleus can be easily rotated in the capsular bag. The hydrodissection is critically important, such that insufficient hydrodissection results in the bisected nuclear fragments not being rotated for further dissection. The anterior chamber is again filled with a sufficient amount of viscoelastic material, and phaco prechop is then performed.

**TABLE 2. Choice of Phaco Prechop Technique**

Prechopper Prechop
Emery grade 2 to 3 nuclei
Counter Prechop/Double Chopper Prechop
Nuclei harder than grade 3 or 4
Weak ciliary zonules
Traumatic eye
Post-intraocular surgery such as vitrectomy
Pseudoexfoliation syndrome, etc.
Incomplete CCC

Phaco prechop can be performed most easily and effectively with special dividing forceps, the phaco prechopper. Two phaco choppers or specially designed nucleus sustainers can be used for the bimanual dividing procedure termed the "double chopper prechop" technique. According to the hardness of the nucleus and the conditions of the capsulorhexis and ciliary zonules, three different phaco prechop methods may be selected (Table 2):

The *prechopper prechop* technique is performed with a phaco prechopper alone. Most of our cataract cases are suitable for this technique. However, if the nucleus is too hard for insertion of the prechopper into its core, the procedure should be converted to the "counter prechop" technique.

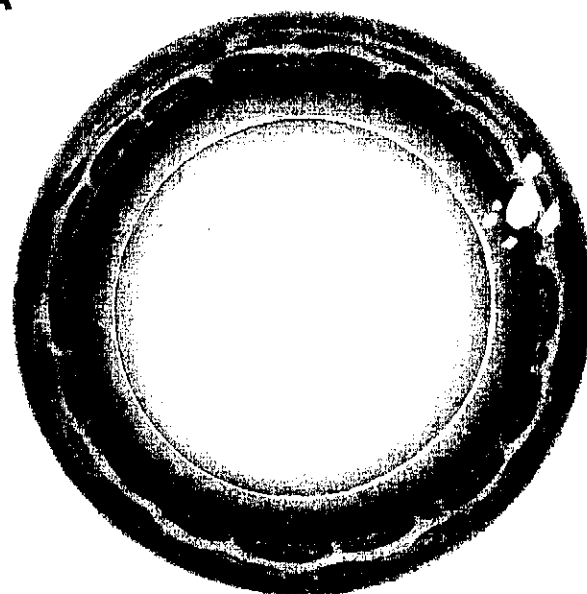
**A****B**

Figure 1. Prechopper prechop technique. Perform a complete CCC and permit a sufficient hydrodissection, allowing the nucleus to rotate freely in the capsular bag. Refill the anterior chamber with a sufficient amount of a viscoelastic material. Expose the nuclear surface for better visualization of the tip of the prechopper during insertion. If nuclear visibility is hindered by excess cortex, remove it during injection of the viscoelastic material or aspirate it with an irrigation and aspiration (I & A) tip. Once the surgeon has mastered the "phaco prechop" technique, the cortex removal step before prechop may be omitted.

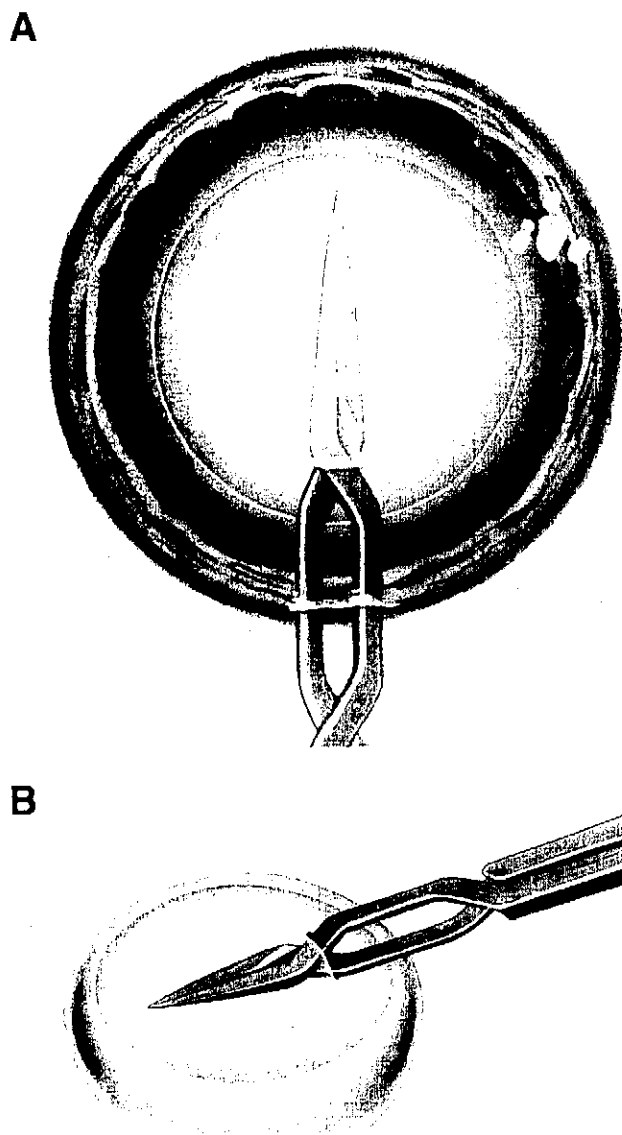


Figure 2. Insert the phaco prechopper slowly and straight into the core of the nucleus. Keep the prechopper closed during insertion. Insertion should be toward the central core of the nucleus. If the direction of the insertion is inappropriate, the nucleus will rotate and there will not be sufficient force to drive the prechopper into the nucleus. An insertion too shallow will scramble the epinucleus and decrease the visibility of the nucleus. If the nucleus is too hard to insert the prechopper, stop the insertion and convert to the "counter prechop" technique.

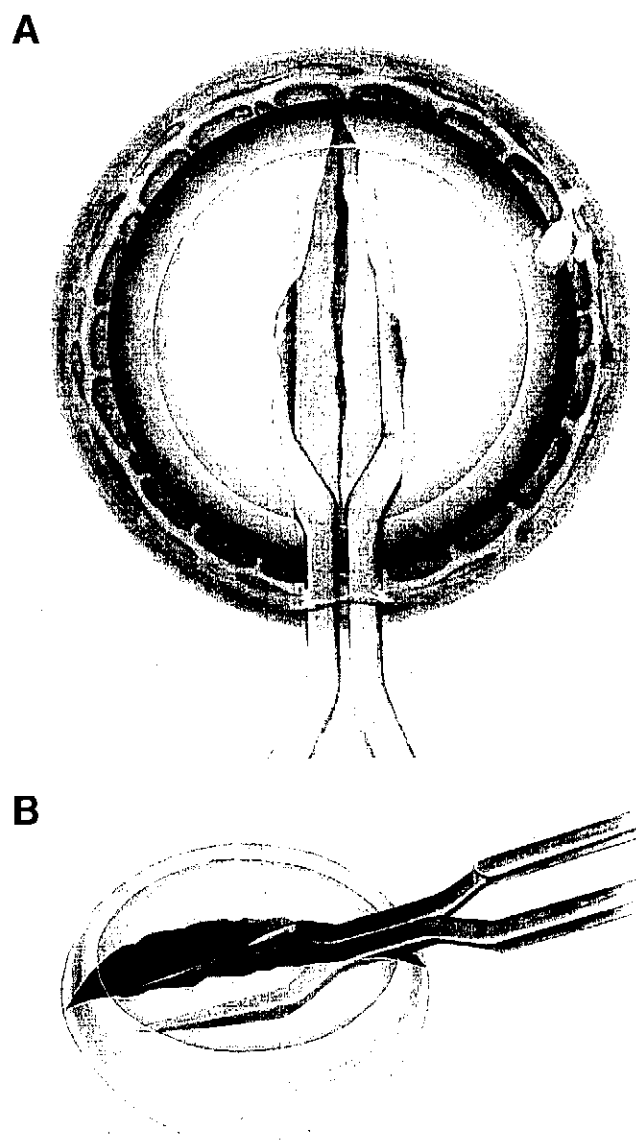


Figure 3. Open the prechopper slowly to bisect the nucleus. If the nucleus is not divided by this single action, place the prechopper in the deepest portion of the nuclear valley formed by the two incompletely divided nuclear fragments. Repeat the opening procedures to complete the division over the entire depth and length of the nucleus until the posterior capsule is reached. When complete nuclear division has been attained, the inner surface of the posterior capsule will be visible between the prechopped nuclear fragments. Complete nuclear division is critical to achieving effective phacoemulsification. If the lens is too soft and the tip of the prechopper might sink into the nucleus, switch to a prechopper with flat tips.

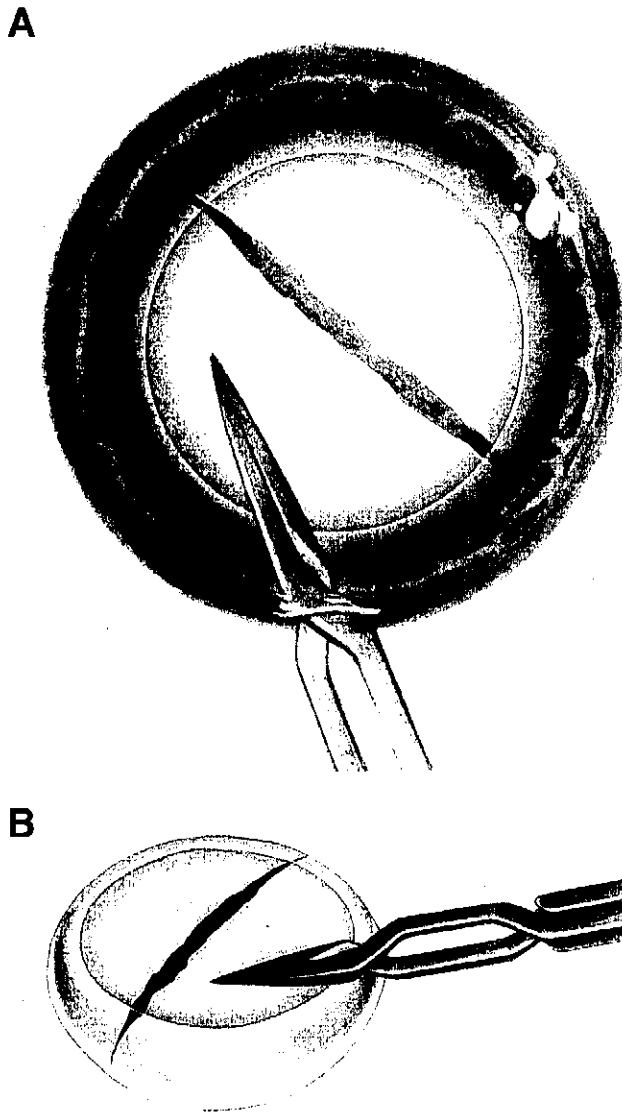


Figure 4. Rotate the bisected nuclear fragments  $90^\circ$  by pushing on the nuclear surface with the prechopper. The nucleus can be rotated easily if each bisected nuclear fragment is temporarily restored to its original position. An adequate amount of viscoelastic material in the anterior chamber and application of slight downward force also facilitate rotation. If an adequate hydrodissection is not achieved, rotating the nucleus will be difficult. Try repeating hydrodissection until the nucleus can be rotated freely in the capsular bag. Then refill the anterior chamber with the viscoelastic material again and proceed to the further prechop step. The degree of nuclear rotation should be exactly  $90^\circ$ . If the rotation angle is less than  $90^\circ$ , the bisected nuclear fragments may slide during the second insertion of the prechopper. Also, the direction of the insertion may not be along the lens fiber structure and the nucleus will not crack.

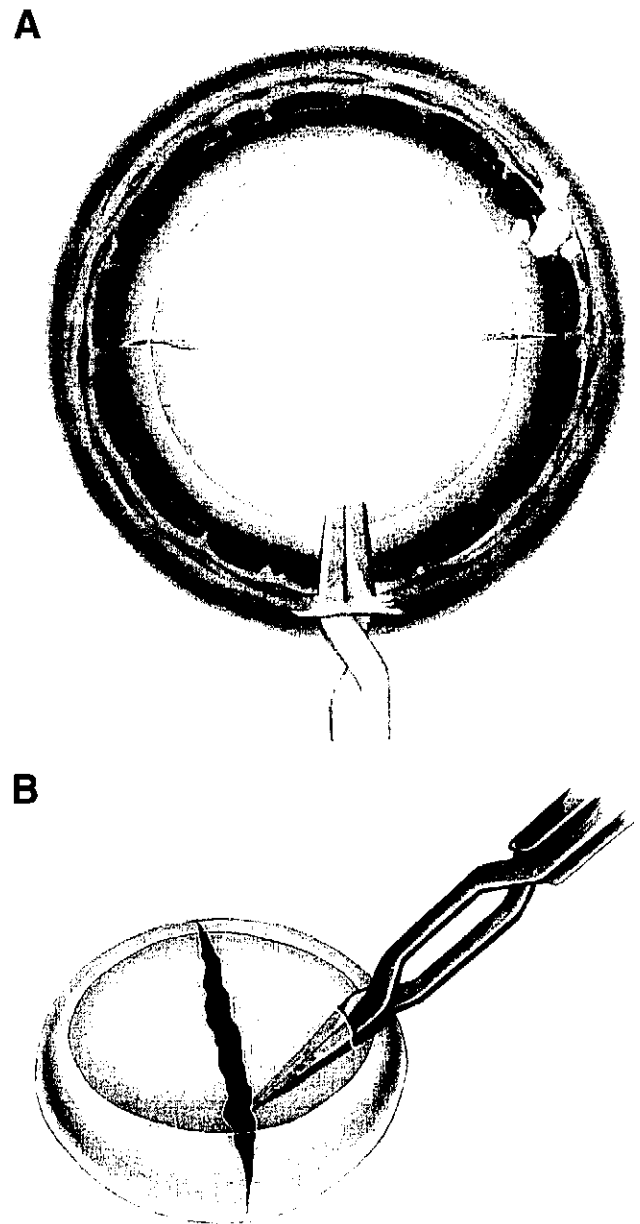


Figure 5. Insert the prechopper deep into the core of the bisected nuclear fragment on this side. The direction of prechopper insertion should be toward the core of the nucleus and perpendicular to the initial crack line. If the nuclear rotation is insufficient and the angle of the prechopper insertion is not perpendicular to the initial crack line, the nuclear fragments may rotate or not provide sufficient resistance to prechopper insertion. The prechopper should be inserted deep enough to achieve complete nuclear division.

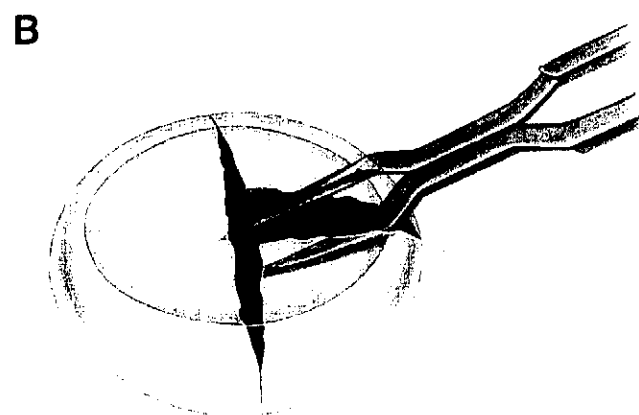
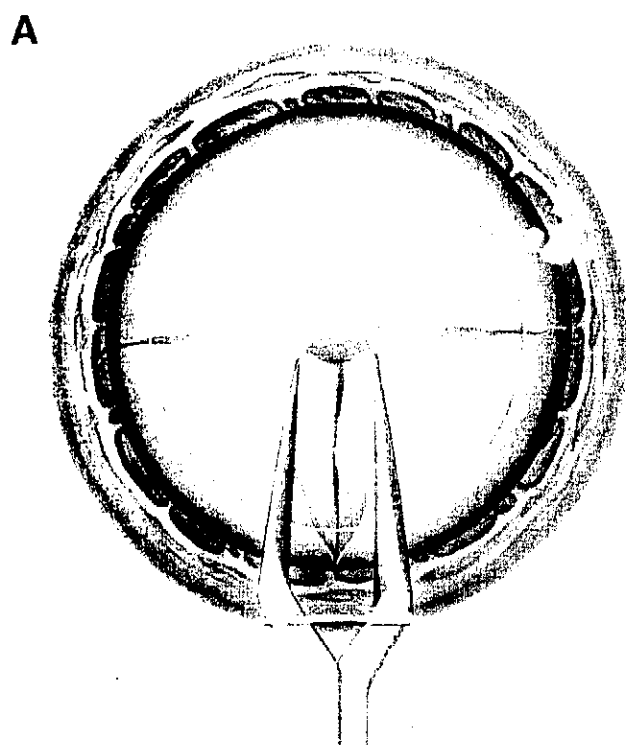


Figure 6. Open the prechopper and divide the bisected nucleus in the same way. If the nucleus is not divided by a single action, place the prechopper at the deepest point and open it again. Repeat the opening actions to complete the division until the inner surface of the posterior capsule is visible between the prechopped nuclear fragments.

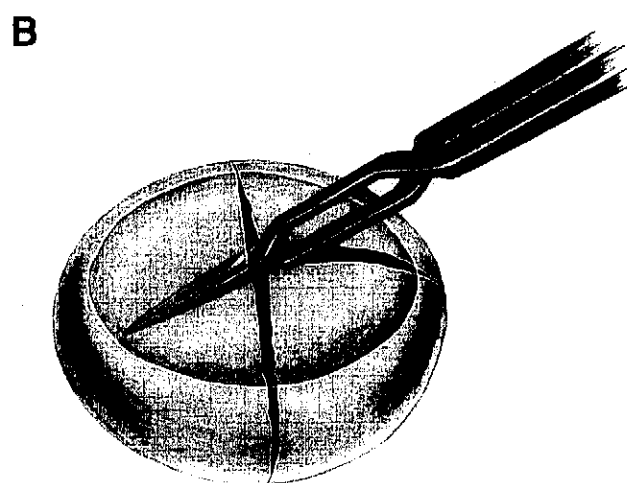
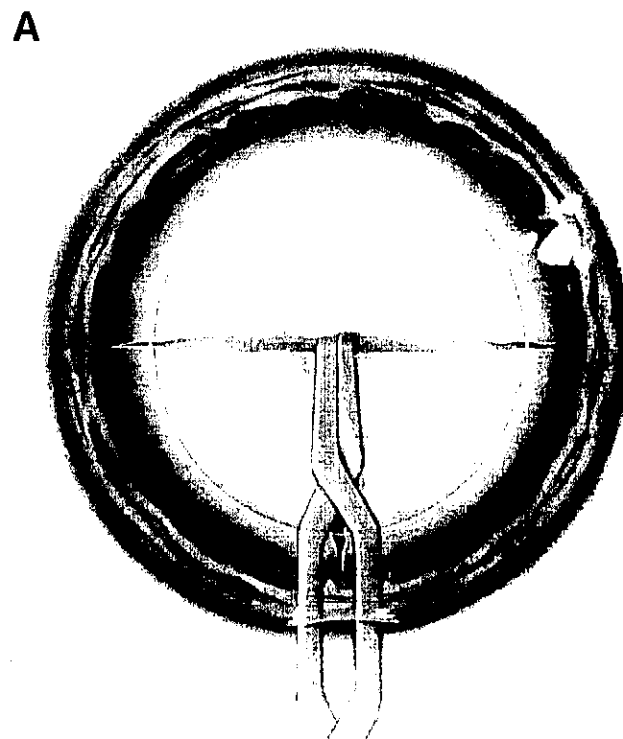


Figure 7. Then insert the prechopper into the hardest remaining portion of the bisected nucleus on the other side. If insertion is difficult because of the nuclear core's hardness, insert the prechopper from toward the top of the nuclear core downwards. If prechopper insertion on this side is still difficult, rotate the nucleus 180° and insert the instrument on the equator side (Figures 30-34).

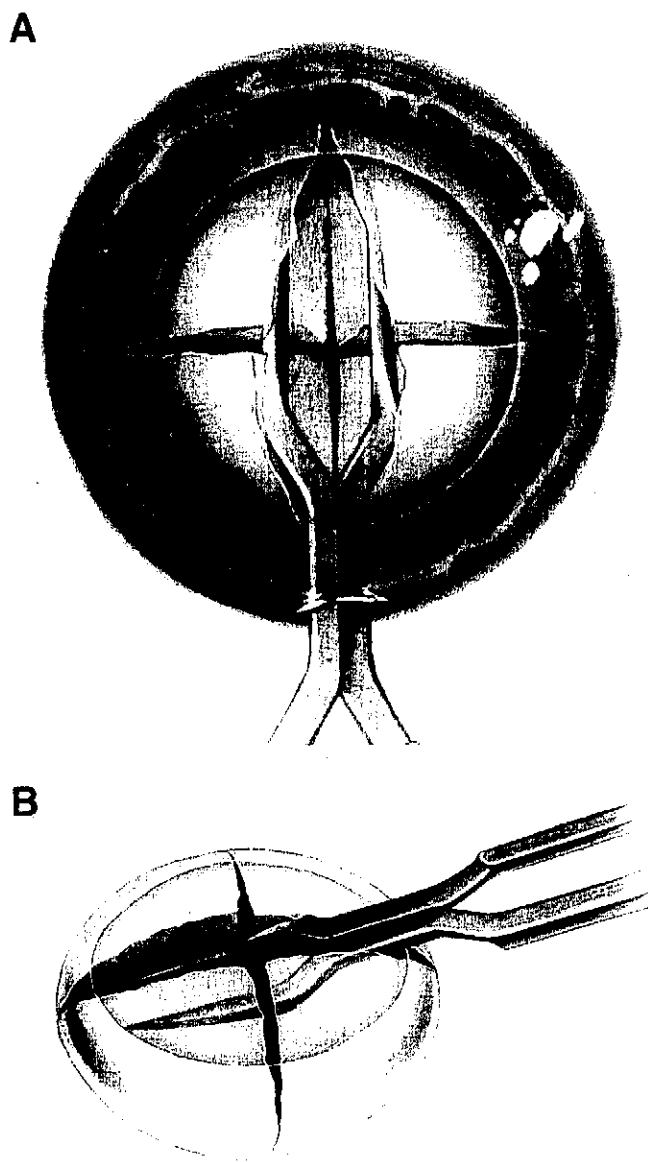


Figure 8. Open the prechopper repeatedly until the nucleus has been divided completely to its bottom. If the viscoelastic material has leaked from the wound during the prechopping procedure and the visibility of the nucleus is hindered by the cortex, add more viscoelastic material to the anterior chamber.

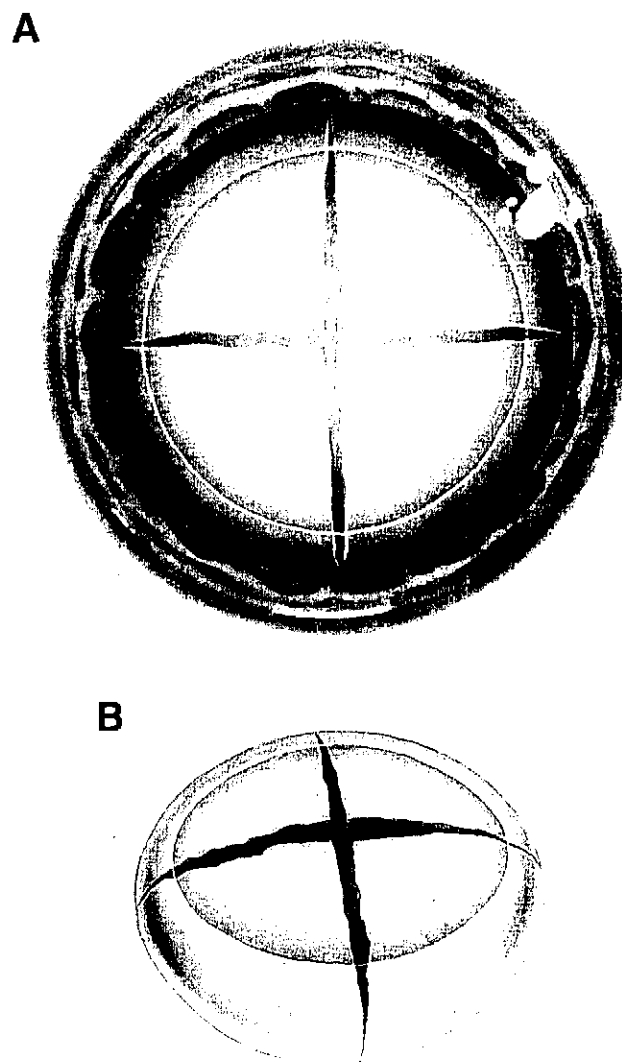


Figure 9. Completion of quadrisection of the nucleus. It is extremely important to achieve complete nuclear division. Merely making a crack in the nucleus as a result of an incomplete prechop procedure offers little advantage in the following phacoemulsification. The nucleus must be chopped from the nuclear surface to the bottom of the posterior capsule. Insert the phaco prechopper or inject viscoelastic material to ascertain that the nucleus has been completely divided into four pieces.

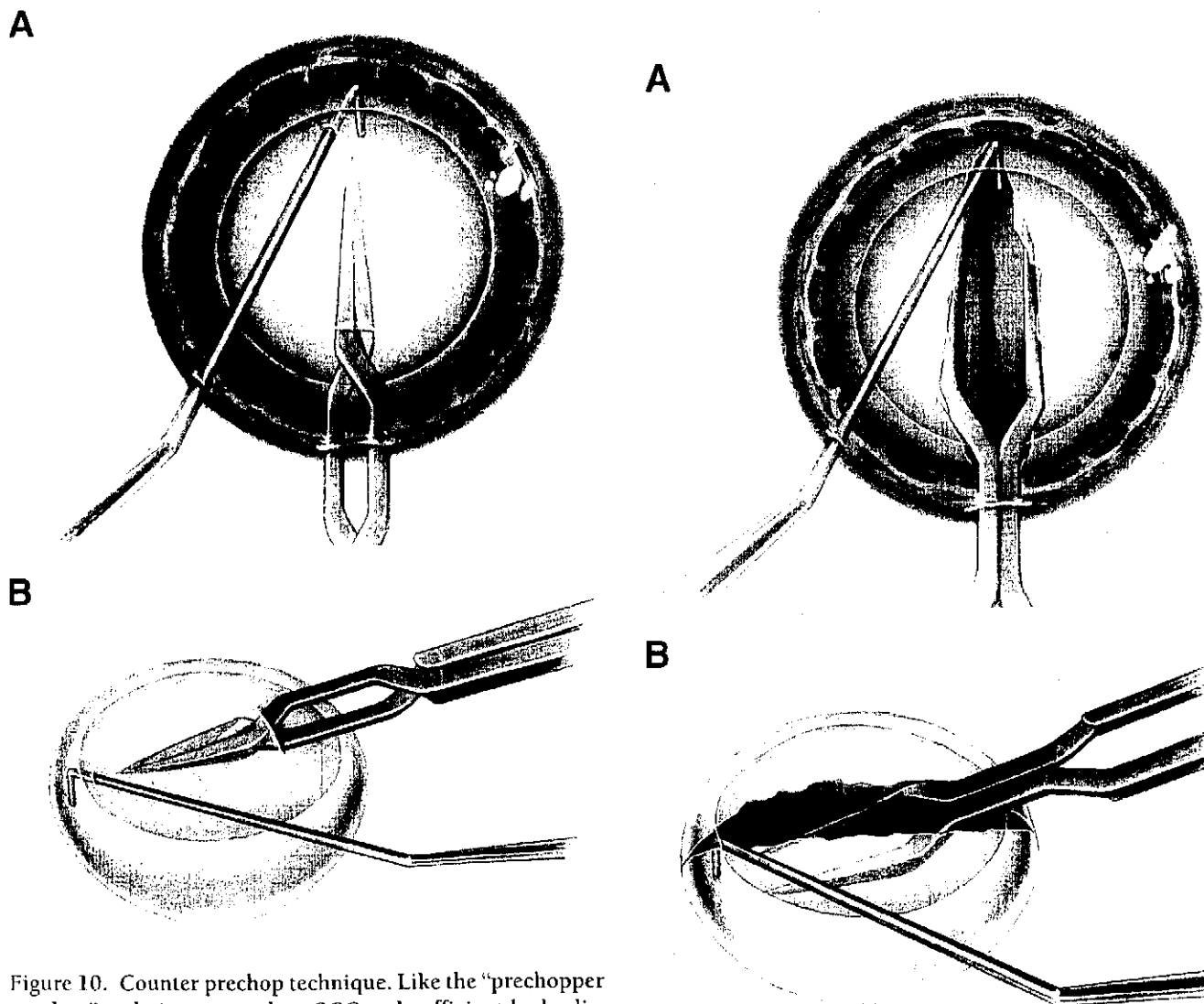
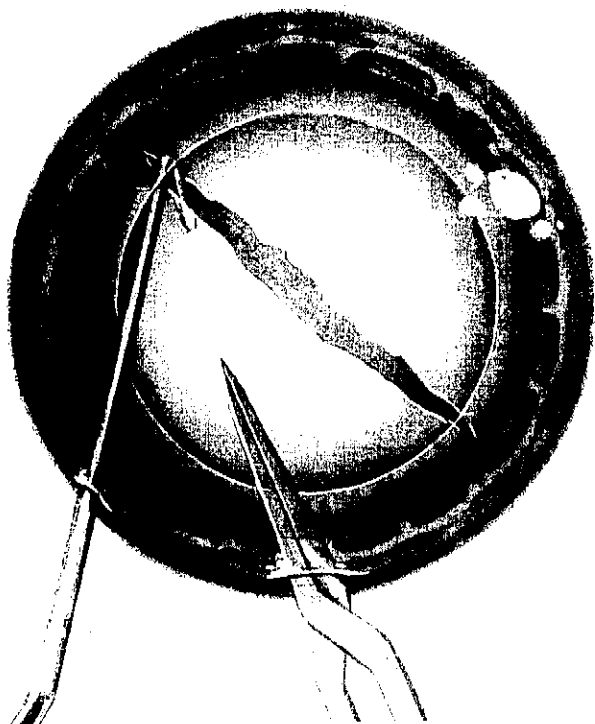


Figure 10. Counter prechop technique. Like the "prechopper prechop" technique, complete CCC and sufficient hydrodissection are the most important prerequisites. After refilling the anterior chamber with viscoelastic material, insert a nucleus sustainer or a phacochopper via the side port and pass it just beneath the anterior capsulorhexis edge to the equatorial portion of the nucleus. It is important not to damage the capsule or the ciliary zonules with the nucleus sustainer by supporting the nucleus over the anterior capsule. While sustaining the nucleus with the nucleus sustainer, insert the prechopper directly into the core of the nucleus. The direction and the depth of prechopper insertion is the same as in the "prechopper prechop" technique. The tip of the prechopper, the core of the nucleus, and the tip of the nucleus sustainer should be positioned on the same axis to avoid rotational movement of the hard nucleus.

Figure 11. Open the prechopper to bisect the nucleus. If the nucleus cannot be prechopped completely in a single action, repeat the opening action at the deepest point until complete nuclear division can be attained all the way to the bottom of the nucleus. When nuclear division is complete, the inner surface of the posterior capsule will be directly visible between the bisected nuclear fragments. Complete division is very important to subluxate and phacoemulsify the nuclear fragment with the aspirating power of the phaco tip, especially when the nucleus is sclerotic and hard.

A



B

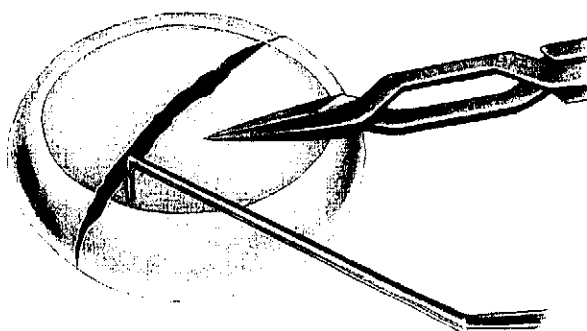
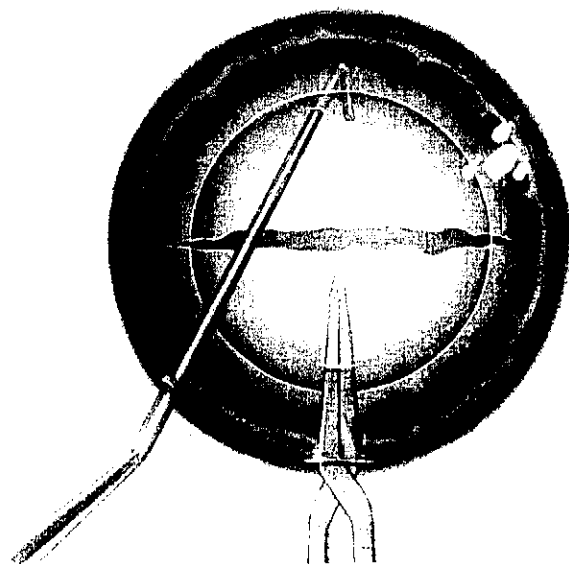


Figure 12. Rotate the nucleus  $90^\circ$  to set the nucleus in the next prechopping position. Use both of the instruments to push and pull the nucleus. Nuclear rotation is easier if the bisected nuclear fragments are temporarily returned to their original positions. The degree of nuclear rotation should be exactly  $90^\circ$ . If the rotation angle is less than  $90^\circ$ , the bisected nuclear fragments may slide during the second insertion of the prechopper or else the direction of the insertion may not be along the lens fiber construction.

A



B

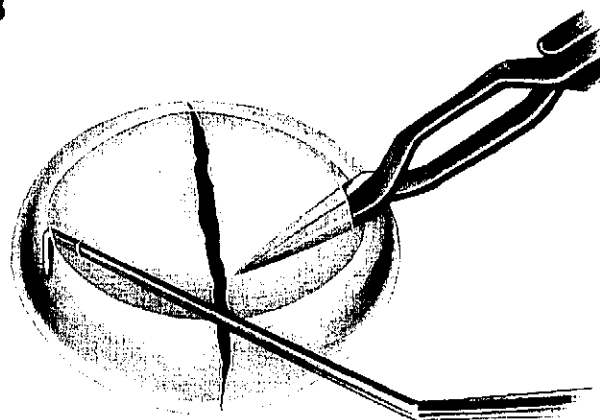


Figure 13. While holding the nucleus in the same position with a nucleus sustainer, insert the prechopper into the core of the bisected nuclear fragment on this side. The direction of the prechopper insertion should be toward the core of the nucleus and perpendicular to the initial crack line. Prechopper insertion should be deep enough to achieve complete nuclear division.



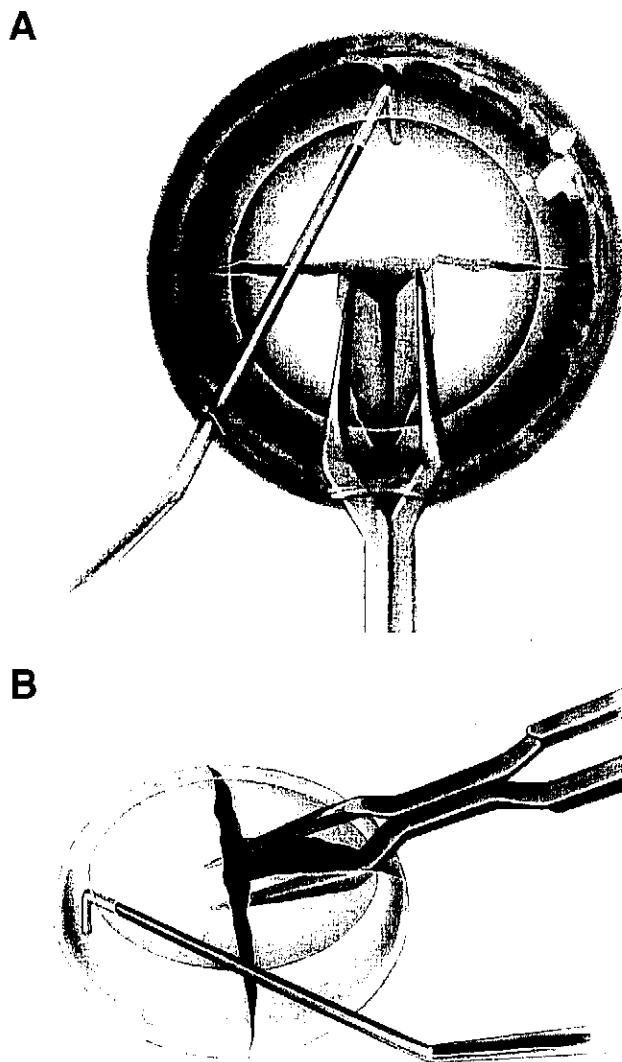


Figure 14. Open the prechopper and divide the bisected nucleus in the same way. If the nucleus is not divided by a single action, place the prechopper in the deepest portion of the nuclear valley formed by the two incompletely divided nuclear fragments. Repeat the opening actions to complete the division, over the entire depth and length of the nucleus, until the inner surface of the posterior capsule becomes visible between the prechopped nuclear fragments.

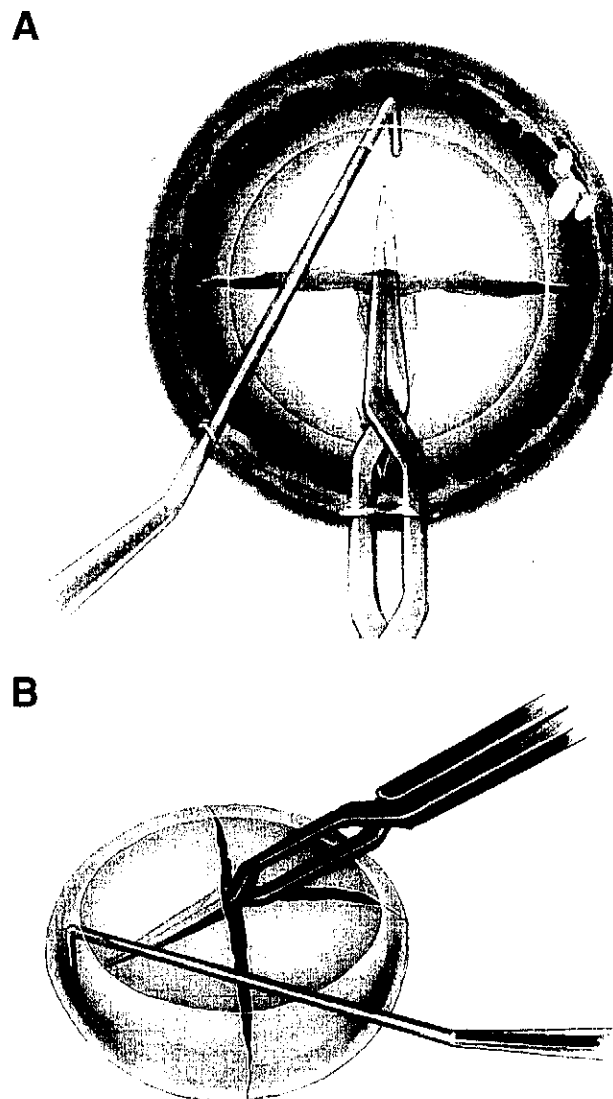


Figure 15. Then insert the prechopper into the remaining portion of the bisected nucleus on the other side. The prechopper should be inserted into the hardest portion of the nucleus. The nucleus sustainer on the left hand is used to provide sufficient supporting force to the nucleus during insertion of the prechopper.

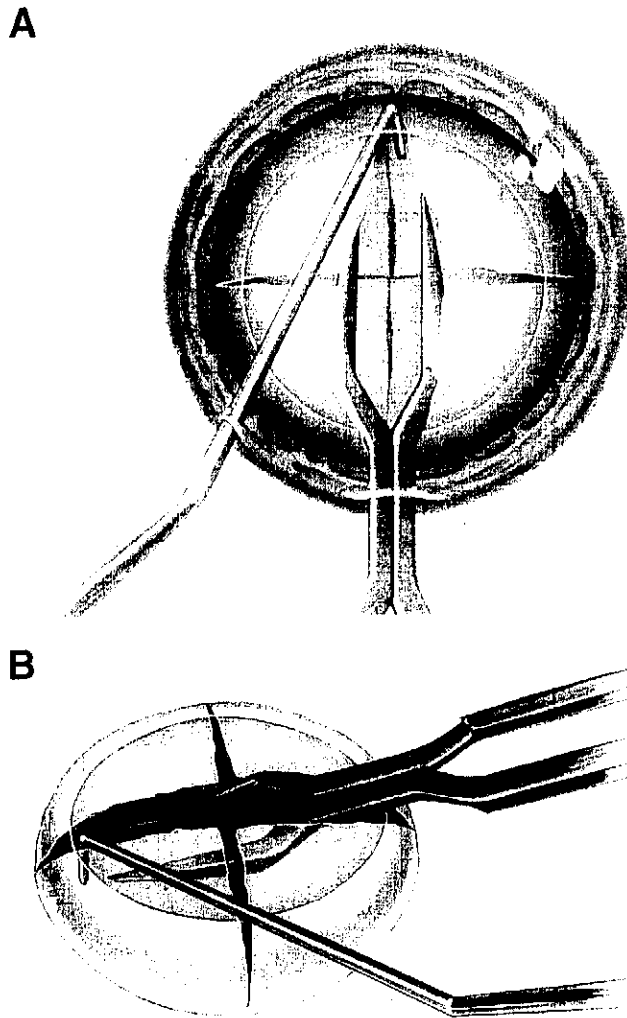


Figure 16. Open the prechopper repeatedly until complete nuclear division to the bottom of the nucleus has been achieved. Always be careful not to place any stress on the cornea or the ciliary zonules. If the viscoelastic material has leaked from the wound, during the prechopping procedure supply more viscoelastic material to protect the corneal endothelium.

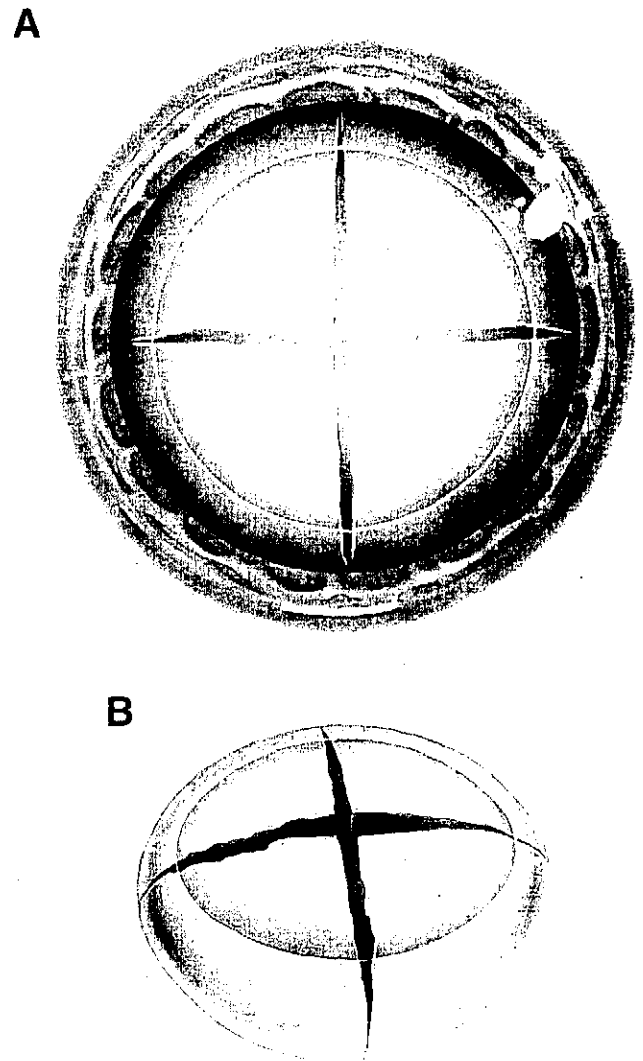


Figure 17. Completion of the nuclear quadrisection. It is extremely important to make a complete nuclear division, especially when the nucleus is hard. Merely cracking the nucleus part way because of an incomplete prechop technique is of little advantage in the following phacoemulsification. The nucleus must be chopped from the nuclear surface to the bottom until reaching the posterior capsule. Insert the phaco prechopper or inject the viscoelastic material to ascertain that the nucleus has been completely divided into four fragments.

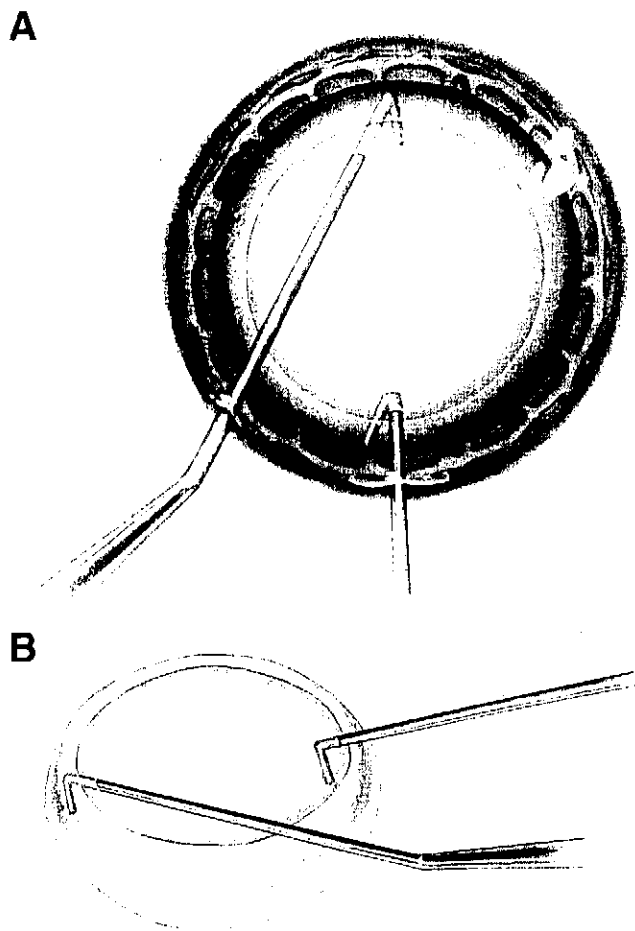


Figure 18. Double chopper prechop technique. After complete CCC and sufficient hydrodissection, fill the anterior chamber with viscoelastic material. Insert the first nucleus sustainer via the side port at the left, passing just beneath the anterior capsulorhexis edge to the equatorial portion of the nucleus. It is important to avoid damaging the anterior capsule edge or the ciliary zonules by incorrectly inserting the sustainer over the anterior capsule. Position the second nucleus sustainer via the wound into the equator of the nucleus opposite the sustainer on the left. Both sustainer tips and the center of the nucleus should be aligned along the same axis to prevent rotation of the nucleus.

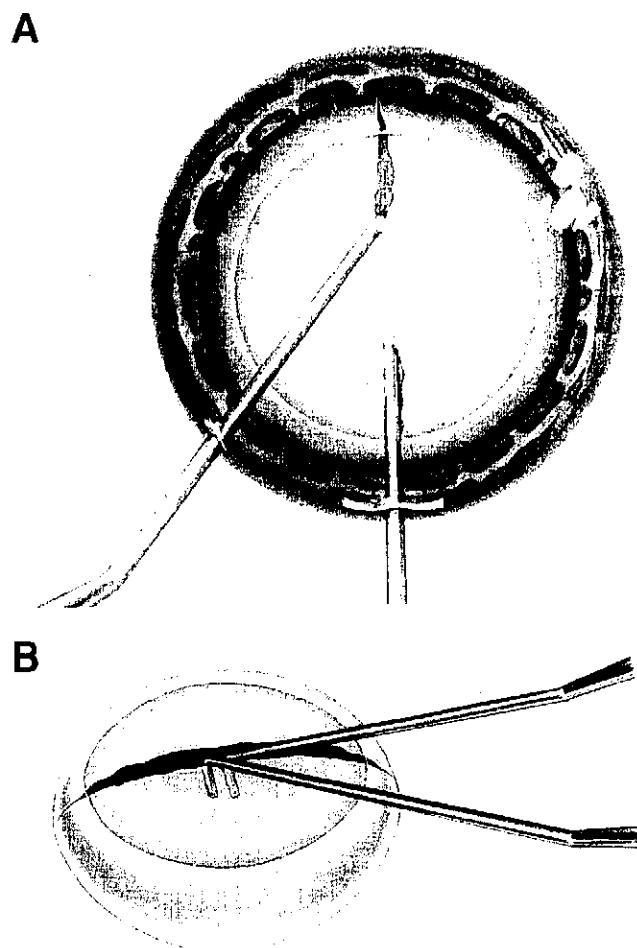


Figure 19. Simultaneously bring both nucleus sustainers closer to the center of the nucleus. Always concentrate the forces at the tips of the sustainers so as to grasp the center of the nucleus firmly, otherwise the nucleus may rotate. As the tips of the sustainers come closer, the anterior portion of the nucleus will be cut half way to the bottom but not completely.

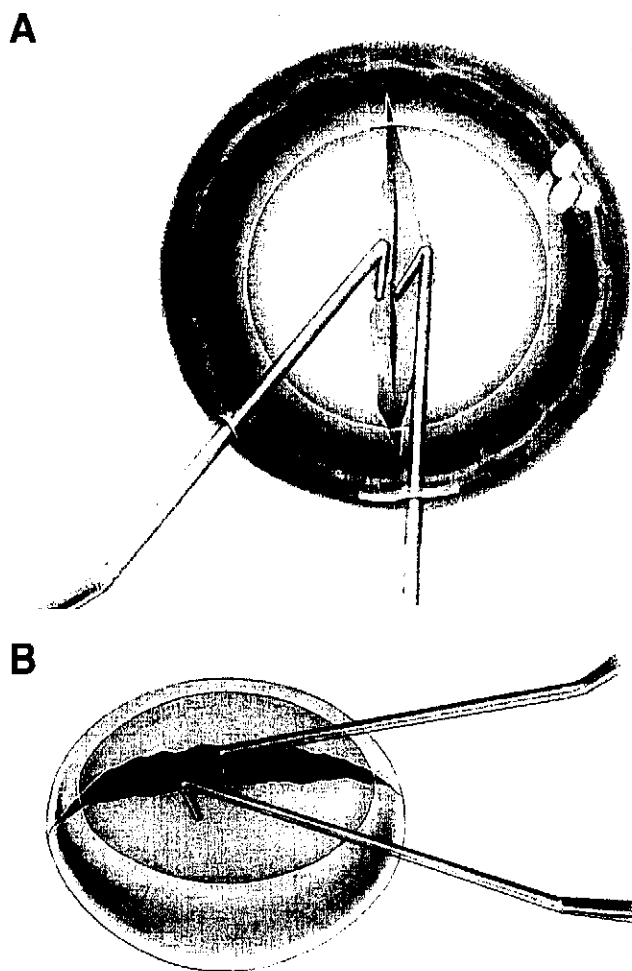


Figure 20. At the center of the nucleus, change the direction of force on the two nucleus sustainers  $90^\circ$  to separate the nucleus into two fragments. Complete the nuclear division all the way to the bottom of the nucleus. Repeat the separating procedure until the inner surface of the posterior capsule is visible along the entire length of the nuclear crack.

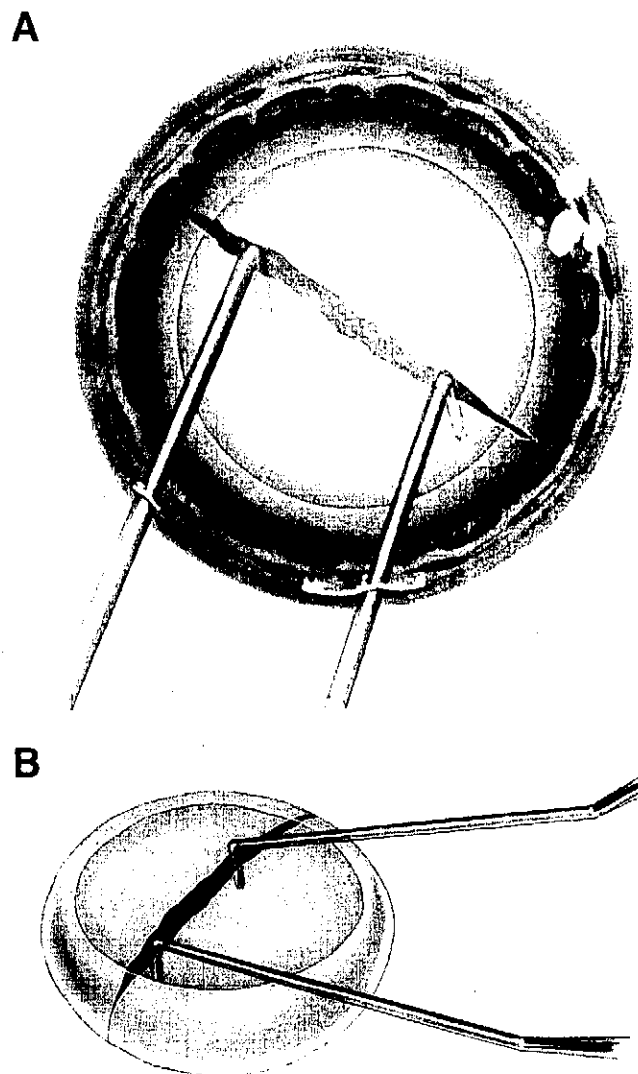


Figure 21. Rotate the nucleus  $90^\circ$  to set the nucleus in the next prechopping position. The degree of nuclear rotation is discretionary, and depends on the number of degrees at which the following prechopping procedure can be carried out most easily. Use the two sustainers to push and pull the nucleus.

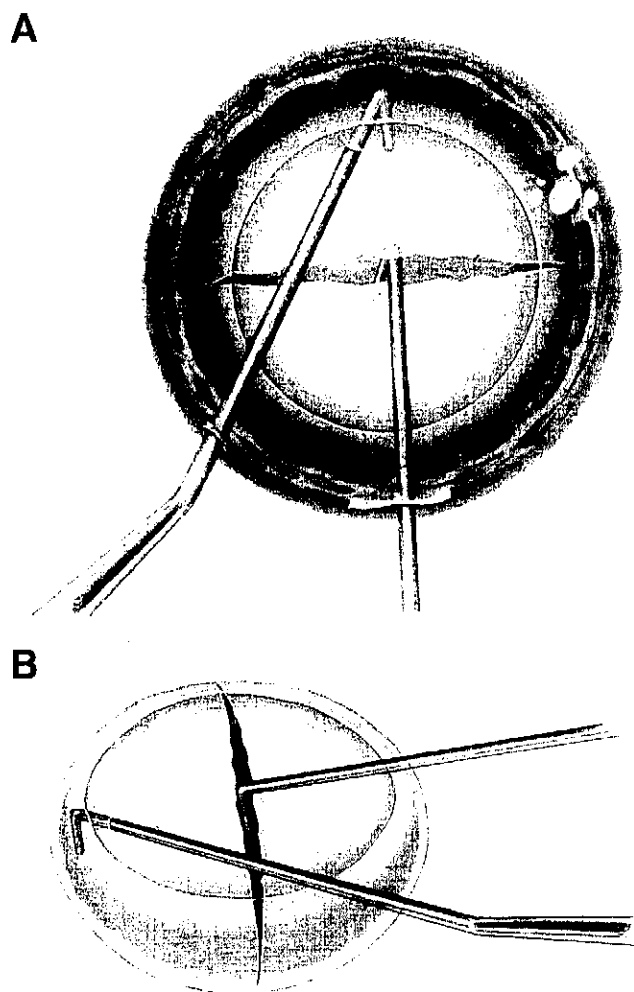


Figure 22. Insert the nucleus sustainer on the left to the equatorial portion of the nucleus, passing just beneath the anterior capsulorhexis edge. Place the other nucleus sustainer at the center of the nuclear crack. Then bring the two nucleus sustainers closer simultaneously. Always maintain the force at the tips of the sustainers to hold the nucleus firmly, otherwise it may rotate. As the tips of the sustainers come closer together, the anterior portion of the nucleus will be cut in half.

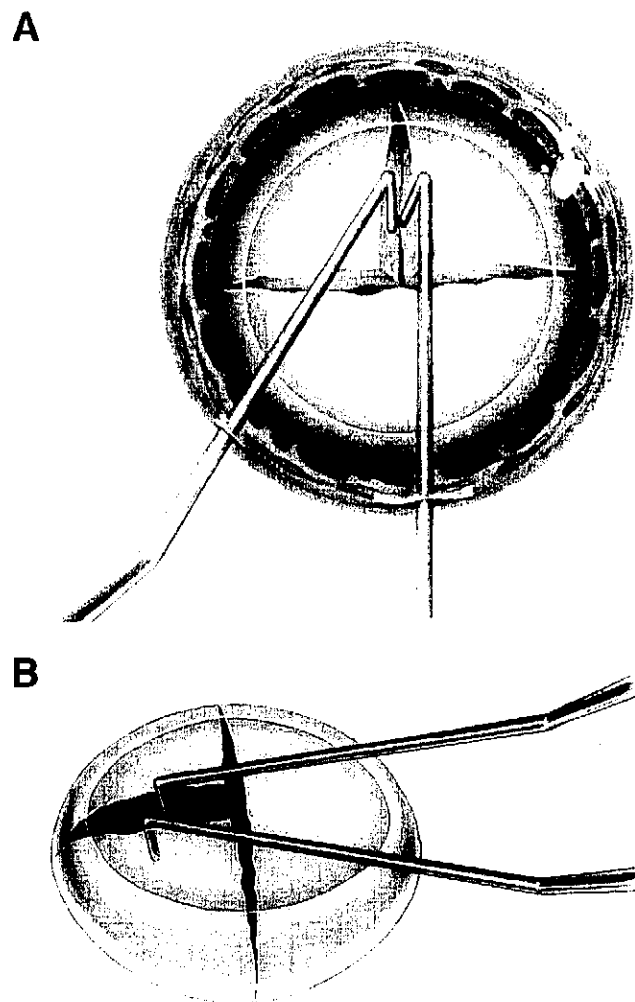


Figure 23. At the center of the bisected nucleus change the direction of the forces on the two nucleus sustainers  $90^\circ$  to separate the nuclear fragment completely into two pieces. It is important to complete the division to the bottom of the nucleus so that the inner surface of the posterior capsule becomes visible. The nucleus may then be rotated by the number of degrees that will make the next prechopping procedure easy to perform.

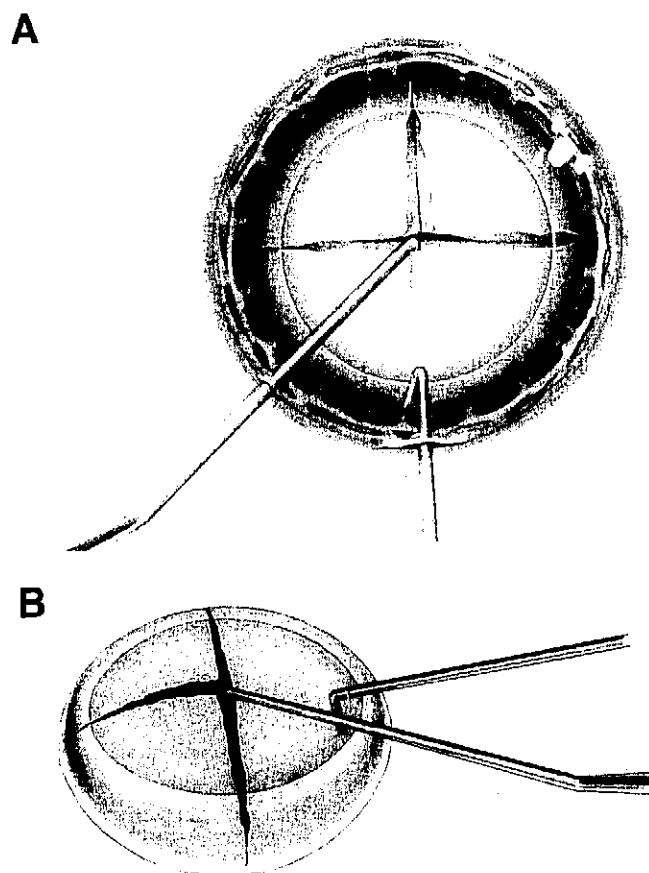


Figure 24. Insert the nucleus sustainer on the right into the equatorial portion of the nucleus, passing it just beneath the anterior capsulorhexis. It is important not to damage the anterior capsule or the ciliary zonules by placing the sustainer blindly over the anterior capsule. Place the other nucleus sustainer in the center of the nuclear crack.

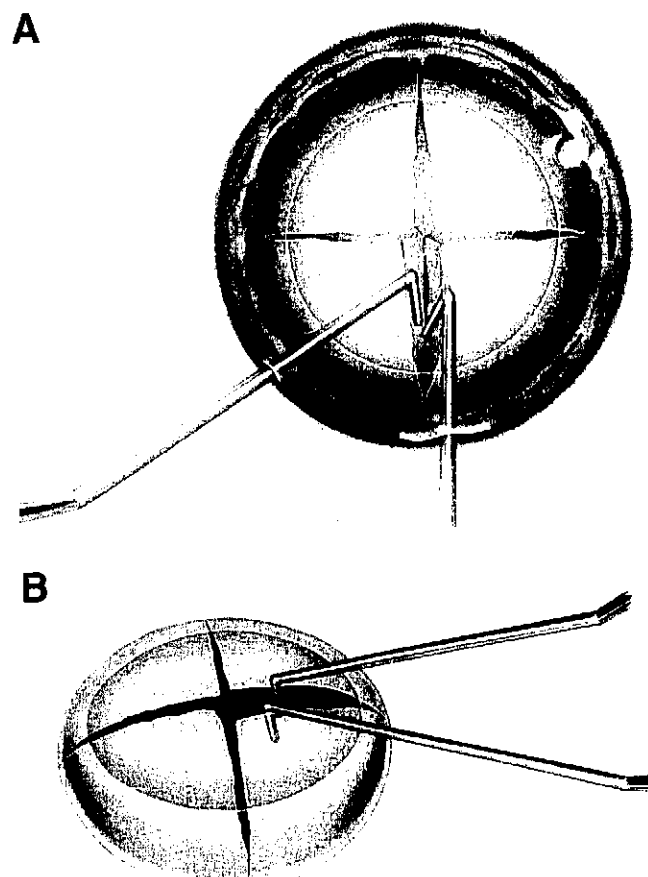
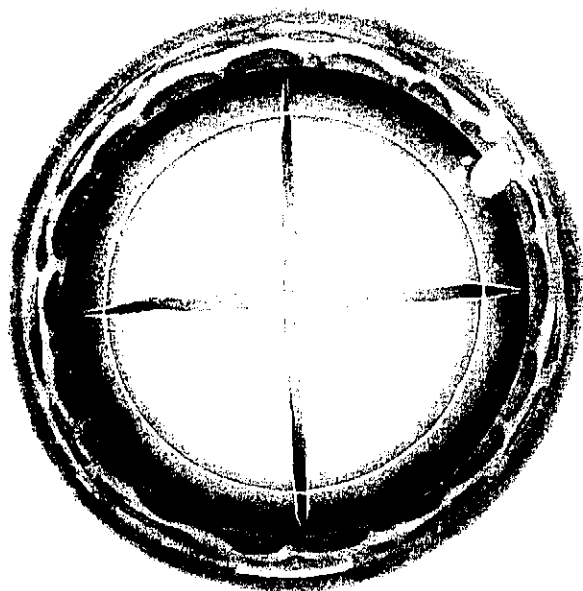


Figure 25. Simultaneously bring the two nucleus sustainers closer to each other. Always concentrate the forces on the tips of the sustainers, holding the nucleus firmly and not rotating it. As the two tips of the sustainer come closer, the anterior portion of the nucleus will be cut in half. At the center of the bisected nucleus, change the direction of the force on the two nucleus sustainers  $90^\circ$  to separate the nuclear fragment into two pieces. Repeat the separating procedure until complete nuclear division is achieved.

A



B

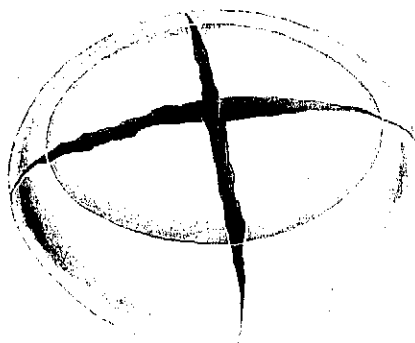


Figure 26. Completion of quadrisection of the nucleus. It is very important to make a complete division, especially when the nucleus is hard. Merely making a crack in the nucleus part way offers little advantage in the following phacoemulsification. The nucleus must be chopped thoroughly from the anterior surface to the bottom until reaching the posterior capsule. If the inner surface of the posterior capsule is visible, this is a sign of complete nuclear division.

The *counter prechop* technique is used for harder nuclei and cases with weak ciliary zonules. By sustaining the nucleus with a second instrument from the side port, stress on the ciliary zonules is reduced during insertion of the prechopper. With this technique, nuclei of any hardness can be prechopped.

The *double chopper prechop* technique is a bimanual phaco prechop technique, which can be performed with two phaco choppers or nucleus sustainers but not with a phaco prechopper. Hard nuclei are an indication for this technique, though it is relatively difficult, and greater technical skill is needed than with the other prechop methods.

### Prechopper Prechop

Nuclei of Emery grade 2 or 3 can be prechopped with this technique. Complete CCC and sufficient hydrodissection,

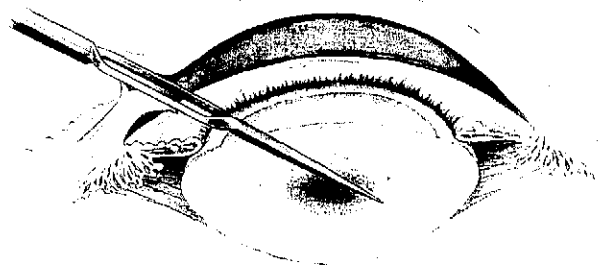


Figure 27. Prechopper prechop technique. Notice the angle and depth of prechopper insertion. The tip of the prechopper should be inserted sufficiently deep into the hardest core of the nucleus. An insertion too shallow will not provide a sufficient separating force to the nucleus when the tips of the prechopper are opened. Preliminary removal of the cortex may improve observation of the depth of prechopper insertion even if the surgeon is not familiar with this technique.

allowing the nucleus to rotate freely in the capsular bag, is the most important prerequisite (Fig 1). In the course of mastering the phaco prechop technique, aspiration of the cortex within the area of the capsulorhexis opening will facilitate visualization of the nucleus. A sufficient amount of viscoelastic material in the anterior chamber also enhances visualization of the nucleus. Once the surgeon has mastered the technique, phaco prechop can be performed even under conditions of poor visibility of the nucleus because of excessive cortex or a small pupil. Insert the closed prechopper straight into the core of the nucleus (Fig 2). The direction and the depth of the insertion are very important (Fig 27). Insertion should be straight along the lens fiber construction and deep enough to provide a sufficient separating force on the nucleus during opening of the prechopper. Then, open the prechopper slowly to bisect the nucleus (Fig 3). If the nucleus has not been divided by this single action, place the prechopper at the deepest portion of the nuclear valley formed by the two incompletely divided nuclear fragments. Repeat the opening procedure to complete

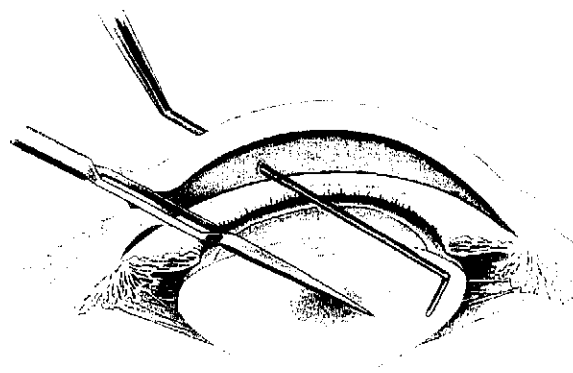


Figure 28. Counter prechop technique. A hard nucleus is sustained by the nucleus sustainer inserted via the side port. The tip of the sustainer is inserted just beneath the anterior capsule at the equatorial portion of the nucleus. The stress on the capsular bag and ciliary zonules during insertion of the phaco prechopper is markedly reduced by this technique.

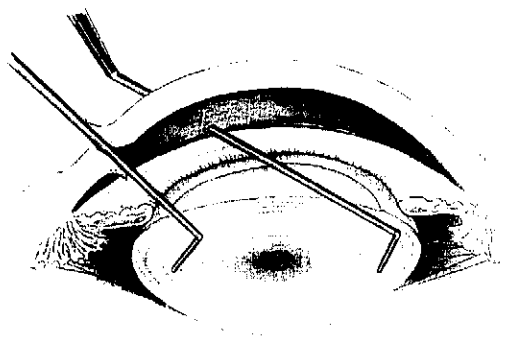


Figure 29. Double chopper prechop technique. Two nucleus sustainers or phacochoppers are inserted through the wound and the side port to hold the nucleus in the capsular bag. Pay attention to the depth of the insertion of the instruments. During the prechopping procedure, always imagine the three-dimensional position of the nucleus held by the instruments so as not to expose the cornea and the ciliary zonules to unnecessary force.

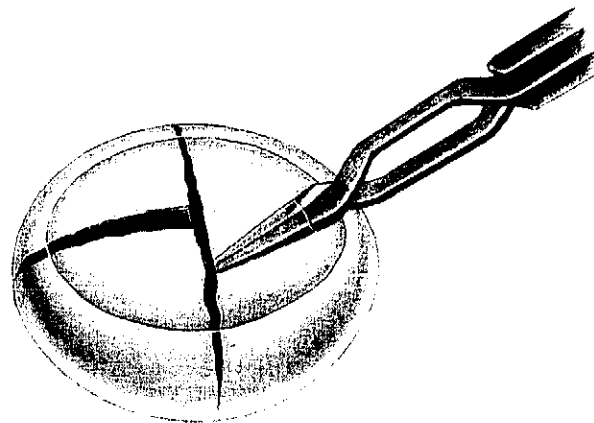


Figure 32. Insert the prechopper in the equatorial portion of the nucleus. The prechopper can be inserted more easily from this side. The direction of prechopper insertion should be toward the core of the nucleus and deep enough to attain complete division.

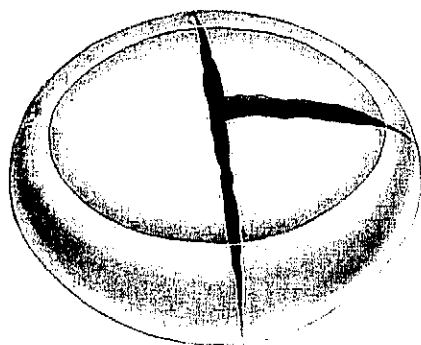


Figure 30. If the core of the bisected nuclear fragment is too hard to insert the prechopper on the wound side, do not exert excessive stress on the ciliary zonules by forcibly inserting the prechopper.

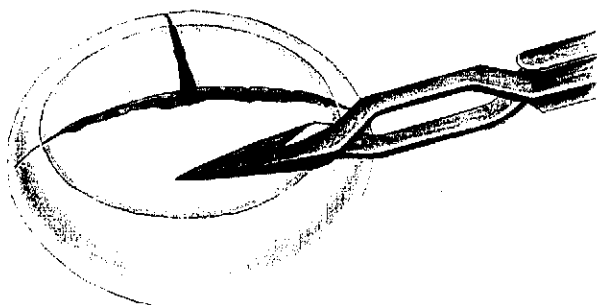


Figure 31. Rotate the nucleus 180°. Nuclear rotation will be easier if the divided nuclear fragments are temporarily returned to their original position and the larger fragment is manipulated with the prechopper.

the division, for the entire depth, reaching the posterior capsule. Complete nuclear division is critical to achieving the following phacoemulsification. In the event of a relatively hard nucleus, if the direction of the insertion is appropriate, the nucleus will crack on its own, even if the insertion of the prechopper is not particularly deep. Only with the proper direction and force of the insertion and with the separating force toward the nuclear fibers can phaco prechop be attained. Then, rotate the bisected nuclear fragments 90 degrees, pushing on the nuclear surface with the prechopper (Fig 4). Nuclear rotation is simplified if each bisected nuclear fragment is transiently restored to its original position. An adequate amount of viscoelastic material in the anterior chamber and a slight downward pushing force also facilitate rotation. The degree of rotation should be exactly 90 degrees. If the rotation angle is less than 90 degrees, the direction of the following prechopper insertion will be not along that of the lens fiber

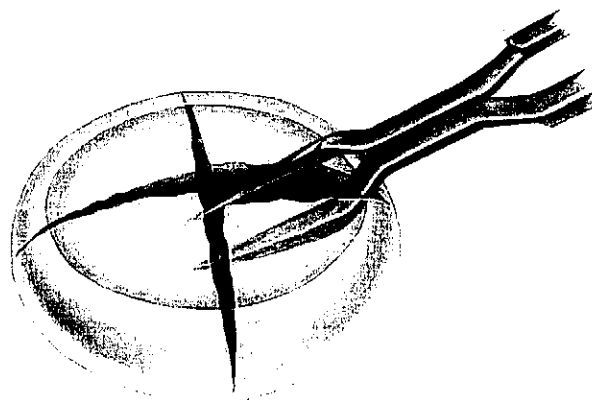


Figure 33. Open the prechopper and divide the bisected nucleus in the same way. If the nucleus has not been divided by a single action, place the prechopper at the deepest point and repeat the procedure until the inner surface of the posterior capsule becomes visible between the prechopped nuclear fragments.



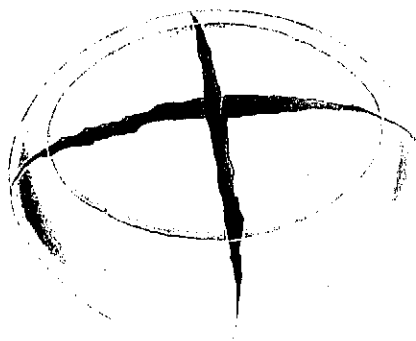


Figure 34. Completion of quadrisection of the nucleus. The nucleus must be chopped from the nuclear surface to the bottom until reaching the posterior capsule.

construction, and the nucleus will not crack. Insert the prechopper deep into the core of the bisected nuclear fragment on this side (Fig 5) and divide it in the same way (Fig 6). Then insert the prechopper into the remainder of the bisected nucleus on the other side (Fig 7) and complete quadrisection of the nucleus (Fig 8). If the core of the nucleus is too hard to insert the prechopper from this side, rotate the nucleus 180 degrees and insert the instrument from the equator side of the nucleus (Figs 30 to 34). Finally, ascertain that the nucleus has been divided thoroughly to its bottom (Fig 9). Injection of viscoelastic material between the divided nuclear fragments or manual inspection using the nucleus sustainer is helpful.

### Counter Prechop

For nuclei harder than Emery grade 3 and cases with any signs or history of ciliary zonule weakness, phaco prechop should not be performed using the phaco prechopper alone. To protect the ciliary zonules from excessive force during insertion of the prechopper, the nucleus should be sustained by the second instrument. This phaco prechop technique, performed with

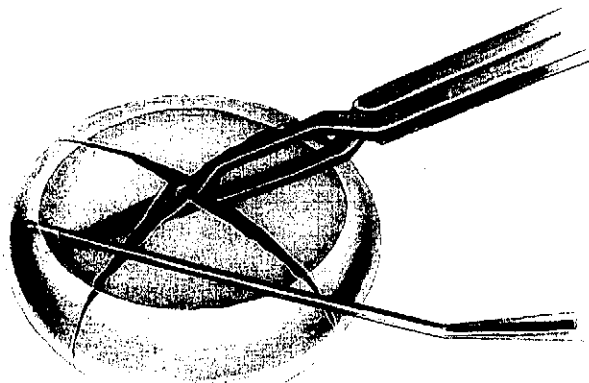


Figure 35. Multiple prechop technique with a phaco prechopper. If the nucleus is hard, eg, grade four or five, further prechopping into smaller fragments greatly facilitates the following phacoemulsification. The quadrisectioned nuclear fragments can be prechopped in half by the "counter prechop" technique.

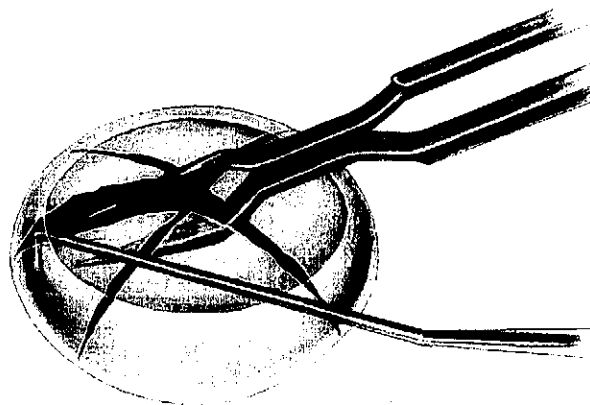


Figure 36. A hard nucleus can be divided into eight pieces in the same way. During the prechopping procedure, the viscoelastic material may leak from the wound. If that happens, do not hesitate to supply adequate viscoelastic material for easier visualization and safer manipulation.

the assistance of the second instrument, is called the "counter prechop" technique. The second instrument used in this technique can be a phaco chopper or a Sinskey hook. However, to protect the posterior capsule and to secure nuclear support, the author recommends using a special nucleus sustainer, the tip of which has an attached microball and is longer than a Sinskey hook.

Like the "prechopper prechop" technique, complete CCC and sufficient hydrodissection are the most important prerequisites for this technique (Fig 1). The nucleus should be adequately hydrodissected such that it rotates freely in the capsular bag, facilitating the following rotation of the prechopped nuclear fragments. Fill the anterior chamber with a sufficient amount of viscoelastic material. Insert the nucleus sustainer from the side port, passing just beneath the anterior capsulorhexis edge to the equatorial portion of the nucleus (Fig 28). It is important not to damage the anterior capsule or the ciliary zonules with the nucleus sustainer. This is achieved

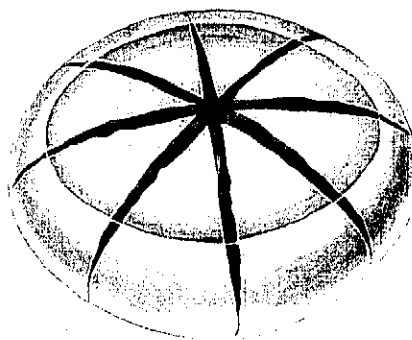


Figure 37. Completion of the division of a hard nucleus into eight segments. It is extremely important that each prechopped nuclear fragment be divided completely from the surface to the bottom, reaching the posterior capsule. If nuclear division is incomplete, it will be impossible to sublaxate the nuclear segments with the aspiration power during phacoemulsification.

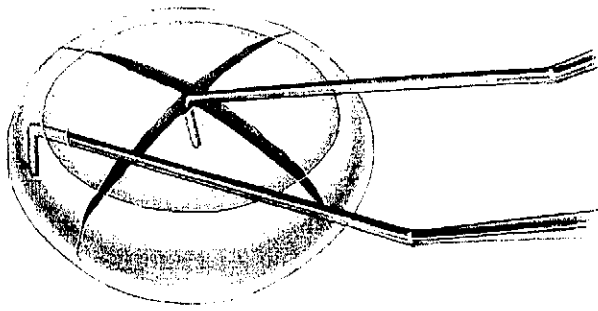


Figure 38. Multiple prechop technique with nucleus sustainers. When the nucleus is even harder, eg, grade four or five, further prechopping into smaller fragments greatly facilitates the following phacoemulsification. The quadrisectioned nuclear fragments can be prechopped into eight pieces by the "double chopper prechop" technique in the same way.

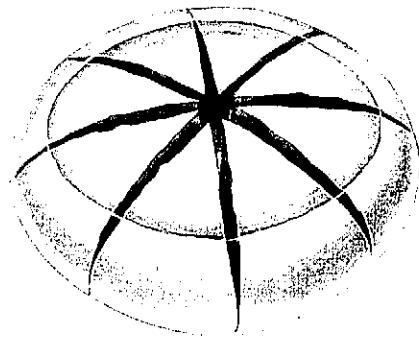


Figure 41. If the viscoelastic material has leaked from the wound during the procedure, add an adequate amount to the anterior chamber and complete the nuclear division. Finally, confirm that every nuclear fragment is completely divided to the bottom. Remember that complete nuclear division is especially important when the nucleus is hard.

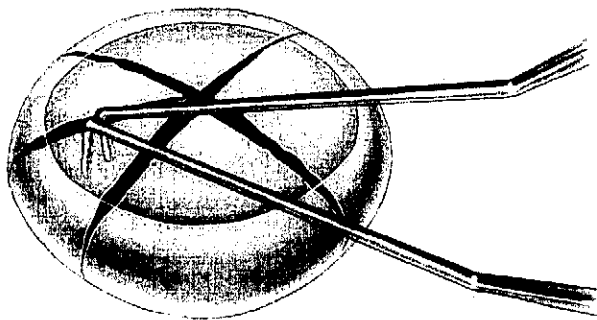


Figure 39. The quadrisectioned nuclear fragment is held with the tips of the nucleus sustainers. Always be careful not to incite a rotatory movement to the nuclear fragment during the prechopping procedure. As the tips of the two nucleus sustainers come closer the quadrisectioned nuclear fragments can be divided in half.

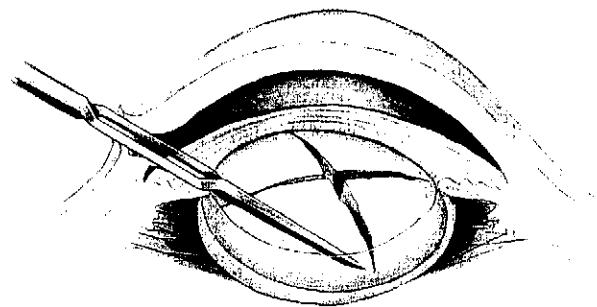


Figure 42. Flip and re-prechop technique. If the nucleus has not been prechopped completely to the bottom, the prechopping procedure can be performed again from the posterior pole of the nucleus. Refill the anterior chamber with a sufficient amount of viscoelastic material. When pushing the peripheral portion of the nucleus downwards, flip the nucleus in the capsular bag. The phaco flip can be usually performed with a dull 27-gauge needle. If the phaco prechopper is used, be careful not to damage the posterior capsule with the sharp tip of the instrument.

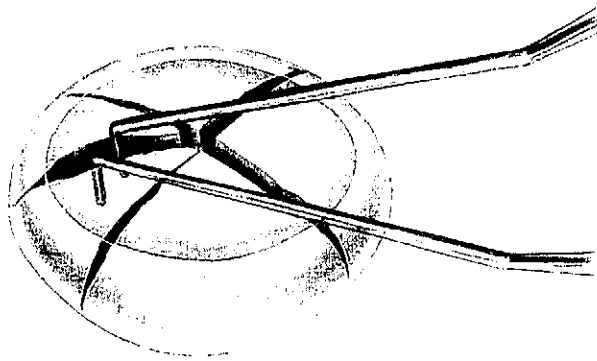


Figure 40. When the nucleus is sclerotic hard, it is especially important to make complete divisions from the surface to the bottom of the nucleus. Repeat the separating procedure until the inner surface of the posterior capsule becomes visible.

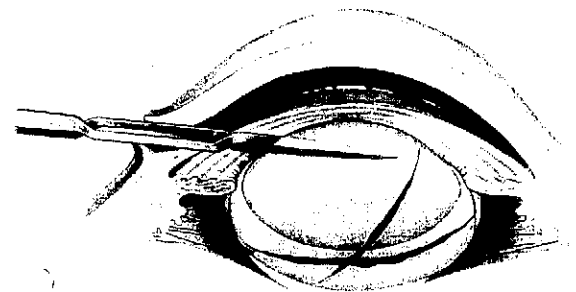


Figure 43. If the flipped nucleus is placed outside the capsular bag, the supracapsular technique is applied. To sustain the nucleus during the prechopping procedure it may be better to replace the nucleus into the capsular bag.

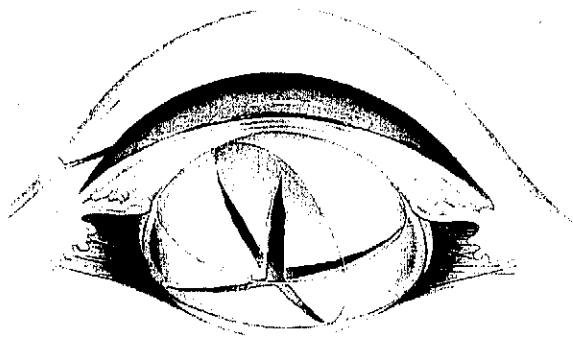


Figure 44. Once the nucleus has been turned over it is easy to identify any cracks in it that have not reached the posterior end. Rotate the nucleus to where the prechopper can be inserted along the incomplete nuclear crack.

By supporting the nucleus over the capsule. Sustaining the nucleus with the nucleus sustainer, insert the prechopper directly into the core of the nucleus (Fig 10). In the case of a hard nucleus, the tip of the prechopper, the core of the nucleus, and the tip of the nucleus sustainer should be positioned on the same axis to avoid rotational movement of the nucleus. Open the prechopper to bisect the nucleus (Fig 11). If the nucleus cannot be prechopped completely in a single action, repeat the opening action at the deepest point until complete division is attained. When the nuclear division has been completed, the posterior capsule will be directly observed between the bisected nuclear fragments. Unlike Dr Nagahara's phaco chop technique, in which the nucleus is sustained unstably by a phaco tip irrigated with balanced salt solution (BSS), phaco prechop can be performed allowing sufficient time for complete nuclear division to be accomplished under stable anterior chamber conditions maintained by viscoelastic material. Rotate the nucleus 90 degrees to set the nucleus to the next prechopping position (Fig 12). Nuclear rotation is easier if the bisected nuclear fragments are temporarily returned to their original positions. Sustaining the nucleus in the same way, insert the prechopper into the core of the nucleus

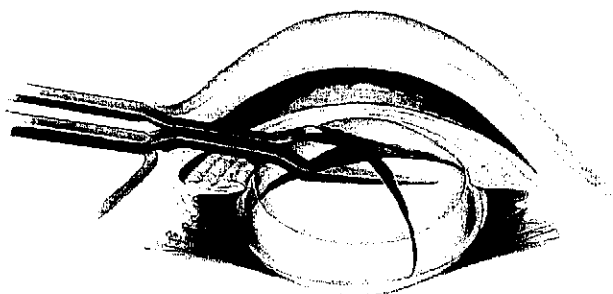


Figure 45. Insert the prechopper along the incomplete crack to complete the nuclear division. If the nucleus is hard, the "counter prechop" technique or the "double chopper prechop" technique can be applied to complete the nuclear division. If it is a relatively hard nucleus, the nucleus can be flipped soon after the hydrodissection and the "prechopper prechop" technique can be performed easily by inserting the prechopper into the relatively harder posterior portion of the nucleus.

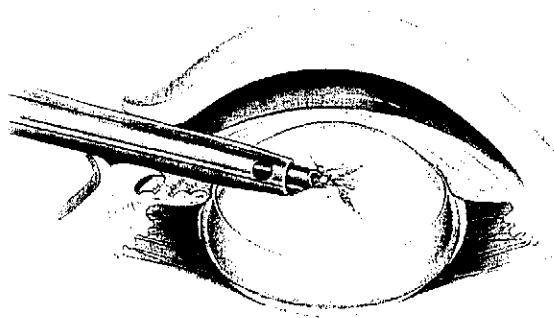


Figure 46. Flip and phaco technique. After flipping the incompletely prechopped nucleus, disassemble the nuclear fragments by phacoemulsifying the posterior pole of the nucleus. Phacoemulsification along an incomplete nuclear crack also facilitates separation of the nuclear fragments. Once the surgeon has become accustomed to management of the incompletely prechopped nucleus the nuclear plate can be flipped using the aspiration power of the phaco tip during the phacoemulsification.

and complete the division (Figs 13-17). In cases with harder nuclei, completion of the nuclear division is especially important. If the nucleus has been only partially divided, the first nuclear fragment will not be drawn out by the phaco tip. Completion of the nuclear division can be ascertained safely by the injection of the viscoelastic material or the nucleus sustainer.

Quadrisection of the nucleus is usually adequate to facilitate the following phacoemulsification. In the case of hard nuclei such as grade 4 or 5, further prechop into smaller fragments greatly facilitates phacoemulsification (multiple prechop technique). The quadrisectioned nuclear fragments can be prechopped into eight pieces in the same way (Figs 35-37).

### Double Chopper Prechop

Nuclei of any hardness can be prechopped with the "prechopper prechop" or "counter prechop" technique. The "double chopper prechop" technique is based on the same concept as the above two prechop techniques, that is, division of the nucleus before phacoemulsification. It differs from other techniques only in that the phaco prechopper is not used. The instruments used for this technique are two nucleus sustainers or phaco choppers. For protection of the posterior capsule, the use of the nucleus sustainer is preferable. This technique is

TABLE 3. Alcon Legacy Setting

	Vacuum (mmHg)	Flow Rate (mL/min) Position 2/Position 3	Max Power (%)
Memory 1	100	20/20	70
Memory 2*	200	25/20	80
Memory 3	300	30/25	90
Memory 4†	400	35/30	90

Bottle height max: 78 cm

Pulse mode: 15 Hz

30-Degree regular US tip

Regular sleeve

Max Vac cassette

\*Routinely used for phaco of epinucleus.

†Routinely used for phaco of nucleus.

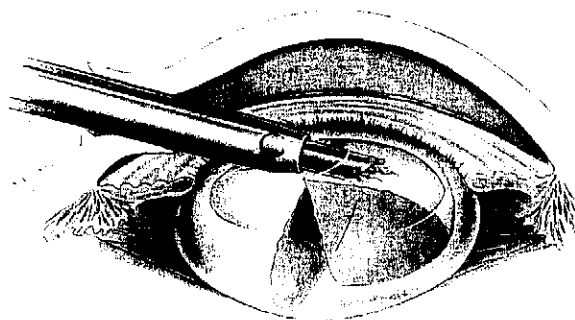


Figure 47. Once the incompletely prechopped nucleus has been disassembled into pieces the following phacoemulsification can be performed like the ordinarily prechopped nucleus is phacoemulsified.

suitable for relatively hard nuclei of Emery grades 3 to 5. Compared with the phaco prechop techniques using a phaco prechopper, the "double chopper prechop" technique requires greater technical skill, especially in cases with very hard nuclei.

After complete CCC and sufficient hydrodissection, fill the

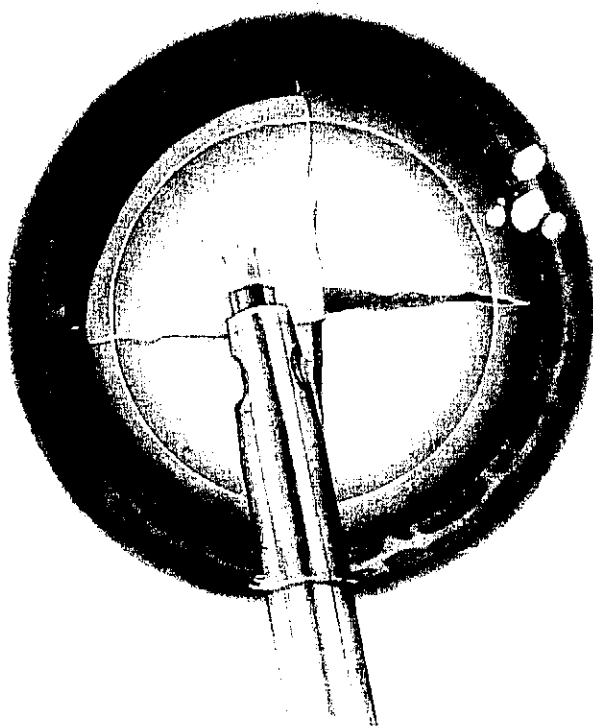


Figure 48. The phaco tip is driven into the nuclear fragment with a short burst of ultrasound power at foot pedal position three. The bevel of the phaco tip is always placed downwards. Keep the foot pedal at position two until the vacuum pressure is increased high enough to sublaxate the nuclear fragment out of its original position. The increase in vacuum pressure can be recognized by the increasing tone level of the phaco machine. Then phacoemulsifying the nuclear fragment in situ at foot pedal position three before the nuclear fragment is totally luxated into the anterior chamber. For easier removal of the first nuclear fragment the nucleus may be rotated 45° more than in the above illustration beforehand.

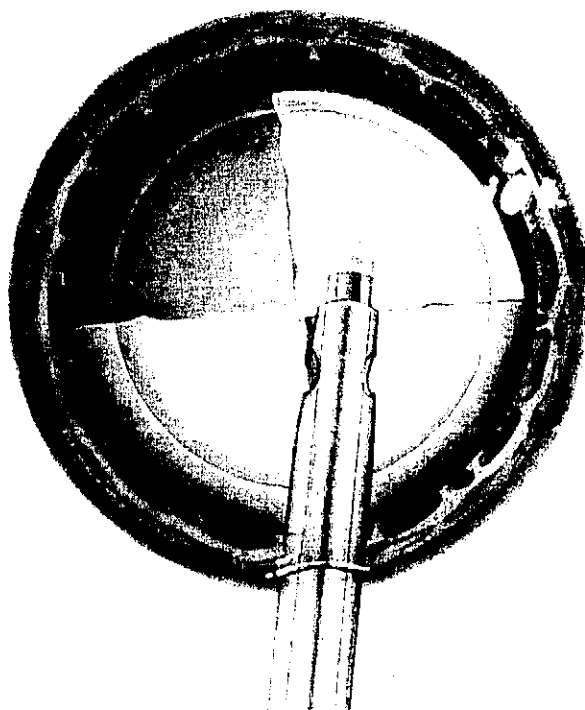


Figure 49. Once the first nuclear fragment has been removed the second fragment can be easily removed from its original position. The fragment is aspirated, sublaxated, and phacoemulsified in the same way. Always keep the bevel of the phaco tip downwards to facilitate aspiration and to avoid the adverse effect of the ultrasound energy on the corneal endothelium.

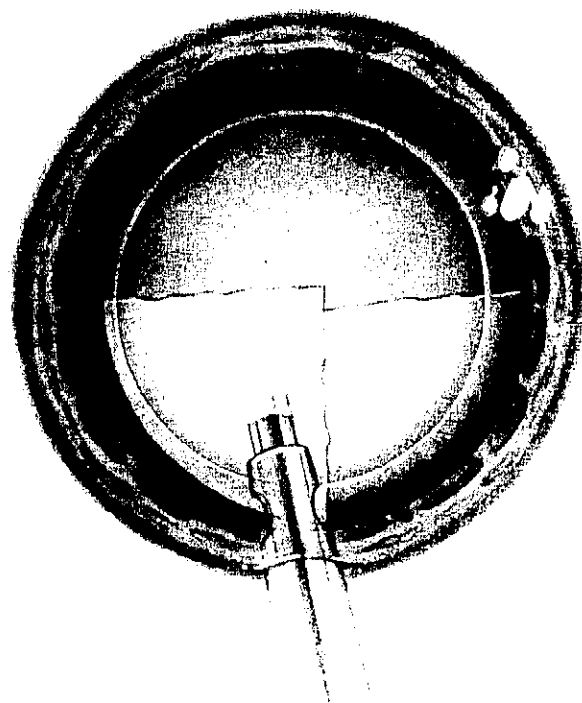


Figure 50. Slide the third nuclear fragment out of its original position and phacoemulsify it in the same way. In a single-handed phaco procedure it is most important to control the nuclear fragments in the anterior chamber so as not to damage the corneal endothelium.

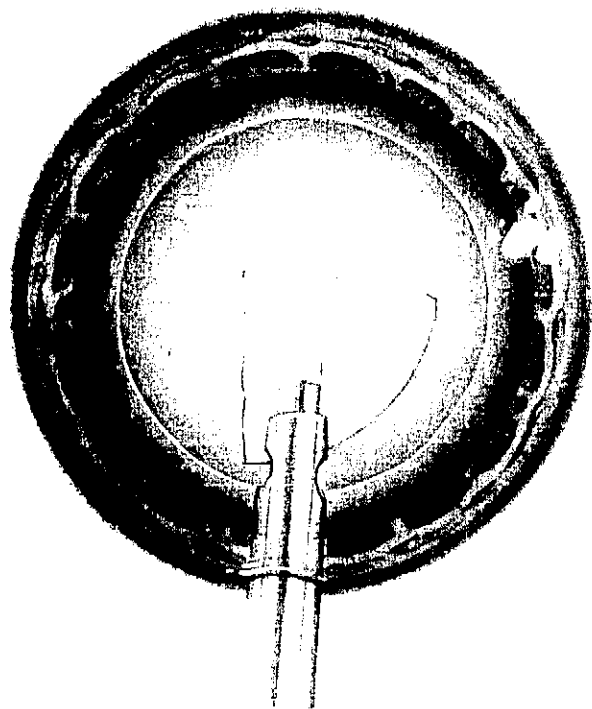


Figure 51. The final nuclear fragment is phacoemulsified in the same way. When the anterior chamber is unstable because of high vitreous pressure or excessive leakage of BSS from the wound, the vacuum pressure may be reduced from 400 mmHg to 300 or 200 mmHg. The epinucleus is usually phacoemulsified at the lower vacuum level of 200 mmHg to prevent damage to the posterior capsule.

anterior chamber with viscoelastic material (Fig 1). Insert the first nucleus sustainer from the side port on the left hand, passing just beneath the anterior capsulorhexis edge to the equatorial portion of the nucleus. It is important to avoid damaging the anterior capsule or the ciliary zonules by incorrectly inserting the sustainer over the anterior capsule, rather than beneath as it should be. Place the second nucleus sustainer from the wound to the equator of the nucleus opposite the sustainer on the left hand (Fig 18). To prevent rotation of the nucleus, both of the sustainer's tips and the



Figure 52. Phaco prechopper (Duckworth & Kent: 2-815-1). Original prechopper made of titanium. Sharp tip is suitable for prechopping hard nucleus.



Figure 53. Phaco prechopper straight type (ASICO: AE-4281) made of stainless steel. Straight type is suitable for clear corneal incisions.

center of the nucleus should be aligned along the same axis (Fig 29). Then bring the two sustainers closer to the center of the nucleus at the same time (Fig 19). Always concentrate the forces on the two tips of the sustainers so as to hold the center of the nucleus firmly; otherwise the nucleus will rotate. At the center, change the direction of the force on the sustainers 90 degrees to separate the nucleus into two fragments (Fig 20). Complete the nuclear division, all the way to the bottom of the nucleus, such that the posterior capsule can be observed. Then rotate the nucleus 90 degrees (Fig 21) and prechop the other nuclear fragments into four pieces in the same way (Figs 22-26). Always take care to avoid exerting stress on the cornea and ciliary zonules.

Although quadrisection of the nucleus is sufficient to facilitate the following phacoemulsification, further division of the nucleus offers further advantages in cases with very hard nuclei. The nuclear fragments can be prechopped into eight pieces in the same way, using two nucleus sustainers (Figs 38-41).

### Difficult Cases—Excessively Soft or Hard Nuclei

Very soft nuclei, such as Emery grade 1, may be difficult to prechop with the conventional prechop methods described. The tips of the phaco prechopper may sink into the nucleus and cannot provide sufficient separating force when opened.

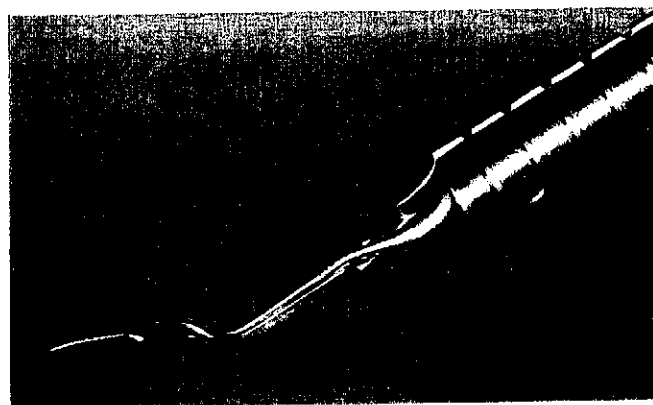


Figure 54. Phaco prechopper angled type (ASICO: AE-4280) made of stainless steel. Angled type is suitable for scleral tunnel incisions.

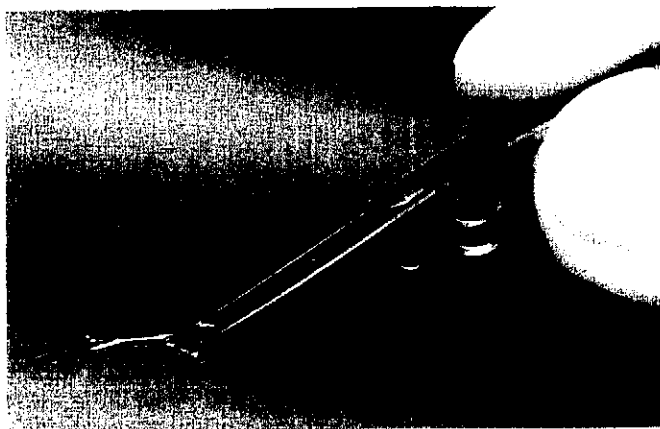


Figure 55. Phaco prechopper angled type (Katena: K5-7230) made of stainless steel. Flat tip is suitable for prechopping relatively soft nucleus.

Although prechopping might seem unnecessary in such soft nuclei, there are actually some advantages in phacoemulsification if a nucleus has already been prechopped.

For prechopping soft nuclei, the phaco prechoppers produced by Katena (K5-7230) and ASICO (AE-9282), which have dull, flat blades compared with other prechoppers, may be helpful. The flat tips will exert sufficient separating force on the soft nucleus on opening. The soft nucleus can be cut rather than prechopped with the "double chopper prechop" technique. Even with a single-handed method, moving the tip of the nucleus sustainer to and fro along the expected line of nuclear division, a very soft nucleus can be cut into four pieces.

In cases with sclerotic hard nuclei, it may be difficult to attain complete nuclear division, that is, all the way to the bottom. In such a situation, it is not possible to aspirate and sublunate the first nuclear fragment with the phaco tip during phacoemulsification. The phaco flip technique is helpful for completing a thorough nuclear division in such a sclerotic hard nucleus. If the nucleus cannot be fully prechopped, or incomplete nuclear division is noticed during phacoemulsification, fill the anterior chamber with viscoelastic material again. Using the 27-gauge dull needle that was used to inject the viscoelastic material, turn the nucleus over in the capsular bag. If a phaco prechopper is used to flip the nucleus, always be careful to avoid damaging the posterior capsule (Figs 42-44). Once the nucleus has been turned over, it is easy to identify any cracks in the nucleus which have not reached the posterior end. Insert

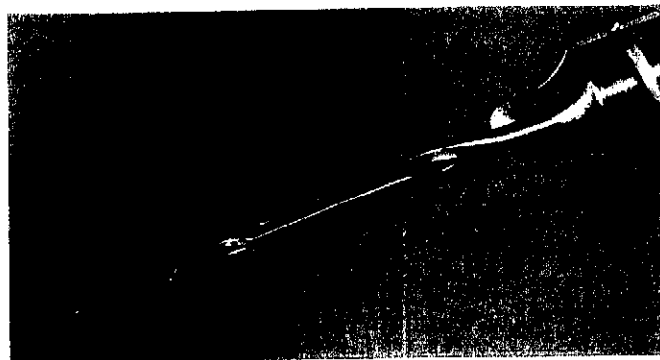


Figure 56. Phaco prechopper universal type (ASICO: AE-8282) made of stainless steel. Universal type is suitable for prechopping both soft and hard nucleus.



Figure 57. Nucleus sustainer (ASICO: AE-2525) is used for sustaining hard nucleus in the "counter prechop" technique and "double chopper prechop" technique.

the prechopper along an incomplete nuclear crack to complete the phaco prechop (Fig 45).

It is also possible to disassemble the incompletely prechopped nuclear fragments by phacoemulsifying the posterior pole of the nucleus (Fig 46). Phacoemulsification along an incomplete nuclear crack also facilitates separation of the nuclear fragments.

### Phaco of the Prechopped Nucleus

For phacoemulsification of the prechopped nucleus, the high-vacuum and high-flow setting of the phaco machine is recommended (Table 3). To satisfy these conditions, the author prefers using Legacy (Alcon Laboratories Forth Worth, TX) with a 30-degree regular phaco tip and Max Vac cassette. Although the micro tip may be superior to the regular tip from the viewpoint of anterior chamber stability, the regular tip is more effective for performing rapid phacoemulsification in the phaco prechop technique.

For phacoemulsification of the nucleus, the author usually sets the vacuum at 400 mm Hg at flow rates of 35 mL/min (foot pedal position 2) and 30 mL/min (foot pedal position 3). With this setting, the prechopped nuclear fragment will be aspirated and sublunate at foot pedal position 2 (Fig 48). Before the nuclear fragment is totally luxated into the anterior chamber, phacoemulsify the nucleus in situ at foot pedal position 3. Each nuclear fragment is aspirated individually for sublunate and phacoemulsification (Figs 49-51). For a single-handed procedure, it is very important to control the nuclear fragments in the anterior chamber so as to avoid damaging the corneal endothelium.

For phacoemulsification of the epinucleus, the setting of the phaco machine is reduced to a 200 mm Hg vacuum and flow

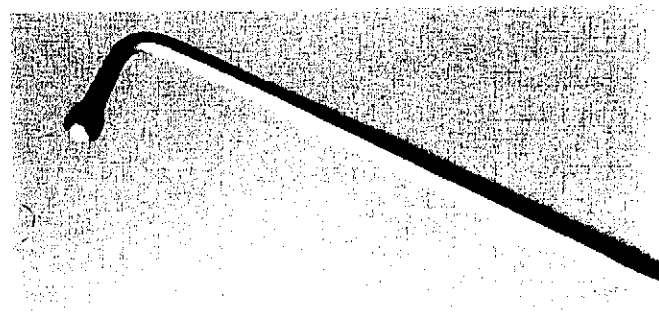


Figure 58. Nucleus sustainer (ASICO: AE-2525). A micro ball is placed to protect the posterior capsule.

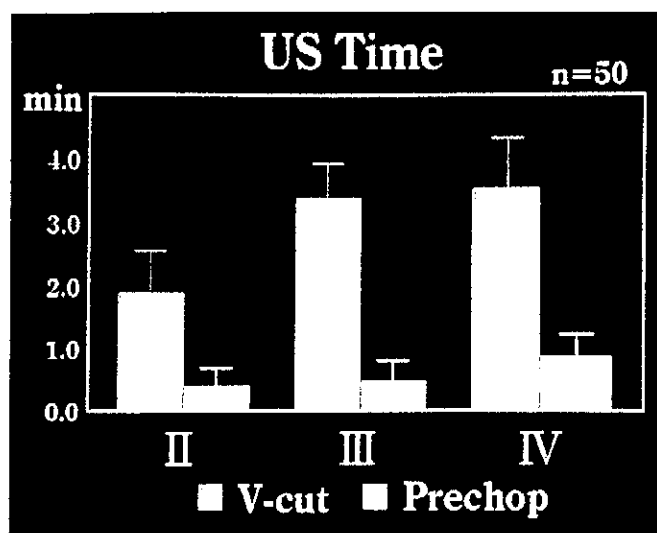


Figure 59. Ultrasound time. Compared with the conventional V-cut grooving method, the ultrasound time is markedly reduced for each nuclear group.

rates of 25 mL/min (foot pedal position 2) and 20 mL/min (foot pedal position 3) flow rate.

Because there is no need to groove the nucleus, the reciprocating movement of the phaco tip is omitted. Because of the markedly shortened ultrasound time and cumulative dissipated energy (Figs 59, 60), the thermal and mechanical damage associated with the corneal wound is diminished. Thus, the corneal wound readily self-seals simply by increasing

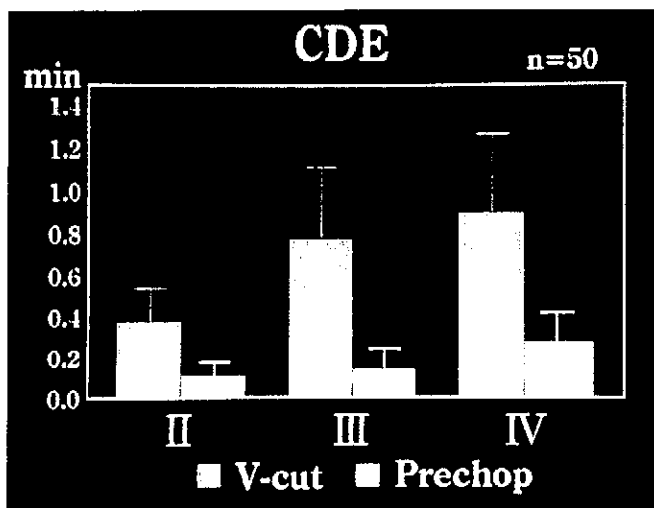


Figure 60. Cumulative dissipated energy. Using 15-Hz pulse mode, the cumulative dissipated energy is also reduced remarkably.

TABLE 4. Corneal Endothelial Loss

Grade 2	2.3%
Grade 3	3.6%
Grade 4	6.3%

NOTE. 3 months after surgery; n = 150.

the intraocular pressure by injecting BSS from the wound or side port. There is no need for stromal hydration to attain self-sealing.

### Clinical Results

Compared with the conventional V-cut grooving method,<sup>3</sup> the ultrasound time was markedly reduced for each nuclear grade (Fig 59). Using a 15-Hz pulse mode also allowed the cumulative dissipated energy to be reduced (Fig 60). Corneal endothelial cell loss was within 10%, 3 months after surgery (Table 4). However, the residents who are not well accustomed with the phaco prechop and one-hand phaco technique, resulted in higher endothelial cell loss. The cell loss seems to be caused by the turbulence of the prechopped nuclear fragments in the anterior chamber. It is thereby most important to control the nuclear fragments during phacoemulsification especially in case of a shallow anterior chamber or an extremely hard nucleus if one-hand phaco technique is used.

In the author's personal experience with approximately 9,000 phaco prechop cases, no significant complications have been encountered in association with this technique. The most common complication has been incomplete nuclear division. In such cases, the nucleus is turned over and phacoemulsified at the posterior pole or prechopped again. Use of the second instrument from the side port has also been found to be helpful for incompletely divided sclerotic hard nuclei. In some cases in which the "counter prechop" technique was performed, a small notch was made in the anterior capsule when a phacochopper was introduced over the anterior capsule rather than beneath it, because of poor visibility of the nucleus.

Two cases of zonular rupture have been reported in Japan. Both had a hard nucleus with pseudoexfoliation syndrome, and the phaco prechop was performed by a resident with a capsulorhexis forceps alone. Prechopping by the "counter prechop" technique, using a phaco prechopper and nucleus sustainer, should have been employed in these cases.

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# Phaco Flip

David C. Brown III, MD

The phaco flip procedure is described with emphasis on the cataract for rotation and flipping. The phaco flip procedure maximizes the efficiencies of the newer generation of phacoemulsifier devices.

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**P**hacoemulsification continues to evolve as a highly effective and clinically successful method for removal of cataractous lenses.

Phaco instrumentation has been improved by extensive computerization, fluidics, and even ultrasonic needles. Still, the most efficient use of the new generation of devices remains total occlusion of the phaco tip. The phaco flip technique is ideally suited for presenting the nucleus to the phacoemulsifier, resulting in 100% occlusion with each engagement of the cataract.

The phaco flip procedure is typically performed through the clear corneal approach. Viscoelastic is instilled in the anterior chamber, and a capsulorhexis is completed. The capsulorhexis can be performed with capsular forceps, a bent-tip needle, or cystotome. The capsulorhexis should be made as large as the zonules or the pupil permit. However, the flip procedure can be performed in eyes with a small or nondilated pupil.

On completion of the capsulorhexis, a Storz E4414WS olive-tipped cannula [Bausch and Lomb Surgical (Storz), St Louis, MO] is placed underneath the anterior capsular flap, and balanced salt solution (BSS) is injected to hydrodissect the nucleus and epinucleus. The olive-tipped cannula is redirected and pressed on the nucleus, depressing it posterior at the 6- and 12-o'clock positions (Fig 1) to help shear any cortical connections to the remaining anterior capsule. The nucleus is dialed (Fig 2) toward superior or inferior, with the olive-tipped cannula, depending on the preference of the surgeon.

The initial dialing movements should be restricted to approximately one clock hour. As the nucleus is gradually loosened from its capsular attachments, the dial sweeps become larger, reaching three to four clock hours, while rotating the nucleus in the plane of the iris. After the nucleus is totally freed of its capsular attachments, the nucleus is inverted by continuing the rotary motion (Fig 3) with the olive-tipped cannula and guiding the nucleus over and upward by posterior pressure along its equator.

As posterior pressure is applied, the dialing motion is continued, and the nucleus follows the curvature of the capsular bag and is inverted. It is important to continue the inversion process until the nucleus is prolapsed and leaning toward the surgeon at approximately a +5-degree angle (Fig 4). It is not necessary, nor desirable, to prolapse the entire nucleus

into the anterior chamber. The tipping of the nucleus toward the surgeon allows an excellent opportunity to engage the nucleus with the phacoemulsifier tip along its equator. In fact, the 30-degree tip is able to nestle up against the inferior portion of the nucleus (Fig 5) and permit total occlusion.

Phacoemulsification is usually performed in small segments around the periphery of the cataract nucleus. The nucleus is manipulated with a Bechert nucleus rotator (Fig 6), which is inserted through the side port incision. The purpose of the Bechert nucleus rotator is not only to rotate the nucleus but also to support it, so that the nucleus does not fall back into the capsular bag. The rotary repositioning of the nucleus provides the phacoemulsifier with solid material for total occlusion with each reposition. The cataract is whittled away from peripheral to central with the phacoemulsifier. Eventually only a small portion of nuclear material is left, which is easily removed with ultrasound.

With phaco flip, bimanual movements of the Bechert nucleus rotator and the phacoemulsifier tip are normally performed in the pupillary aperture and in the plane of the iris. Ideally, there is very little movement of the phacoemulsifier tip, because the cataract is delivered with the nucleus rotator. Leaving the phaco tip in the plane of the iris gives vital clearance from both the posterior capsule and the corneal endothelium. The "safe zone" enjoyed by working in the deepest part of the chamber guarantees an intact posterior capsule and a clear cornea quiet eye with each procedure.

With phaco flip, the epinucleus is usually adherent to the nucleus, and consequently there is seldom a need for other than cortical cleanup. Cortical cleanup is accomplished with a 0.4-mm irrigation and aspiration (I&A) tip.

The capsular bag is normally very clean after phaco flip and hydrodissection. Consequently, polishing the capsule is no longer routinely done.

After the cataract has been removed, Occucoat (Storz) or other viscoelastic is instilled into the anterior chamber, and the foldable lens of choice is implanted in the capsular bag.

Small pupils do not present excessive difficulty with the phaco flip maneuver. The capsulorhexis may be limited in size, because of the inability to perform a large opening because of the size of the pupil. However, the continuous curvilinear capsulorhexis is quite strong, and consequently the nucleus can be flipped so that it is exposed in the pupil. The nuclear flip in the small pupil is accomplished in a similar manner to that with a normal or large pupil. The hydrodissection is done with the olive-tipped cannula. Often it is not possible to see the fluid wave passing beneath the nucleus and epinucleus in these cases because of poor light reflex. However, a fluid wave is introduced at the 6 o'clock position, and commonly the olive-tipped cannula is moved to the 12 o'clock end of the capsulorhexis, and the hydrodissection maneuver is repeated to ensure cleavage of the lens material. After superior and inferior hydrodissection, the nucleus is pushed posterior, at its superior and inferior poles, with the olive-tipped cannula. The

From the University of South Florida, Tampa, FL.  
Address reprint requests to David C. Brown III, MD, 4101 Evans Ave,  
Fort Myers, FL 33901. E-mail: See-your-best.com  
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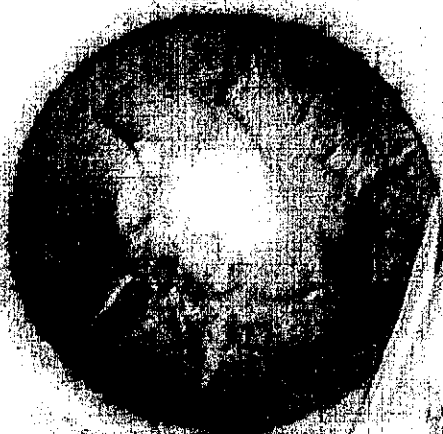


Figure 1. Depressing the nucleus posterior at the 6-o'clock and 12-o'clock positions.



Figure 2. The nucleus is dialed toward superior or inferior, with the olive-tipped cannula.



Figure 3. Continuing the rotary motion with the olive-tipped cannula.



Figure 4. The nucleus is prolapsed and leaning toward the surgeon at approximately a 45-degree angle.



Figure 5. The 30-degree tip nestled against the inferior portion of the nucleus provides a total occlusion.



Figure 6. The nucleus is manipulated with a Bechert nucleus rotator.

rotary motions are initiated as with the larger pupil. It is more difficult to get the nucleus to rotate in a small pupil case because of greater interface between epinucleus and capsule. However, with perseverance and gentle and persistent manipulation, the nucleus will free itself, spin, and then it can be rotated and flipped as with the normal case.

Phacoemulsification is accomplished by attacking the portion of the nucleus that is exposed through the pupil and through the anterior capsulotomy. The nucleus should not be prolapsed through the small capsulorhexis incision, because this will cause the anterior capsule to tear and threaten the integrity of the posterior capsule.

The current phacoemulsifier of choice at the Eye Centers of

Florida is the Storz Millennium. The machine settings are usually 150 mm Hg vacuum and linear ultrasound of 80% power. The MicroFlow needle (Storz) permits the surgery through a small corneal incision, providing a deep, stable chamber and reduced heat contact to the wound.

The Venturi pump gives a quick and firm purchase during phacoemulsification or aspiration. The titanium ultrasonic handpiece offers a smoother, more powerful delivery of ultrasound. This system has contributed to a substantial reduction in my procedural time, with increased safety.

Thus, the combination of the new system with the refinements of the phaco flip technique have resulted in improved efficiency and outcomes for our cataract patients.

# Tilt and Tumble Phacoemulsification

Richard L. Lindstrom, MD

Tilt and tumble phacoemulsification is a modern version of the iris plane technique originally taught by Richard Kratz, MD in the late 1970s. After creating a larger 5.5 to 6.5-mm capsulorhexis, one pole of the nucleus is hydrodissected until it tilts above the capsular bag. The tilted nucleus is rotated to face the incision and half of the nucleus is emulsified outside in at the iris plane. The remaining half nucleus is then tumbled and emulsification continues from the opposite equator outside in until complete. The technique is proving to be a fast, technically simple approach to phacoemulsification that has reduced the author's incidence of posterior capsular tear.

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I was fortunate to be introduced to phacoemulsification in 1977 during a fellowship with William S. Harris, MD, in Dallas, Texas. At that time, phacoemulsification techniques were generally divided into anterior chamber phaco as championed by Charles Kelman, MD, iris plane phaco as championed by Richard Kratz, MD, and posterior chamber phaco as championed by John Sheets, MD, and Robert Sinskey, MD. Under the tutelage of Dr Harris, I had the opportunity to try all of these techniques, and over time I selected the iris plane phacoemulsification technique of Richard Kratz, MD, as my procedure of choice. In this era before capsulorhexis and hydrodissection, I would perform a relatively large can opener anterior capsulectomy just inside the zonules. After this, a portion of the central core nucleus was emulsified, leaving an inferior shelf of tissue. Then, using a bimanual technique, the superior pole of the nucleus was tilted above the capsule and engaged by a beveled phacoemulsification tip. The nucleus was then supported in the iris plane with a nucleus rotator and emulsified (Fig 1). I still found occasions to sublunate the nucleus into the anterior chamber, particularly when I was in trouble or concerned about a capsular tear. I also had indications for posterior chamber phacoemulsification, particularly in very soft nuclei in younger patients. Yet, Richard Kratz's iris plane phacoemulsification remained my procedure of choice for many years, and I taught this technique successfully to hundreds of residents, fellows, and fellow ophthalmologists.

Like others in the 1980s, I experimented with and eventually adopted the technique of continuous tear anterior capsulectomy (capsulorhexis). Initially I used a relatively small-diameter capsulorhexis, in the range of 4.0 to 5.0 mm, especially when using 5.5-mm round optic polymethylmethacrylate intraocular lenses. This small continuous tear anterior capsulectomy made it impossible to sublunate the nucleus safely into the iris plane or anterior chamber, and I therefore

converted to posterior chamber, endocapsular phaco techniques. In most nuclei, I would use a nuclear cracking technique but still found a technique in which I would emulsify the core nucleus and then infracture the peripheral bowl of retained nuclear material and nuclear plate in a so-called one-handed technique useful for soft nuclei in younger patients. Hydrodissection and hydrodelineation became a standard part of my technique to loosen the nucleus and allow it to be rotated easier, and with a small continuous-tear anterior capsulectomy, the nucleus always remained localized in the posterior chamber. Although there are many positive features to the endocapsular cracking techniques, I did find they were more difficult to teach, with a longer learning curve. In addition, I found my procedure times to be somewhat longer than they had been with the iris plane technique. I also noted a mild increase in my capsular tear rate, from approximately 1% to 1.8%. On the positive side, visual recovery was very rapid, especially when I adopted foldable intraocular lenses, and most patients had a crystal clear cornea on the first postoperative day. In time, I was able to reduce my capsular tear rate to 1.3%, but I continued to have an operative procedure that required 10 to 15 minutes to complete. In addition, in some instances when my capsulorhexis was somewhat smaller, in the 4-mm range, particularly in patients with loose zonules such as patients with pseudoexfoliation, I noted other undesirable side effects, such as the capsular-contraction syndrome.

After being influenced by several Japanese investigators who suggested that retained subcapsular epithelium might play a role in postoperative inflammation and capsular opacity, I began to investigate using larger-diameter anterior capsulectomies. Using a continuous tear anterior capsulectomy of 5.5 to 6.5 mm, I returned to the size of anterior capsulectomy that I had used in my early phacoemulsification years when using iris plane and anterior chamber phacoemulsification. During hydrodissection, I would in many cases partially or totally sublunate the nucleus anterior to the capsular rim inadvertently. In those cases, I would simply push the nucleus back into the capsular bag and complete the procedure using a nuclear fracture technique. Over time I learned to take advantage of this capability to sublunate the nucleus into the anterior chamber in high-risk cases. When there was a large anterior segment, as in a myopic patient, a healthy cornea, and a relatively soft nucleus, I often would sublunate the nucleus to a position anterior to the capsular bag and complete a deep anterior chamber phacoemulsification, supporting the nucleus with a nucleus rotator. I found that the larger anterior capsulectomy allowed an easier phacoemulsification, and I did not appear to be sacrificing anything with regard to intraocular lens centration. Fundus visibility was good, and my occasional case of capsular contraction syndrome disappeared. Capsular opacity rates appeared low, and a small randomized study suggested that they were somewhat lower than with the smaller anterior capsulectomy that I had used in the past. The impact of capsulorhexis size on capsular opacity rate and postoperative

From the Division of Ophthalmology, University of Minnesota, Phillips Eye Institute, and Minnesota Eye Laser and Surgery Center, Minneapolis, MN.

Address reprint requests to Richard L. Lindstrom, MD, Minnesota Eye Consultants, P.A., 710 E 24th St, #106, Minneapolis, MN 55404.

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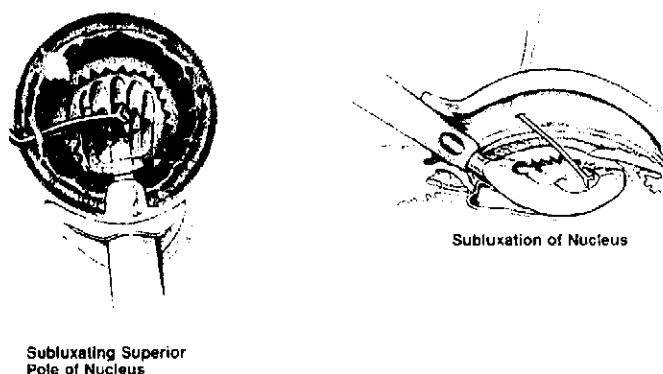


Figure 1. Kratz iris plane method of phacoemulsification (From Lindquist, Lindstrom: *Ophthalmic Surgery*, Vol 19. St Louis, MO, Mosby-Yearbook, 1995 by permission).

inflammation remains controversial, with studies supporting both sides of the equation. I remain impressed that my incidence of capsular opacity and inflammation is somewhat lower with a larger anterior capsulectomy.

I was next influenced by David Brown, MD, and Bill Maloney, MD, with regard to the concept of supracapsular phacoemulsification, in which the nucleus is hydrodissected and tumbled and then pushed back into the posterior chamber anterior to the capsule. After evaluating this technique for a time, I found it technically somewhat difficult to tumble the nucleus safely in all eyes. I also found that my first day postoperative corneas were not as clear as I had been accustomed to seeing them when using an endocapsular approach. I did, however, become quite adept at hydrodissecting until the nucleus tilted, which was the first step before tumbling the nucleus in a supracapsular approach. One day while working on my supracapsular and tumbling technique, I realized that the first step of this procedure tilted the nucleus to a position very similar to that which I had used for years in the Kratz iris plane phacoemulsification approach. Rather than completing the tumbling of the entire nucleus, I simply supported the nucleus in the plane of the iris and anterior capsular leaflet and then emulsified half of it. At that time, with a much smaller nuclear remnant, I tumbled the remaining half upside down and completed the emulsification as I would have in the classical supracapsular approach. To my delight, the surgical technique was fast, simple, and safe. The following day, the corneas of the patients on whom I used this technique were similarly clear to those with my endocapsular nuclear fracture approach. I chose to call the technique "tilt and tumble" and began to refine it so that I could teach it effectively to residents, fellows, and other ophthalmologists with confidence. It is basically "back to Kratz" in the capsulorhexis, hydrodissection, viscoelastic, and modern phaco machine era. In the following paragraphs, I attempt to describe this technique in enough detail to allow an ophthalmologist to evaluate it for his or her own patients.

### Indications

The indications for the tilt and tumble phacoemulsification technique are quite broad. It can be used in either a large or a small pupil situation. I am aware of surgeons who favor it in small pupil settings in which the nucleus can be tilted up such

that the equator is resting in the center of a small pupil and is then carefully emulsified away. It does require a large continuous-tear anterior capsulectomy of at least 5.5 mm. If a small anterior capsulectomy is achieved, I believe that the hydrodissection step, in which the nucleus is tilted can be dangerous, and it would be possible to rupture the posterior capsule during the hydrodissection step. If an inadvertently small anterior capsulectomy is created, I favor converting to an endocapsular phacoemulsification technique. I also convert to an endocapsular approach if I am unable to tilt the nucleus with either hydrodissection or manual technique. Occasionally the entire nucleus will subluxate into the anterior chamber. In this setting, if the cornea is healthy, the anterior chamber roomy, and the nucleus soft, I often will complete the phacoemulsification in the anterior chamber, supporting the nucleus away from the corneal endothelium. The nucleus also can be pushed back inferiorly into the capsular bag to allow the iris plane tilt and tumble technique to be completed. In patients with severely compromised endothelium, such as Fuchs' dystrophy or previous keratoplasty patients with a low endothelial cell count, I often revert to endocapsular phacoemulsification to reduce endothelial trauma to the minimum possible. In a normal eye, I am unable to differentiate my first day postoperative corneal clarity in my endocapsular eyes from my nuclear "tilt and tumble" eyes, but the tilting and tumbling maneuvers do increase the chance of endothelial cell contact of lens material versus an endocapsular phacoemulsification, and I therefore favor the latter in eyes with borderline corneas. The technique is a very good transition technique for teaching residents, fellows, and surgeons who are transitioning to phacoemulsification, because it is easy to convert to a planned extracapsular cataract extraction with the nucleus partially subluxated above the anterior capsular flap at the iris plane.

### Preoperative Preparation

The patient enters the anesthesia induction or preoperative area, and tetracaine drops are placed in both eyes. The placement of these drops increases the patient comfort during the placement of the multiple dilating and preoperative medications, decreases blepharospasm, and also increases the corneal penetration of the drops to follow.

I dilate the patient with 2.5% Neosynephrine (Winthrop Consumer Products, New York, NY) and 1% cyclopentolate every 5 minutes for three doses. I also treat the patient preoperatively with topical antibiotic and antiinflammatory drops at the same time as dilation. I favor both a preoperative topical antibiotic, topical steroid, and topical nonsteroidal. The rationale for this is to preload the eye with antibiotic and nonsteroidal before surgery. The pharmacology of these drugs and the pathophysiology of postoperative infection and inflammation support this approach. An eye that is preloaded with antiinflammatories before the surgical insult is likely to show a much reduced postoperative inflammatory response. Both topical steroids and nonsteroidal drugs have been confirmed to be synergistic in reduction of postoperative inflammation. In addition, the use of perioperative antibiotics appears to be supported by the literature as helpful in reducing the likelihood of postoperative endophthalmitis. Because the patient will be sent home on the same drops used preoperatively, there is no additional cost.

My usual anesthesia is topical tetracaine reinforced with

intraoperative intracameral 1% nonpreserved (methylparaben-free) xylocaine. For patients with blepharospasm, a "miniblock" Obrien facial nerve anesthesia, using 2% xylocaine with 150 units Hyaluronidase per 5 mL xylocaine, can be quite helpful in reducing squeezing. This block lasts 30 to 45 minutes and makes surgery easier for the patient and the surgeon. Patients are sedated before the block to eliminate any memory of discomfort. One way to screen for patients in whom this facial nerve block might be useful is to ask the technicians to make a note in the chart when they have difficulty performing applanation pressures or A-scan because of blepharospasm. In these patients, a mini facial nerve block can be quite helpful.

In younger anxious patients and in those in whom I am quite concerned about cooperation, I continue to perform a peribulbar block. This is basically a clinical-impression-type decision. Naturally, general anesthesia is used for very uncooperative patients and children. Although this is controversial, in some patients when general anesthesia is chosen and a significant bilateral cataract is present, I perform consecutive bilateral surgery, completely re-preparing and starting with fresh instruments for the second eye.

In summary, in the induction area, the patient is dilated maximally and the eye is preloaded with antibiotic, steroid, and nonsteroidal antiinflammatory drops. Appropriate anesthesia is obtained. Oculopression can be used at the surgeon's discretion, and I still favor this in most patients, even when using topical anesthesia. The patient is visited by the anesthesiologist, if used, as well as the circulating nurse and the surgeon. Any questions are answered. The patient is then brought into the surgical suite.

On entering the surgical suite, the patient table is centered on preplaced marks so that it is appropriately placed for microscope, surgeon, scrub nurse, and anesthesiologist access. I favor a wrist rest, and the patient's head is adjusted such that a ruler placed on the forehead and cheek will be parallel to the floor. The patient's head is stabilized with tape to the wrist rest to reduce unexpected movements, particularly when the patient may fall asleep during the procedure and suddenly awaken. A second drop of tetracaine is placed in each eye. I find that if the tetracaine is placed in each eye, blepharospasm is reduced. A periocular preparation with 5% povidone-iodine solution is completed. Personally, I do not irrigate the ocular surface and fornices with povidone-iodine, because I find that the patients under topical anesthesia note a significant burning. If a few drops leak into the eye, this is certainly acceptable.

I have found an aperture drape helpful for topical anesthesia to increase comfort, because I have found that when I tuck the drape under the lids this often irritates the patient's eye and also reduces the malleability of the lids, reducing exposure. Because it is important to isolate the meibomian glands and lashes, if an aperture drape is used I recommend a solid-bladed speculum. Using temporal and nasal approaches to the eye, the solid blades of the speculum are not in the way. In those cases in which a superior approach is planned, I use a drape tucked under the lids, and, in those cases, I favor a Kratz modified Barraquer wire, because this enhances access to the globe. I do, however, find that I am using a superior approach incision less and less.

I currently use balanced salt solution (BSS) in all cases. I have not found for the short duration of a phacoemulsification case that BSS plus provides any clinically meaningful benefit. I place 0.5 mL of the intracameral nonpreserved (sodium bisul-

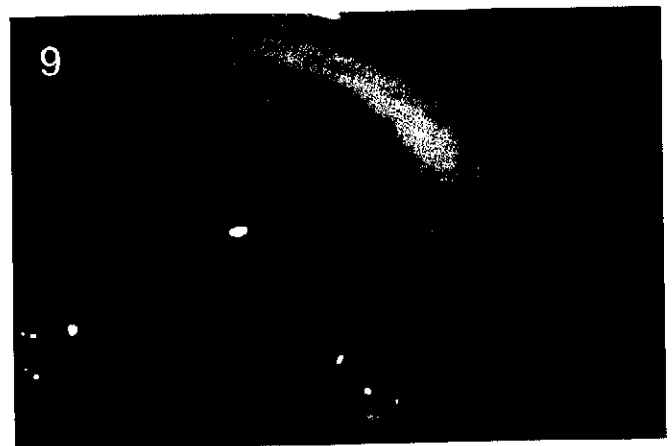
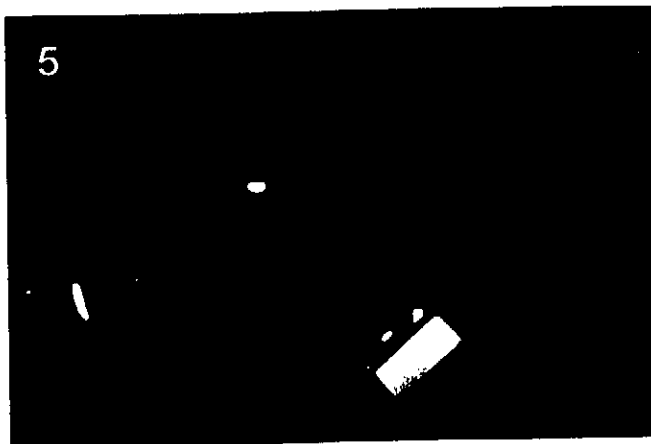
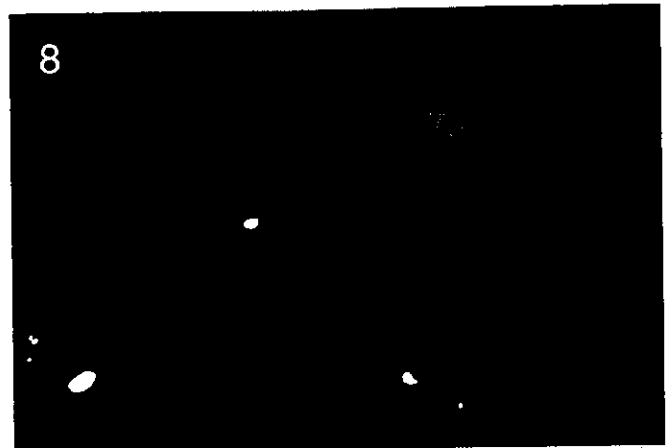
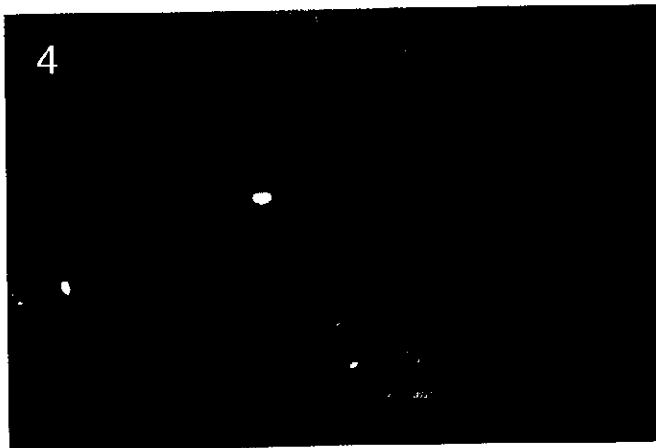
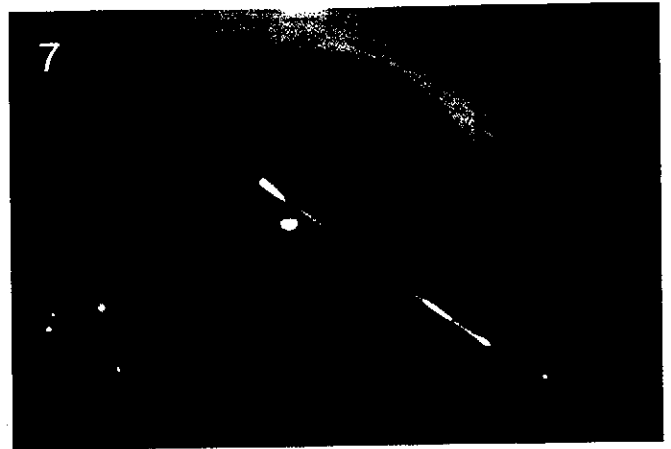
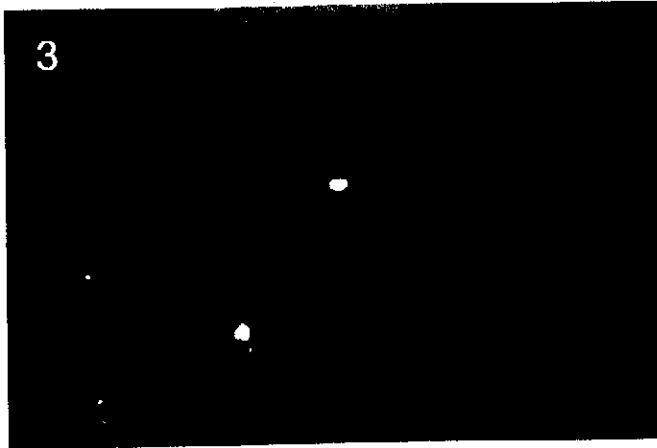
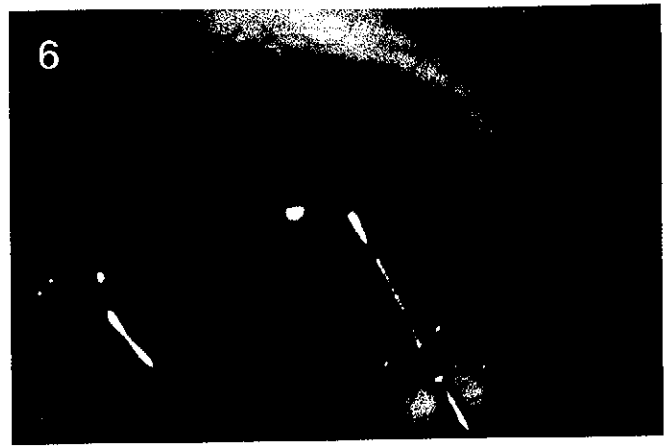
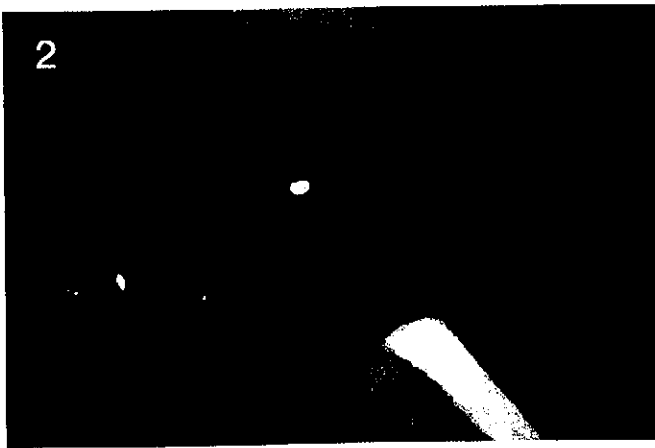
fate-free) epinephrine in the bottle for assistance in dilation and perhaps hemostasis. I also place 1 mL (1,000 units) of heparin sulfate to reduce the possibility of postoperative fibrin. This is also a good antiinflammatory and coating agent. At this dose, there is no risk of enhancing bleeding or reducing hemostasis. I personally also favor 10 mg vancomycin in the 500 mL BSS, although this remains controversial. I personally consider an intraocular lens a high-risk prosthetic case in that the risk of significant loss of vision is clearly high, even though the incidence of infection is relatively low. Although there are no studies to fully document the risk-benefit ratio to the individual patient and to society in general using this approach, my own personal incidence of endophthalmitis has been reduced from approximately 1/1,000 to none in approximately 6,000 consecutive cases since using vancomycin in the bottle intraoperatively.

The lids are separated with a solid-blade speculum. A solid-blade Barraquer speculum is satisfactory, but my associate, Y. Ralph Chu, MD, and I have recently designed an aspirating speculum, called the Lindstrom/Chu speculum, available from Rhein Medical (Tampa, FL), which can be placed temporally or nasally, isolates the lashes, and also can be hooked up to aspiration to remove any pooling of fluid. A final drop of tetracaine is placed in the operative eye, and I am now ready to begin the surgical procedure. I do not like to use more than three drops of tetracaine or other topical anesthetic, because excess softening of the epithelium can occur, resulting in punctate epithelial keratitis, corneal erosion, and delayed postoperative rehabilitation.

## Operative Procedure

The patient is asked to look down. The globe is supported with a dry Murocel sponge [Bausch and Lomb Surgical (Storz), St Louis, MO], and a counter puncture is performed superiorly at the 12-o'clock position with a diamond stab knife. I favor approximately a 1-mm stab incision (Fig 2). Approximately 0.25 mL 1% nonpreserved methylparaben-free xylocaine is injected into the eye (Fig 3). I advise the patient that they will feel a "tingling" or "burning" for a second, and then the eye will go numb. This provides a psychological support for the patient that they will now have a totally anesthetized eye and should not anticipate any discomfort. I tell them that although they will feel some touch and fluid on the eye, they will not feel anything sharp, and if they do, they should advise me, and I will supplement the anesthesia. This injection also firms up the eye for the clear corneal incision. I do not find it necessary to inject viscoelastic.

I prefer a temporal or nasal anterior limbal or posterior clear corneal incision. I define my incision as a modified Langerman incision. A groove is made 400 to 500  $\mu$ m deep into the perilimbal capillary plexus just anterior to the insertion of the conjunctivae (Fig 4). Care is taken not to incise the conjunctivae because this can result in ballooning during phacoemulsification and irrigation aspiration. Some surgeons define this as being a posterior clear corneal incision and others as an anterior limbal incision. The anatomic landmark for me is the perilimbal capillary plexus and the insertion of the conjunctivae. When the groove is made, there will be a small amount of capillary bleeding. Because the incision is into a vascular area, long-term wound healing can be expected to be stronger than it is with a true clear corneal incision. True clear corneal



Figures. 2-9.

incisions, such as performed in radial keratotomy, clearly do not have the wound healing capabilities that a limbal incision demonstrates where there are active blood vessels present.

The anterior chamber is then entered parallel to the iris at a depth of approximately 300  $\mu$ m or above the deepest portion of the groove. This creates the hinge-type or Langerman-type of incision (Fig 5). I like the width of the incision to be 1.75 to 2.00 mm and have designed a keratome with Storz with two small black lines that can serve as a guide to the surgeon in creating an appropriate width incision.

In right eyes, my favorite incision is temporal, and in left eyes, nasal. I have found a nasal clear corneal incision for left eyes to be excellent, allowing the surgeon to sit in the same position for right and left eyes. I simply need to move over approximately 2 to 3 inches in my sitting position, and I can continue with my phacoemulsifier, scrub nurse, and instruments to my right, sitting comfortably oblique at approximately a 45° angle at the patient's head. The nasal cornea is thicker, has a higher endothelial cell count, and allows very good access for phacoemulsification. The nasal limbus is approximately 0.3 mm closer to the center of the cornea than the temporal limbus, and this can, in some cases in which there is excess edema, reduce first-day postoperative vision more than one might anticipate with a temporal incision. There also can, in some patients, be pooling. For this reason, I do favor an aspirating speculum. It is also helpful to tip the head slightly to the left side. Nonetheless, I have found in my left eyes a nasal clear corneal approach to be excellent, and I offer this as an alternative for surgeons who find the temporal position uncomfortable.

Although I personally create my groove by simply taking the keratome and tipping it up and using the tip of the keratome, many surgeons use a guarded knife to create a consistently deep incision. I find that an astigmatic keratotomy blade can be quite useful in this regard. This blade also can be helpful when patients present with high astigmatism and an intraoperative astigmatic keratotomy is thought to be appropriate.

In some patients, I select a corneal scleral incision, for example, in those who have had a previous radial keratotomy or have findings of peripheral corneal ulcerative keratitis, in some patients with very low endothelial cell counts, and in any case in which there was any significant peripheral pathological condition or thinning. I do find that my type of anterior limbal or posterior corneal incision can be made temporally, nasally, in the oblique meridian, or even superiorly without induction of significant corneal edema or endothelial cell loss.

When I select a corneal scleral incision, I raise a small conjunctival flap with a Westcott scissors. Before this, I hold a Murocel sponge in the area of the limbus where the conjunctival flap will be raised, soaked in tetracaine or nonpreserved

xylocaine, for 30 to 60 seconds to enhance anesthesia. Mild cautery can be applied, or one can use a Murocel soaked in thrombin 1/1,000 of BSS to effect hemostasis. If there is minimal capillary oozing, the mild bleeding also can simply be ignored. Thrombin solution is also very useful in anterior segment reconstruction cases in which excess bleeding is noted.

I personally close all clear corneal incisions larger than 4 mm with a horizontal mattress, X, or single radial suture. I have found that the least early astigmatism is induced with the horizontal mattress suture, and I personally favor this. A corneal scleral incision greater than 5.5 mm is also closed with one horizontal mattress suture. I find that my incision, if 3 mm in length, tends to cause an induction of  $0.25 \pm 0.25$  diopters of astigmatism. If it is placed on the steeper meridian, it therefore can be expected to reduce the astigmatism somewhere between 0 and 0.50 diopters. If the incision is 4 mm in length, I find a reduction in astigmatism of  $0.50 \pm 0.50$  or 0 to 1.00 diopter if the incision is placed on the steeper meridian. In routine cataract surgery, I do not use incisions larger than 4 mm, and I do favor an incision in the 3-mm range, because I am very secure that these will be self-sealing. I find that with modern injector systems, most foldable intraocular lenses can be implanted through a 3-mm anterior limbal incision.

In select patients, I perform an intraoperative astigmatic keratotomy at the 7- to 8-mm optical zone. I personally do this at the beginning of the operation. The patient's astigmatism axis is marked carefully using an intraoperative surgical keratometer, which allows one to delineate the steeper and flatter meridian and not be concerned about globe rotation. I find that one 2-mm incision at a 7- to 8-mm optical zone will correct 1 diopter of astigmatism, and two 2-mm incisions will correct 2 diopters of astigmatism in a cataract-age patient. One 3-mm incision will correct 2 diopters; and two 3-mm incisions, 4 diopters. One can combine a 3-mm and a 2-mm, correcting 3 diopters. Larger amounts of astigmatism also can be corrected using the Arc-T nomogram. Depending on the age of the patient, one can correct up to 8 diopters of astigmatism with two 90° arcs. Many surgeons have moved to a peripheral corneal limbal arcuate incision, but I continue to favor the 7- to 8-mm optical zone because of my years of experience with this approach. There certainly is a variation in response, but I have not found any significant induced complications with this approach. My outcome goal is 1 diopter or less of astigmatism in the preoperative axis. I would prefer to undercorrect rather than overcorrect. The key in astigmatism surgery is "axis, axis, axis." If one is not careful in preoperative planning and the incision are placed more than 15° off axis, one is better avoiding this approach.

The anterior chamber is constituted with a viscoelastic. My studies have not found any significant difference between one viscoelastic or another with regard to postoperative endothelial cell counts. I have found Occucoat (Storz) to be an excellent viscoelastic that can also be used to coat the epithelial surface during surgery. This eliminates the need for continuous irrigation with BSS. It gives a very clear view. It is also economically a good choice in most settings. I have also been very happy with the Amvisc Plus [Bausch and Lomb Surgical (Chiron), Claremont, CA], as we can obtain 0.8 cc of it at a very fair price.

I then fashion a relatively large-diameter continuous tear anterior capsulectomy (Figs 6, 7). This can be made with a

Figure 2. A clear corneal counter puncture is made at 12:00 o'clock with a 1-mm diamond blade.

Figure 3. One-fourth milliliter of nonpreserved (methylparaben-free) xylocaine is injected into the anterior chamber.

Figures 4-5. A "modified Langerman"—anterior limbal incision is created with a 2.5- to 3.2-mm diamond keratome.

Figures 6-7. A large (5.5-6.5 mm) continuous tear anterior capsulectomy is performed.

Figures 8-9. Hydrodissection is continued until the nucleus tilts out of the capsular bag. If necessary, the nucleus is rotated to the incision.

cystatome or forceps. I personally prefer a cystatome. I would like it to be 5.5 to 6.5 mm in diameter and inside the insertion of the zonules. In my opinion, the larger the better, because there is less subcapsular epithelium and an easier cataract operation. I still believe that less subcapsular epithelium leaves one with a lower inflammation postoperatively and less capsular opacity. I have not seen any change in intraocular lens decentration. With some intraocular lenses, the capsule seals down to the posterior capsule around the loops rather than being symmetrically placed over the anterior surface of the intraocular lens. These eyes, in my opinion, do extremely well, and I am beginning to wonder if this is not preferred to having the capsule anterior to the optic. This is also certainly a controversial position.

I then perform hydrodissection using a Pearce hydrodissection cannula (Visiter, Sarasota, FL) on a 3-cc syringe filled with BSS. Slow continuous hydrodissection is performed gently, lifting the anterior capsular rim until a fluid wave is seen. At this point, irrigation is continued until the nucleus tilts on one side, up and out of the capsular bag (Fig 8). If one retracts the capsule at approximately the 7:30-o'clock position with the hydrodissection cannula, usually the nucleus will tilt superiorly. If it tilts in another position, it is simply rotated until it is facing the incision (Fig 9).

Once the nucleus is tilted, some additional viscoelastic can be injected under the nucleus, pushing the iris and capsule back. Also, additional viscoelastic can be placed over the nuclear edge to protect the endothelium. The nucleus is emulsified outside-in while supporting the nucleus and the iris plane with a second instrument, in my case, a Rhein Medical or Storz Lindstrom Star or Lindstrom Trident nucleus rotator (Fig 10). Once half of a nucleus is removed, the remaining half is tumbled upside-down and attacked from the opposite pole (Fig 11). Again it is supported in the iris plane until the emulsification is completed (Figs 12, 13). Alternatively, the nucleus can be rotated and emulsified from the outside edge in, in a carousel or cartwheel type of technique. Finally, in some cases, the nucleus can be continuously emulsified in the iris plane if there is good followability until the entire nucleus is gone.

I have found this to be a very fast and very safe technique, and, as mentioned before, it is a modification of the iris plane technique taught by Richard Kratz, MD, in the late 1970s and 1980s. It is basically "back to Kratz" in the modern phacoemulsification, capsulorhexis, hydrodissection, and viscoelastic era. My surgery times now range between 5 and 10 minutes rather than 10 to 15 minutes with this approach. In addition, my capsular tear rate has now gone under 1%. I have therefore found it to be a technique that is easier, faster, and safer. It is true that in this technique the phacoemulsification tip is closer to the iris margin and also somewhat closer to the corneal endothelium. There is, however, a significantly greater margin of error with regard to the posterior capsule. Care needs to be taken to position the nucleus away from the corneal endothelium and away from the iris margin when using this approach.

If the nucleus does not tilt with simple hydrodissection, it can be tilted with a second instrument such as a nuclear rotator (Storz), Graether collar button, or hydrodissection cannula.

When using this approach of phacoemulsification with the Storz Premier instrument, I use a vacuum of 60 mm Hg and an anterior chamber maintainer pressure of 60 mm Hg. I personally favor the Storz Microflow Plus needle with a 30° bevel.

When using a peristaltic machine, I use a slightly higher vacuum in the range of 80 to 100 mm Hg. I favor a relatively high bottle with some overflow of fluid.

Again, I find that for me a 30-degree bevel needle is appropriate for this approach. When using tilt and tumble, very high vacuum settings are not necessary and may be inappropriate. The iris margin is in the vicinity of the phacoemulsification tip, and it is possible to core through the nucleus and aspirate the iris margin if very high vacuums are used.

More recently, I have had an opportunity to work with the dual-function Storz Millennium, and I find this machine to be excellent for all cataract techniques including "tilt and tumble." I set my vacuum with a range of 60 to 100 mm Hg and my ultrasound power from 10% to 60% with the Storz Millennium. I arrange the foot pedal such that I have surgeon control over ultrasound on the vertical or pitch motion of the foot pedal, and then on the yaw or right motion foot pedal, I have vacuum control. I therefore can engage the tissue, emulsify it, and, as needed, apply additional ultrasound with a downward movement and additional vacuum with a right movement of the foot pedal. This allows very efficient emulsification, and the Millennium is my current preferred machine.

After completion of nuclear removal, the cortex is removed with the irrigation aspiration hand piece. I favor a 0.3-mm tip and use the universal hand piece with interchangeable tips. I use a curvilinear tip for most cortex removal and then remove the cortex under the incision with a Lindstrom right angle sand-blasted tip currently manufactured by Rhein and Storz (Fig 14). If there is significant debris or plaque on the posterior capsule, I attempt some polishing and vacuum cleaning, but I do not favor extensive polishing or vacuum cleaning because most of my capsular tears with this technique occur during capsular polishing and vacuuming. Many times there is an unexpected small burr or sharp defect on the irrigation and aspiration (I&A) tip, which results in a capsular tear after a case that was otherwise well done.

The anterior chamber is reconstituted with viscoelastic, and I insert an intraocular lens, using an injector system (Figs 15, 16). My current lenses of choice include the plate haptic silicone intraocular lens and the three-piece silicone lenses that are injectable through a 3-mm incision. In select cases, I use an acrylic implant, although with a cross-action folder this requires enlargement of the incision. I have found that one can inject the acrylic lens with care through a Bartelt injector, but proper technique is necessary or the loops can be damaged.

Figure 10. The first half of the nucleus is emulsified in the iris plane using an "outside in" phacoemulsification approach. I prefer a 30° bevel microflow plus needle and Storz Millennium machine.

Figure 11. The remaining half of the nucleus is tumbled upside down with a nucleus rotator.

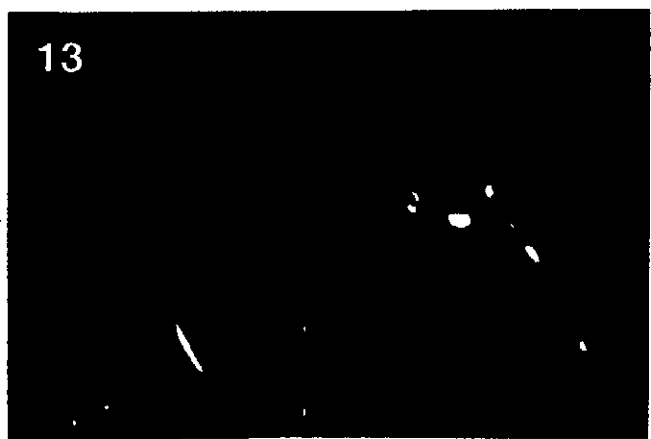
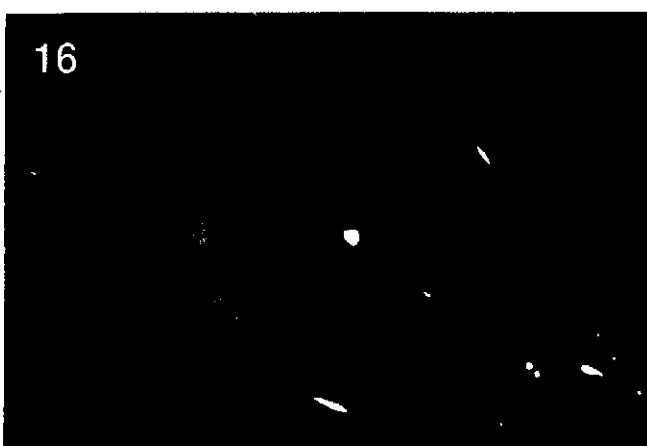
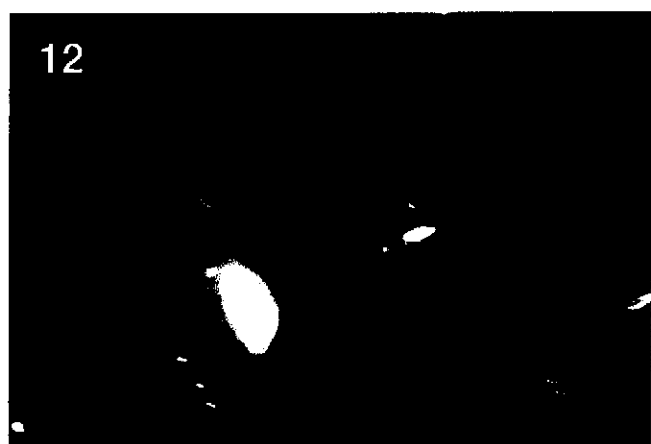
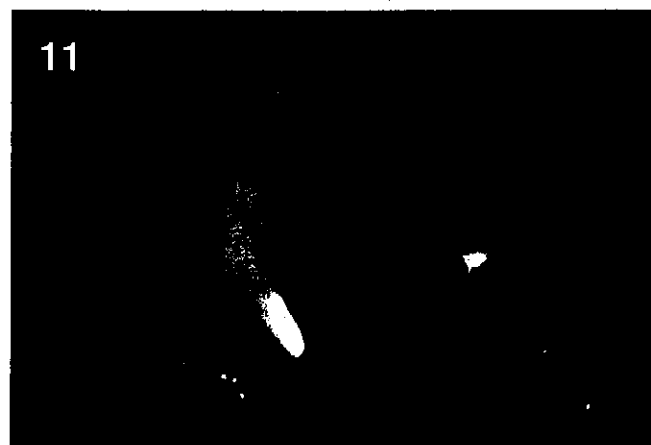
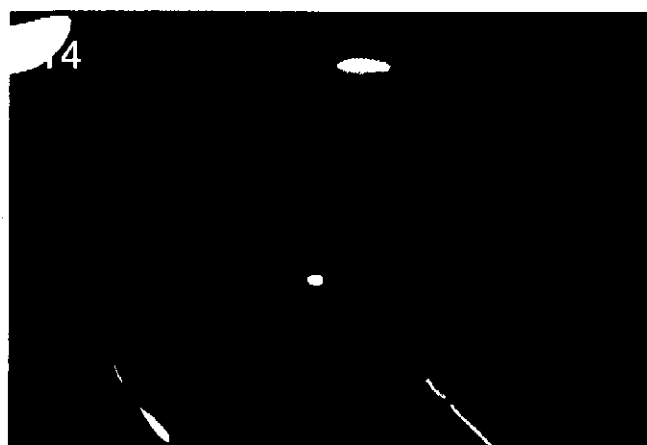
Figures 12-13. The remaining half of the nucleus is supported in the iris plane with a nucleus rotator and emulsified outside in.

Figure 14. The cortex under the incision is removed with a Lindstrom sand-blasted right-angle tip.

Figures 15-16. A foldable IOL is implanted with the capsular bag using an injector system.

Figure 17. The eye at completion of the procedure: Note the left nasal clear corneal incision.





Figures. 10-17.

Excess viscoelastic is removed with irrigation aspiration. I simply push back on the intraocular lens and slowly turn the irrigation aspiration to the right and left two or three times, allowing a fairly complete removal of viscoelastic under the intraocular lens.

I favor injection of a miotic and personally prefer Carbastat (Ciba Vision, Atlanta, GA) over Miochol (Ciba Vision) at this time, because it is more effective in reducing postoperative intraocular tension spikes and has a longer duration of action. I find it is necessary to dilute the carbachol 5 to 1, or one can obtain an excessively small pupil, which results in dark vision for the patient at night for 1 to 2 days. I firm up the eye through the counterpuncture and evaluate the incision. If the chamber remains well constituted and there is no spontaneous leak from the incision, I do not think that wound hydration is necessary. If there is some shallowing in the anterior chamber and a spontaneous leak, I will then perform wound hydration, injecting BSS peripherally into the incision and hydrating it to push the edges together. I believe that within a few minutes these clear corneal or posterior limbal incisions seal, much as a LASIK flap will stick down, through the negative swelling pressure of the cornea and capillary attraction. It is important to leave the eye slightly firm at 20 mm Hg or so to reduce the side effects of hypotony and also help the internal valve incision to appropriately seal (Fig 17).

At completion of the procedure, I place another drop of antibiotic, steroid and nonsteroidal, on the eye. I also use one drop of an anti-hypertensive such as Betagan (Allergan Pharmaceuticals, Irvine, CA) or Alphagan (Allergan Pharmaceuticals) to reduce postoperative intraocular tension spikes.

### Postoperative Care

No patch is routinely used for the topical and intracameral approach. If mini-block of the lids has been performed, this will wear off in 30 to 45 minutes, and there is usually adequate lid function for a normal blink at the completion of the procedure. Patients are advised that they will have some erythropsia, meaning they will see a pink afterimage for the rest of the day, but usually this will resolve by the next morning. They are also told that their vision may be a little dark at night from the miotic, and not to be concerned if they wake up at night and their vision seems dark.

The patient is seen on the first postoperative day and then at approximately 2 to 3 weeks postoperatively. At this time, a refraction and complete examination with the slit lamp and fundus evaluation is performed. If there is no inflammation, patients are seen again 1 year postoperatively. If there is still persistent inflammation, additional postoperative antiinflammatory medications are recommended, and the patient is asked to return again at 2 to 3 months postoperatively.

Topical antibiotic, steroidal and nonsteroidal, are used twice a day, usually requiring a 5-mL bottle and 3 to 4 weeks of therapy. Occasionally a second bottle of steroid and nonsteroidal is necessary if flare and cell persist at the 3-week examination. There are minimal restrictions, including a request that there be no swimming and no very heavy lifting for 2 weeks. Many patients are given half-glasses the first postoperative day, allowing functional vision at distance and near. I personally consider the ideal postoperative refractive spherical equivalent for a monofocal lens to be  $-0.62$  diopters with less than 0.50 diopters astigmatism in the same axis as preoperatively. Most

- **Tetracaine pre-dilation QU**
- **Antibiotic / steroid / nonsteroidal preop**
- **Intracorneal non-preserved Xylocaine**
- **Facial nerve mini-block for blepharospasm**
- **Aperture drape for topical cases**
- **Heparin, Vancomycin, Epinephrine in BSS bottle**
- **Solid blade aspirating speculum**
- **Modified Langerman clear corneal incision**
- **Left eye done**
- **Right eye done**
- **On-axis vs. intraoperative AK for astigmatism**
- **Large continuous tear anterior capsulectomy**
- **Nuclear Tilt and Supracapsular phaco.**
- **Storz Premiere/Millennium with Barrett microflow 30° phaco needle.**
- **Right angle Lindstrom I&A control.**
- **Carbachol for miosis & pressure control.**
- **Postop drops b.i.d. only.**
- **2 postop visits routine, 3 optional.**
- **Kaizan concept of incremental improvement**

Figure 18. Summary of key points.

patients can see 20/30+ and J3+ with this type of correction. I will use monovision in the appropriate settings. More recently I am finding good results with the Allergan ARRAY multifocal intraocular lens. In this setting, I target plano to  $-0.25$  diopter with minimal astigmatism.

The second eye is done at 1 month or more postoperatively except in rare situations. I prefer to defer any yttrium aluminum garnet (YAG) lasers for 90 days to allow the blood aqueous barrier to become intact and capsular fixation to be firm, especially in plate haptic intraocular lenses. In my experience, the lowest YAG laser capsulotomy rates have been with the plate haptic silicone intraocular lens and the acrysoft intraocular lens (Alcon, Ft Worth, TX).

### Conclusion

In summary, the key points are listed in Figure 18. I hope other surgeons will find this approach to cataract surgery useful. These techniques must be personalized, and every surgeon will find that slight variations in technique are required to achieve optimum results for their own individual patients in their own individual environment. Continuous efforts at incremental improvement result in meaningful advances in our ability to help the cataract patient obtain rapid, safe, visual recovery after surgery.