Phaco Techniques

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Part A: Disassembling the Nucleus—An Overview

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The introduction of the continuous curvilinear capsulorrhexis by Howard Gimbel and Thomas Neuhann in the early 1990s solved two critically important problems for phacoemulsification surgeons and created a new challenge. The traditional can opener capsulotomy, used for years by phaco surgeons, was prone to the development of radial tears. These tears often “zipped” around the equator of the lens capsule, extended to the posterior capsule, and were a major source of intraoperative complications. Even when the radial tears remained small and caused no intraoperative problems, asymmetric capsular contractional forces associated an irregular capsular margin frequently lead to intraocular lens (IOL) decentration. Gimbel and Neuhann’s new technique resulted in greater stability of the capsular bag. The old method of tipping the entire nucleus of a dense cataract into the pupillary plane could no longer be used. The new challenge for surgeons was to devise a method for removing an 8- to 10-mm nucleus through a 4- to 7-mm capsular opening.

Surgeons struggled initially as they attempted to modify their techniques of phacoemulsification to meet the challenge posed by capsulorrhexis. “Endocapsular” techniques of emulsifying the nucleus entirely within the capsular bag were proposed by a number of surgeons, but the awkwardness and inherent difficulties and dangers of performing these techniques prevented them from gaining wide acceptance. Gradually, a variety of techniques for cracking or fracturing the nucleus within the capsular bag evolved, and the approach of first disassembling the nucleus and then bringing sections of the nucleus into a "safe zone" for emulsification became the foundation of all phaco techniques used today.

The term divide and conquer was first proposed by Howard Gimbel. Dr. Gimbel described a systematic fracturing of the nucleus within the capsular bag using the phaco tip and a surgical spatula. John Shepherd modified Gimbel’s approach and developed an elegant technique for divide and conquer that is widely used.
today. This technique involves the creation of two deep grooves in the nucleus that intersect centrally, followed by the cracking of the nucleus into four separate quadrants. Kunihiro Nagahara soon followed with an alternative approach for disassembling the nucleus, using a horizontal chopping technique. His innovative concept of using the phaco tip to stabilize the nucleus and then to use a chopping device to create countertractional forces within the nucleus is the basis of a variety of chopping techniques used today. The horizontal chop involves placement of a chopping device under the anterior margin of the capsulorrhexis and then, after stabilizing the nucleus with the phaco tip, pulling the chopper horizontally toward the center to the nucleus. The vertical chop technique utilizes a sharp chopper that is embedded in the nucleus centrally. The chopper is pushed downward as the phaco tip is lifted upward, creating a cleavage plane. As a fissure develops, the crack is completed by separating the chopper and phaco tip in a direction 90 degrees to the axis of the cleavage plane.

Divide and conquer, horizontal chopping, and vertical chopping techniques all have one thing in common: they create cleavage planes that allow the surgeon to disassemble the nucleus into smaller fragments. These smaller fragments can then be drawn away from the capsule and into the center of the anterior segment where they can be emulsified more safely. The fundamental difference in these techniques is the direction of the forces that create the cleavage planes. With divide and conquer techniques, the forces are radial and centrifugal. With horizontal chop, the forces are radial and centripetal. With the vertical chop, the forces are anterior-posterior and centrifugal. This tectonic concept of disassembly techniques is best understood diagrammatically (Figures 5-1 through 5-3). In the following parts of this chapter, these three standard techniques of nucleus management will be discussed in detail, using both coaxial and bimanual methods of phacoemulsification.

REFERENCES
Divide and conquer is the most versatile and reliable of all methods for nuclear disassembly. Surgeons new to phacoemulsification often view divide and conquer as a beginning technique, yet because of its many virtues, divide and conquer is widely used by experienced surgeons both as a primary approach and as a dependable fallback maneuver in difficult cases.

**ADVANTAGES OF THE DIVIDE AND CONQUER**

**Requires Less Bimanual Manipulation and Lower Vacuum Setting**

Divide and conquer is easier to learn than chopping techniques, and it is a safer procedure for beginning surgeons. Chopping techniques require the surgeon to impale the nucleus, using phaco power and high vacuum, and simultaneously engage and crack the nucleus using a chopper in the second hand. The basic fracturing maneuver of divide and conquer is less demanding. It requires the opposing action of both hands, but this is accomplished under nonturbulent conditions without the use of phaco power or vacuum. Divide and conquer, moreover, can be performed effectively with lower levels of vacuum and flow than chopping techniques. This leads to greater anterior chamber stability and prevents structures in the anterior chamber from moving too quickly.

**Relies Primarily on Visual Assessments**

The successful performance of divide and conquer relies primarily on visual, rather than tactile, signs. Groove depth, a fundamental assessment in divide and conquer, is judged by the light reflex of the fundus, especially in denser nuclei. This assessment is a relatively easy one to make, even for the inexperienced surgeon. Chopping techniques rely more heavily on kinetic and tactile clues, which must be learned and vary greatly from patient to patient.

**More Protective of the Corneal Endothelium**

Divide and conquer tends to be more gentle on the corneal endothelium because the technique creates space in the posterior chamber and encourages phacoemulsification farther from the endothelium. Chopping techniques can be performed safely, but there is a tendency with these techniques to bring the nuclear fragments into the anterior chamber where phaco energy is more damaging to the cornea.

**Useful for Nuclei of All Densities**

Divide and conquer is a highly versatile procedure that can be used effectively for a full range of nuclear densities from the very soft to the most dense. Chopping techniques that depend on the phaco tip to impale and stabilize the nucleus work best on medium to dense nuclei. With divide and conquer, small variations of technique allow the surgeon to manage cataracts of all densities.

**FUNDAMENTALS OF DIVIDE AND CONQUER**

The basic divide and conquer technique involves the creation of two deep grooves in the nucleus that intersect centrally, followed by the cracking of the nucleus into four separate quadrants. This cracking is accomplished by placing a spatula or chopping device at the base of one side of the groove and the phaco tip at the other side. Using either direct or cross-action force with these instruments, the vertical margins of the groove are separated, and the nucleus is fractured along the axis of the groove. Proper placement of the cracking instrument and the phaco tip at the base of the groove is critical to the success of this maneuver (Figure 5-4). If the instruments are placed along the anterior margin of the groove, the forces created by the separation of the instruments will tend to compress rather than crack the nucleus (Figure 5-5). Care should be taken also to make sure that cleavage of the nucleus is complete before an attempt is made to remove the quadrants. Nuclear fracture should occur centrally first. Repositioning of the instruments may be necessary to extend the fracture to the peripheral rim of the
nucleus. Once the fracture extends the periphery in all quadrants, the quadrants should mobilize easily. Each quadrant is then engaged by the phaco tip and brought into the pupillary plane in the center of the pupillary axis for safe phacoemulsification.

**DIVIDE AND CONQUER: A STEP-BY-STEP APPROACH**

**Step 1. Choose a Keratome That Fits the Phaco Tip.** Make sure that the width of the keratome you are using is a perfect fit for your phaco tip. Too small an incision can restrict infusion and result in an incisional burn. Too large of an incision will result in excessive outflow of fluid and chamber instability.

**Step 2. Create a 5- to 7-mm Capsulorrhexis.** Make your capsulorrhexis 5 to 7 mm in diameter. If the capsulorrhexis is too small, mobilization of the quadrants of the nucleus is made difficult. This is particularly true of larger, denser nuclei. Be careful, however. Attempts to make a larger capsulorrhexis may increase the risk of “losing the rhexis” and creating a posterior tear.

**Step 3. Hydrodissect.** Hydrodissect thoroughly (see Chapter 4). Prior to introducing the phaco tip, place additional viscoelastic in the anterior chamber and use a chopper to check the mobility of the nucleus. The nucleus should spin freely within the capsular bag. If it does not, spend the extra time to complete the hydrodissection. This is time well spent. Failure to free the nucleus from its cortical attachments at this stage of the procedure will force you to struggle with nuclear rotation later and increase the risk of zonular injury.

**Step 4. Sculpt the Nucleus.** Using moderate flow, low phaco power, and low vacuum, begin the sculpting of the grooves. Low vacuum will allow you to create the grooves without engaging and grabbing the nucleus. Start the groove at the proximal margin of the capsulorrhexis. Carry the groove across to the distal margin. Use phaco power only as you sculpt forward. This will reduce phaco time and help to limit the phaco energy released in the anterior chamber (Figure 5-6).

**Step 5. Deepen the Grooves.** Carry the groove posteriorly until you see a good fundus reflex. As a rule of thumb, three times the width of the phaco tip is usually deep enough for most nuclei. Softer nuclei are often not as thick axially as dense nuclei. Care must be taken not to groove too posteriorly in these eyes.

**Step 6. Complete Grooves Before Cracking.** Before attempting to crack the nucleus, rotate the nucleus 90 degrees and create the second groove, intersecting centrally with the first. The nuclear plate is easier to rotate if both grooves are made prior to cracking. Also make sure that you do not leave a mound of unsculpted nucleus at the intersection of the two grooves. This can make cracking more difficult and can
be avoided by simply carrying each sculpting pass continuously across the intersection (Figure 5-7).

Step 7. Crack the Nucleus Into Quadrants. With the phaco device in irrigation only, place the phaco tip and a second instrument at the base of the groove, distal to the intersection of the two grooves. Spread apart and gently lift the edges of the groove until a crack is seen posteriorly in the nuclear plate. Reposition the instruments as necessary to complete the crack through the peripheral rim of the nucleus. Rotate the nuclear plate, using a chopper or spatula, and repeat this maneuver until all four quadrants are freely mobile. Take the time to make sure that disassembly is complete before moving to the next stage of the procedure. As previously noted, the most common error made by beginning surgeons is the failure to place both of the instruments at the base of the groove. The spreading of instruments placed too anteriorly in the groove creates vectors that compress rather than separate the posterior aspect of the groove (Figures 5-8 and 5-9).

Step 8. Phaco the Quadrants. After the nuclear plate is disassembled, you can begin the process of
removing the individual quadrants of nucleus. Using higher flow and vacuum levels, engage a nuclear quadrant distal to the intersection of the grooves. Right-handed surgeons will find it easier to engage the distal quadrant to the left. Impale the quadrant, wait just a moment for vacuum to increase and then draw the quadrant to the center of the pupil in the pupillary plane, and begin emulsification. The second instrument should be used to keep the nuclear fragment in the pupillary plane well away from the corneal endothelium (Figures 5-10 and 5-11).

**Additional Tips**

For very dense nuclei, several modifications of technique are useful. First, retract the phaco irrigation sleeve, exposing slightly more phaco tip. This allows the phaco tip to impale and to cut dense nuclei more efficiently. Second, attempt to make the capsulorrhexis wider for very dense nuclei. Dense nuclei also tend to be very large nuclei. A small capsulorrhexis makes delivery of large dense nuclear sections into the pupillary plane more difficult. Trypan blue facilitates visualization of the capsule and makes creation of a larger capsulorrhexis safer and easier, especially for beginning surgeons. Third, make the angle of intersection of the grooves 60 and 120 degrees, rather than at 90 degrees. Remove one of the 60-degree “quadrants” first. This smaller segment will slide into the pupillary axis more easily than larger, wider sections of the dense nucleus. Fourth, use a chopping device to break larger sections of hard nucleus into more manageable segments. For the surgeon unaccustomed to using a chopper, this can be done safely once the nucleus is brought into the pupillary plane and away from the posterior capsule.

For very soft nuclei, disassembly in the usual manner can be difficult because the nuclear material tends to crumble rather than crack. Fortunately, soft nuclei usually do not need to be cracked. In these cases, once the nucleus is freely mobile after hydrodissection and hydrodelineation, and the grooves have been completed, simply engage each quadrant with the phaco tip in irrigation and aspiration and fold the nuclear segments into the pupillary plane. Ultrasonic energy is often not needed for removal of soft nuclei.

**Part C: Phaco Chop Techniques**

David F. Chang, MD

Phaco chop refers to an advanced set of phaco techniques that should not be attempted until one has already mastered the divide and conquer method.\(^1\)\(^2\) Compared to chopping, the latter method is easier to learn because it is much less dependent upon bimanual
instrument coordination. The phaco tip essentially performs a lamellar dissection of the nucleus as the central trough is sculpted. For this reason, experience with divide and conquer phaco teaches resident surgeons about the relative dimensions and densities of the entire spectrum of nuclei. Furthermore, if attempts at chopping the nucleus fail, divide and conquer becomes a reliable backup technique.

**Classification of Chopping Techniques**

Since Kunihiro Nagahara of Japan first introduced the concept of phaco chop in 1993, many different chopping variations have been described. This wide assortment of modifications can be confusing to residents and transitioning surgeons. For simplification, I first proposed that all chopping methods be conceptually divided into two general categories: horizontal and vertical chopping. Both variations share the same advantage of manually fracturing the nucleus but they accomplish this objective in different ways. The classic Nagahara technique exemplifies horizontal chopping, so named because the instrument tips move toward each other in the horizontal plane during execution of the chop (Figure 5-12). In vertical chopping, the two instrument tips move toward each other in the vertical plane as the chop is performed in order to fracture the nucleus (Figure 5-13).

The stop and chop method of Paul Koch is a hybrid of divide and conquer and chopping, which avoids having to make the difficult first unsculpted chop. Although chopping the heminuclei does reduce total phaco time, significant ultrasound energy is still necessary in order to sculpt the central trench. For this reason, stop and chop does not deliver the full benefits of nonstop chopping that are listed below. Takayuki Akahoshi and Jochen Kammann pioneered the variation of prechopping the nucleus prior to insertion and use of the phaco tip. The inability to immediately aspirate lens debris created with the initial chop, however, may impair visibility for subsequent steps. With dense nuclei it is also difficult to tell how deeply the splitting instrument has penetrated and how close it is to the posterior capsule. Finally, prechopping requires additional steps and instrumentation that are unnecessary when the phaco tip itself is utilized as the chopping platform.

**Four Advantages of Phaco Chop**

The following four advantages are universal to both horizontal and vertical chop.

**Reduction in Phaco Energy and Heat Delivery**

Pure chopping techniques eliminate lens sculpting. Ultrasound energy is not required to subdivide the nucleus and is reserved for the phaco-assisted aspiration of mobile fragments. The marked reduction in phaco power and energy is particularly important for brunescent nuclei where the risk of endothelial cell loss, wound burn, and posterior capsule rupture is higher.

**Reduction in Stress on the Zonules and Capsular Bag**

The capsular bag immobilizes the nucleus during sculpting, and removing a bulky brunescent lens may become problematic for this reason. Unlike a soft nucleus that absorbs instrument pressure like a pillow, a large rigid lens directly transmits instrument forces, such as sculpting, rotation, and cracking directly to the capsular bag and zonules. In contrast, with chopping it is the phaco tip that braces and immobilizes the nucleus against the incoming mechanical force of the chopper (see Figures 5-12D and 5-12E). The manual forces, generated by one instrument tip pushing against the other, replace the need for ultrasound energy to saw through the nucleus. In addition, these manual instrument forces are directed centripetally inward and away from the zonules, rather than outward toward the capsule. This significant difference in zonular stress is readily appreciated when chopping and sculpting are compared from the Miyake-Apple viewpoint in cadaver eyes.

**Supracapsular Emulsification**

Chopping provides many of the same advantages of so-called supracapsular phaco techniques. With phaco chop, emulsification of nuclear fragments is not performed until they have been elevated out of the capsular bag. This allows nearly all phacoemulsification to be performed centrally in the pupillary plane at a safe distance from both the endothelium and posterior capsule (see Figure 5-13K). The phaco tip does not need to travel beyond the central 2- to 3-mm zone of the pupil, which decreases the chance of inadvertently cutting the iris or capsulorrhexis edge in small pupil
cases. In contrast to supracapsular techniques such as phaco flip, however, the all-or-none requirement of prolapsing the entire nucleus anteriorly through the capsulorrhexis is avoided.

**Decreased Reliance on the Red Reflex**

The increasingly brighter red reflex appearing at the base of the trench during sculpting allows us to judge the depth of the phaco tip and its proximity to the posterior capsule. In contrast, the instrument maneuvers performed during chopping are more tactile and kinesthetic. Because it is not necessary to directly visualize the precise depth of the phaco tip, chopping is advantageous in the presence of a poor red reflex, such as with diminished corneal clarity, smaller pupils, and mature nuclear or cortical cataracts (see Figure 5-12).

In addition to improved surgical efficiency, safety is enhanced by these aforementioned attributes of reduced phaco power, reduced zonular stress, decreased reliance on the red reflex, and the supracapsular and central location of emulsification. These universal advantages that both horizontal and vertical chopping share make them optimal techniques for difficult and complicated cases. The improved ability to handle brunescent nuclei, white cataracts, loose zonules, posterior polar cataracts, crowded anterior chambers, capsulorrhexis tears, and small pupils should be the primary motivation for a divide and conquer surgeon to transition to phaco chop.\(^4,13,14\)

**Horizontal Phaco Chop**

The horizontal chopping technique relies upon compressive force to fracture the nucleus. This exploits natural fracture planes in the lens created by the lamellar orientation of the lens fibers. Hydrodelineation is particularly important for horizontal chopping because it decreases the diameter of the endonucleus that must be peripherally hooked and divided by the chopper.\(^3\) In addition, the soft epinucleus provides a working zone for the horizontal chopper where it can be manipulated peripheral to the endonuclear equator without overly distending or tearing the capsular bag. Finally, the epinuclear shell restrains the posterior capsule from trampolining toward the phaco tip as the final endonuclear fragments are emulsified.

**Horizontal Chop: A Step-by-Step Approach**

**Step 1. Place the Chopper Tip in the Epinuclear Space.** The critical first step is to hook the nuclear equator with the chopper tip within the epinuclear space of the peripheral capsular bag prior to initiating the horizontally directed chop (see Figures 5-12A through 5-12C).\(^3\) Prior to placing the chopper, the central anterior epinucleus should be aspirated with the phaco tip (see Figure 5-12A). This allows one to better visualize and estimate the size of the endonucleus and the amount of separation between the endonucleus and the surrounding capsular bag.

The chopper tip touches and maintains contact with the anterior endonucleus as it travels peripherally beneath the opposing capsulorrhexis edge (see Figure 5-12A). This ensures that the chopper tip stays within the bag as it descends to hook the endonucleus peripherally. Although some surgeons tilt the chopper tip sideways to reduce its profile as it passes underneath the capsular edge, this is generally unnecessary unless the capsulorrhexis diameter is small. Instead, the horizontal chopper tip can remain in a vertical upright orientation because, like an elastic waistband, the capsulorrhexis will stretch to accommodate it without tearing (see Figure 5-12B).

Once it reaches the epinuclear junction, the vertically oriented chopper tip descends into the epinuclear space alongside the edge of the endonucleus (see Figure 5-12C). This step is easiest to perform with a smaller endonucleus surrounded by a large epinucleus. Nudging the nucleus with the chopper confirms that it has hooked the equator and that it is within, rather than outside, the capsular bag. Trypan blue dye improves visualization of the anterior capsule for this step and is a useful teaching aid (see Figures 5-12A through 5-12C).\(^15\)

**Step 2. Impale and Immobilize the Nucleus With the Phaco Tip.** Next, one must deeply impale and immobilize the nucleus with the phaco tip (see Figure 5-12D). The phaco tip should be directed vertically downward and positioned as proximally as possible in order to maximize the amount of nucleus located in the path of the chopper. If the depth of the phaco tip is too shallow, sufficient compression of the central nucleus cannot occur. Once impaled, the phaco tip holds and stabilizes the nucleus with vacuum in foot pedal position 2.

**Step 3. Execute the First Chop.** The chopper tip is drawn directly toward the phaco tip, and upon contact, the two tips are moved directly apart...
**Figure 5-12A.** Horizontal chop of mature white cataract following trypan blue capsular staining. Chang microfinger-style horizontal chopper (Katena, ASICO) maintaining contact with anterior endonuclear surface.

**Figure 5-12B.** The horizontal chopper passes beneath distal capsulorrhexis edge while oriented vertically.

**Figure 5-12C.** The horizontal chopper tip drops into the epinuclear space and hooks the nuclear equator.

**Figure 5-12D.** Phaco tip impales centrally with 320 mmHg vacuum.

**Figure 5-12E.** Chopper cuts toward the fixating phaco tip.

**Figure 5-12F.** Instrument tips separate upon contact to split the nucleus in half.
from each other (see Figures 5-12E and 5-12F). This separating motion occurs along an axis perpendicular to the chopping path and propagates the fracture across the remaining nucleus located behind and beneath the phaco tip. The denser and bulkier the endonucleus, the further the hemisections must be separated in order to cleave the connecting nuclear attachments. Thanks to the elasticity of the capsulorhexis, a wide momentary separation of large heminuclei will not tear the capsular bag. In order for the initial chop to succeed, enough of the central endonucleus must lie within the path of the chopper. Particularly if the anterior epinucleus has not been removed, it is easy to misjudge the depth of the two instrument tips. If the phaco tip is too superficial or too central, or the chopper tip is not kept deep enough throughout the course of the chop, the nucleus will not fracture. Instead, the chopper will only score or scratch the anterior surface. The larger and denser the nucleus is, the more important and more difficult proper positioning of the two instrument tips becomes. A counterproductive but natural tendency to elevate the chopper tip during the chop arises from a fear of perforating the posterior capsule.

The tactile “feel” of the horizontal chop will vary significantly as one proceeds up along the spectrum of nuclear density. A soft nucleus has the consistency of soft ice cream and no resistance is felt as the chopper is moved. With a medium-density nucleus, the chopper encounters slight resistance, indicating that some compression is taking place. This resistance is much greater while chopping a dense nucleus, where the compressive force is followed by a sudden snap as the initial split occurs. To develop sufficient compressive force, one must move the chopper tip directly toward the phaco tip until they touch before commencing the sideways separating motion. Veering the chopper tip to the left as it approaches the phaco tip limits the compressive force and causes the nucleus to swivel.

Step 4. Remove the First Chopped Fragment. Upon completion of the initial chop, the nucleus should be divided in half. After rotating the bisected nucleus 30 to 45 degrees in a clockwise direction, repeating the same steps of hooking the equator and chopping toward the phaco tip creates a small, pie-shaped fragment (see Figures 5-12G through 5-12K). The strong grip afforded by high vacuum facilitates elevation of this first piece out of the bag. Insufficient holding force may be the result of inadequate vacuum settings or failure to completely occlude the tip. Burst mode enhances the phaco tip’s purchase of a firm nuclear piece by better preserving the initial seal around the opening.

Step 5. Chop and Phaco Additional Nuclear Segments. Every subsequent chop is a repetition of these steps, and each wedge-shaped piece is emulsified as soon as it is created. Once half of the capsular bag is vacated, the phaco tip can impale and transport the remaining heminucleus toward the center of the pupil. This allows the horizontal chopper tip to be positioned
under direct visualization against the outer edge of the heminucleus and without having to pass it beneath the anterior capsule.

One advantage of horizontal chopping is that larger nuclear pieces can be subdivided into smaller and smaller fragments. The size of the pieces should be kept proportional to the size of the phaco tip opening. Poor followability and excessive chatter of firm fragments engaged by the phaco tip may indicate that they are too large. Because of their greater overall dimensions, brunescent nuclei will need to be chopped into many more pieces than softer nuclei.

**Step 1. Impale the Nucleus With the Phaco Tip.** Similar to horizontal chop, it is helpful to first aspirate the anterior epinucleus (see Figure 5-13A). Whereas sufficient depth of the chopper tip is the key for horizontal chopping, an adequately deep purchase with the phaco tip is the most crucial factor in vertical chop (see Figure 5-13B). This is because the centrally impaled phaco tip must completely immobilize the nucleus against the incoming sharp chopper tip in order to generate enough shearing force to fracture it. The need for a strong purchase is also why high vacuum and burst mode are more critical for vertical than for horizontal chop.

**Step 2. Incise the Nucleus With the Vertical Chopper, Then Lift With the Phaco Tip.** Whereas the horizontal chopper moves inward from the periphery toward the phaco tip, the vertical chopper is used like a spike descending from above to incise the nucleus just anterior to the centrally impaled phaco tip (see Figure 5-13C). Depressing the sharpened chopper tip downward while simultaneously lifting the nucleus slight upward imparts a shearing force that fractures the nucleus (see Figures 5-13D and 5-12J).
**Figure 5-13A.** Vertical chop. Chang vertical chopper (Katena, ASICO) in profile following aspiration of the anterior epinucleus.

**Figure 5-13B.** Central nucleus is impaled with the phaco tip using burst mode and 399 mmHg vacuum. Note the retraction of the phaco sleeve to permit deeper penetration.

**Figure 5-13C.** Sharp vertical chopper tip is positioned just anterior to the phaco tip prior to incising into the nucleus.

**Figure 5-13D.** As the chopper tip descends into the nucleus, the phaco tip lifts slightly.

**Figure 5-13E.** Further penetration of the chopper tip results in a fracture line.

**Figure 5-13F.** Sideways separation of the tips completes the division of the nucleus.
This contrasts with the compressive force produced by horizontal chopping. After initiating a partial-thickness split, the embedded instrument tips are used to pry the two hemisections apart (see Figure 5-13F). Just as with horizontal chopping, this sideways separation of the instrument tips extends the fracture deeper until the remainder of the nucleus is cleaved in half. The vertically chopped edges appear sharp, like pieces of broken glass, because there is none of the crushing force that characterizes horizontal chop.

Step 3. **Chop All Fragments Before Removing Them.** In horizontal chop, sequentially removing each newly created fragment provides the chopper with increased working space within the capsular bag. In contrast, one need not remove the vertically chopped pieces until the entire nucleus is fragmented. This is because the presence of the adjacent interlocking pieces better stabilizes and immobilizes the section that is being chopped (see Figures 5-13G through 5-13I). In contrast to horizontal chopping, the vertical chopper is never placed peripheral to the equator of the nucleus. Therefore, removing fragments to vacate space within the capsular bag early on provides no real advantage (see Figure 5-13K).

**COMPARING HORIZONTAL AND VERTICAL CHOP—WHICH TECHNIQUE?**

Although I use both techniques with equal frequency, each employs different mechanisms that have complimentary advantages and disadvantages. It is worth learning and utilizing both variations for this reason. Vertical chopping requires less dexterity of the nondominant hand and is therefore easier for most transitioning surgeons to learn. Vertical chopping also requires a nucleus that is brittle enough to be snapped in half, which means that it is ineffective for soft nuclei. The ability of the horizontal chopper tip to easily slice through a soft nucleus instead of fracturing it makes horizontal chopping the method of choice for these cases.

Horizontal chop is also my preference for loose zonule cases, such as traumatic cataracts. Because
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of the oppositely directed, compressive instrument forces, horizontal chop produces the least amount of nucleus movement or tilt. Finally, horizontal chop is more effective for subdividing smaller, mobile nuclear fragments—particularly brunescent ones. Attempting to vertically chop and shear such fragments will often dislodge the small piece instead. Trapping and then crushing fragments between the horizontal chopper and the phaco tip will immobilize and divide them most effectively.

The limitation of horizontal chopping is in its relative inability to transect thicker brunescent nuclei. Indeed, horizontal chopping should never be utilized in the absence of an epinuclear shell since there will be insufficient space in the peripheral bag to accommodate the chopper. Frequently, the horizontally directed path of the chopper is not deep enough to sever the leathery posterior plate of an ultra-brunescent nucleus. If this occurs, the partially chopped pieces will still be connected at the apex, like flower petals. In such cases, one should try to inject a dispersive viscosurgical device (OVD) through one of the incomplete cracks in the posterior plate to distance it from the posterior capsule. Since a dispersive OVD resists aspiration, the surgeon can attempt to carefully phaco through the remaining connecting bridges.

Because vertical chop is more consistently able to fracture the leathery posterior plate, it is well suited for denser nuclei. With an ultra-brunescent lens, the vertical chopper should approach the embedded phaco tip from a diagonal angle. This provides more of a horizontal vector force that pushes the nucleus against the tip, while the downward vertical vector force initiates the fracture. This “diagonal” chop therefore combines the mechanical advantages of both strategies. With denser nuclei, one should also begin by sculpting a small pit or half trench centrally. By entering at the base of the pit, the phaco tip can impale more deeply than would have been possible without this preliminary debulking. Retracting the irrigation sleeve further maximizes penetration. One should later switch to horizontal chopping for subdividing brunescent fragments into smaller pieces. This will improve followability and reduce endothelial cell loss due to chatter and particle turbulence at the phaco tip.

**Stepwise Game Plan for Learning Horizontal Chop**

Of the two different techniques, the greater requirement for bimanual dexterity with the chopper makes horizontal chopping more difficult to learn. The most difficult steps are the initial ones—the first chop across the entire unsculpted diameter of the nucleus and removal of the first segment. Each subsequent step becomes progressively easier as additional space is vacated within the capsular bag. Logically, the safest strategy would allow surgeons to learn the steps in the reverse order, starting with the easiest maneuvers first. In the proposed game plan, the component skills can be isolated, developed, and rehearsed while performing divide and conquer or stop and chop cases. These principles and the same stepwise learning progression are equally applicable to mastering vertical phaco chop.

**Figure 5-13J.** With high vacuum (400 mmHg) grip of one segment, the two instrument tips pry the pieces apart. The sharp edges of the fragments result from a shearing force.

**Figure 5-13K.** After vertically chopping the entire nucleus into multiple pieces, the fragments are elevated out of the capsular bag.
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TRANSITIONING TO PHACO CHOP:
A STEP-BY-STEP APPROACH

Step 1. Practice Using a Chopper as the Second Instrument for Divide and Conquer. The larger profile of the chopper tip is both unfamiliar and intimidating for those accustomed to a spatula-like second instrument. In chopping, one must be able to manipulate the chopper shaft and tip without deforming the side-port incision. In preparation for chopping, one should become adept with using the chopper as the second instrument during divide and conquer.

Step 2. Use the Chopper to Move and Manipulate Nuclear Quadrants. Two additional exercises can assist in developing the necessary horizontal chopper skills. When performing divide and conquer, use the microfinger-shaped chopper to tumble the quadrants out of the capsular bag. This provides practice with using the chopper to hook the equator of the endonucleus, and this skill is easier to learn with mobile quadrants that are not tightly wedged within the capsular bag. This identical maneuver can later be used to tumble chopped fragments out of the bag if necessary. Explore the capsular bag with the horizontal chopper following removal of the endonucleus. Surgeons are usually surprised at how deeply the chopper tip must be lowered in order to contact the central posterior capsule (Figure 5-14). Visualizing and understanding this spatial relationship is invaluable in overcoming the fear of lacerating the posterior capsule with the chopper.

Step 3. Practice Chopping the Quadrants. In divide and conquer, the first heminucleus is further divided into two quadrants that are elevated and emulsified in the pupillary plane. Take the opportunity to chop each quadrant into smaller pieces. By holding the quadrant away from the anterior or posterior capsule in the center of the pupil, one can visualize in three dimensions how best to orient the horizontal chopper in order to split the nucleus. After removing the first two quadrants, carry the remaining heminucleus to the center of the pupil where it can be chopped without having to pass the chopper tip peripherally beneath the anterior capsule. Chopping these larger mobile segments also allows the surgeon to experience the tactile feedback of chopping through nuclei of varying density.

Step 4. Master Stop and Chop. After sculpting a groove and cracking the nucleus in half, the chopper must be passed peripherally beneath the anterior capsule to hook the equator of the heminucleus. This is considerably easier than chopping the entire unsculpted endonucleus for three reasons. First, one is chopping across a shorter distance (the radius instead of the diameter). Second, by placing the phaco tip into the trough and up against the side of the heminucleus, proper depth and positioning of the phaco tip are ensured. Finally, the trough provides some vacant space, which facilitates removal of the first chopped fragment.

Step 5. Next Master Partial Stop and Chop. The next intermediate training step is what this author calls "partial" stop and chop. After sculpting one half of a groove, the nucleus is rotated for 180 degrees and the remaining unsculpted portion is chopped in the following manner. The phaco tip is impaled into the remaining ledge of nucleus where the groove ended centrally. The partial groove ensures that the phaco tip will be impaled at an appropriately deep level. One can draw the nucleus toward the phaco incision using a high vacuum purchase. This often exposes the distal equator of the endonucleus, which can be hooked with the horizontal chopper under direct visualization. The ensuing full-thickness chop is easier thanks to

Figure 5-14. After removing the endonucleus, the horizontal chopper is used to explore the capsular bag and palpate the posterior epinucleus. Note the depth of the posterior capsule as indicated by the defocus of the iris plane.
the partial groove having already thinned out
the proximal nucleus (like a scored aspirin tab-
let). Unlike Dewey’s original description, this
“partial” stop and chop technique emphasizes
the key skill of hooking the nuclear equator
with the chopper, which alternatively can be
performed prior to impaling the nucleus with
the phaco tip.\textsuperscript{15}

Step 6. \textbf{Proceed to “Pure” Horizontal Chop.} After
mastering “classic” and “partial” stop and chop,
one is now ready to progress to pure horizontal
chopping in which the entire nuclear diameter
is cleaved in half without any sculpting (see
Figures 5-12A through 5-12F).\textsuperscript{3} For horizontal
chop, softer and smaller endonuclei should be
mastered before progressing to firmer and larg-
er endonuclei. Horizontal chopping in particu-
lar requires significant bimanual dexterity, and
the chopper must be maneuvered like a row-
boat oar with the side-port incision serving as
the stationary fulcrum. Just like a golfer prac-
tices swings, a helpful exercise is to perform
“practicing” chops in the anterior chamber above
the nucleus prior to initiating the first chop.\textsuperscript{15}
This allows the surgeon to verify proper orien-
tation of the chopper tip and shaft as he or she
practices the full sequence of motions. If the
surgeon finds that the chopper is distorting or
displacing the incision or that the hand posi-
tion is awkward or uncomfortable, it is better
to correct the problem at this point rather than
after the chopper is inside the capsular bag.

**Summary**

Horizontal and vertical chopping are variations that
rely upon different mechanisms to provide complemen-
tary advantages and common benefits. Mastering both
methods affords surgeons greater flexibility in dealing
with the wide range of nuclear densities and other sur-
gical variables.\textsuperscript{3,17} With dense lenses, one may employ
both techniques during the same case.\textsuperscript{17} Transitioning
surgeons should consider learning vertical chopping
first. In addition to increasing surgical efficiency for
routine cases, chopping provides an increased margin
of safety for complicated cases (see Figure 5-12).\textsuperscript{3,13,14}

A more detailed discussion of chopping tech-
niques is available in the author’s book \textit{Phaco Chop:
Mastering Techniques, Optimizing Technology, and Avoiding
Complications},\textsuperscript{7} from which much of this content was
excerpted.

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Recent advances with the AMO (Santa Ana, CA) WhiteStar “micro-pulsed” technology markedly reduce the risk of thermal injury to the eye and allow today’s surgeon to perform microincisional bimanual phacoemulsification. In our experience, separating the inflow from the outflow in a phaco procedure has several advantages. These include superior control of the globe, enhanced cortical cleaving hydrodissection, use of irrigation fluid as an instrument to mobilize material, and reduced effective phaco time.

**Part D: Bimanual Vertical Chop Technique**

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BIMANUAL VERTICAL CHOP: A STEP-BY-STEP APPROACH

**Step 1. Create Microincisions Sized Precisely to Match the Phaco Instrumentation.** To begin the bimanual vertical chop technique, start with a paracentesis type of incision to the left and the right, constructed with a trapezoidal blade. The blade selected should create an incision that measures 1.2 mm internally, precisely the size required for 20-gauge instrumentation used for bimanual microincision phacoemulsification. Fill the anterior chamber with a dispersive viscoelastic that will remain in the eye during our high-flow, high-vacuum chop technique.

**Step 2. Perform Capsulorrhexis Using Microincision Forceps.** The capsulorrhexis may begin with either a linear central capsular tear created with a capsulotomy needle or with a simple pinch of the central capsule, using microincisional forceps. These forceps are then used to perform a continuous curvilinear capsulotomy through the small side-port incisions on the right or the left. The microincision forceps (MST, Redmond, WA), designed to open and close through a 1.2-mm incision, allow excellent control of the capsulorrhexis; additionally, the small incisions facilitate control of the capsulorrhexis because the viscoelastic does not exit the eye. Loss of chamber stability, caused by the outflow of viscoelastic material through a larger standard phaco incision, can make the creation of a round central capsulorrhexis more difficult. One of the advantages of microincision techniques is that the chamber remains very stable during the completion of the capsulorrhexis. This allows us to better control the size, diameter, and position of our capsulorrhexis.

**Step 3. Hydrodissect and Hydrodelineate the Nucleus.** Cortical cleaving hydrodissection is performed by tenting up the anterior capsule and injecting balanced salt solution under the rim of the capsule. A fluid wave then advances completely across the posterior capsule. Frequently, the fluid wave is trapped temporarily between the lens and the posterior capsule, which causes the lens to prolapse anteriorly. Repositioning the lens by pushing posteriorly with the cannula in the center decompresses the fluid that is trapped, forcing it around the equator and lysing the corticocapsular connections. The lens is then rotated to make sure it is free. Hydrodelineation can be carried out by embedding the tip of the cannula in the center of the lens and advancing until the resistance of the endonucleus is encountered. A slight to-and-fro motion of the cannula will create a small space into which balanced salt solution is injected. The fluid flows between the endonucleus and the epinucleus, forming the golden ring seen in Figure 5-15.
Step 4. **Embed the Nucleus With the Phaco Needle; Stabilize the Nucleus With the Vertical Irrigating Chopper, Then Lift With the Phaco Needle to Create a Vertical Chop.** The phaco needle is then embedded proximally with high vacuum and 40% power (Figure 5-16). A vertical irrigating chopper is then used to split the nucleus in two pieces. As vacuum builds to occlusion, the endonucleus is held firmly by the phaco needle. At the moment occlusion is reached, the aspiration flow rate drops to zero. Then move into foot position two so that high vacuum is maintained and the power goes to zero (see Figure 5-15). The blade of the
irrigating vertical chopper is brought down just distal to the phaco tip as the phaco tip is lifted slightly. As a full-thickness cleavage plane develops, dividing the nucleus in two, separate the chopper and the phaco needle to ensure a complete chop (Figure 5-17).

**Step 5. Chop and Phaco Additional Nuclear Segments.** The lens can then be rotated with the irrigating chopper so that the first heminucleus can be chopped. If there is a disparity in size, the larger half is moved distally and chopped next. The phaco needle is now embedded to the right using high vacuum and low levels of power. The surgeon may then either make additional chops or, alternatively, a quadrantsized piece may be chopped off and consumed (Figure 5-18). The remaining quadrant of the first heminucleus may then be impaled with the phaco tip and aspirated (Figure 5-19).

To address the second half of the nucleus, it is first rotated with the irrigating chopper so that it is in the distal capsule. The phaco needle is embedded in the smaller heminucleus and it is subdivided with the irrigating chopper, again using high vacuum and low levels of power (Figure 5-20). As the final quadrant is grasped and pulled centrally for aspiration, the sharp blade of the irrigating chopper is turned sideways as a safety precaution (Figure 5-21).

**Step 6. Aspirate the Epinucleus.** To address the epinucleus, reduce phaco settings, turning down both the vacuum and flow rate. The rim of the epinucleus is then trimmed, disallowing the epinucleus from flipping into the phaco needle with the stream of irrigation fluid or the irrigating chopper itself. The advantage of the trimming procedure lies in the aspiration of cortical material from behind the epinuclear shell. In most cases, this step eliminates the need for irrigation/aspiration prior to IOL insertion. Once three quadrants of the epinuclear shell have been rotated and trimmed, the final quadrant is used to flip the epinuclear bowl into the phaco needle (Figure 5-22). Following aspiration of the epinucleus the capsule is often entirely clean of cortex (Figure 5-23).
Step 7. **Enlarge the Microincision or Create a New Incision for IOL Implantation.** The incision for the lens is constructed with the differentially beveled 3D Blade (Rhein Medical, Tampa, FL), which reproducibly creates a 2.5-mm incision at the shoulders. The relatively larger incision (approximately 2.5 mm) that is constructed for IOL insertion seals quite nicely because it has been only minimally disturbed. We always perform stromal hydration at all the incisions and perform a Seidel test at the conclusion of the case. Careful attention to sealing clear corneal incisions may be critical for the prevention of postoperative infection.

**Summary**

Bimanual phaco with a vertical chop technique allows efficient lens extraction with rapid visual rehabilitation. Tangible benefits of separating inflow from outflow include enhanced cortical cleaving hydrodissection, use of irrigation fluid as an instrument to mobilize material, and reduced effective phaco time.