

## **Phaco Chop Techniques: Comparing and Integrating Horizontal and Vertical Chopping**

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Both horizontal and vertical chop accomplish manual fragmentation of the nucleus. Although this is done in different ways, both methods offer important universal benefits:

- reduced phaco power and time
- reduced stress on the zonules
- limitation of most ultrasound and vacuum to the supracapsular, central pupillary zone
- reduced reliance on the red reflex due to the more kinesthetic nature of the procedure.

This handout will review the principles of each method, and the relative advantages and disadvantages of these two contrasting strategies. Finally, the concept of combining the horizontal and vertical vectors into “diagonal” chopping will be discussed as a strategy for brunescient nuclei.

### **Horizontal Phaco Chop**

Kunihiro Nagahara’s original technique represents the classic horizontal chopping method. All subsequent variations of horizontal chop make use of the same principle whereby the chopper hooks the endonucleus inside the capsular bag and initially chops centrally toward the fixating phaco tip in the horizontal plane.

### **Stop and Chop**

Paul Koch’s “Stop and Chop” method is a hybrid of divide-and-conquer and horizontal chopping. His technique begins with sculpting a traditional deep, central groove in order to crack the nucleus in half. One then *stops* the divide-and-conquer method, and *chops* the hemi-nuclei. Although the Koch method utilizes some horizontal chopping, this author coined the term “Non-stop Chop” to differentiate and designate pure chopping techniques that eliminate all sculpting.

The advantage of “Stop and Chop” is that it avoids the difficult first chop. As a result, one chops only across the radius, rather than the full diameter of the nucleus. Second, unlike with the initial “non-stop” chop, the phaco tip can be positioned within the trough up against the side of the hemi-nucleus that is to be cleaved. Finally, the presence of the trough facilitates removal of the first fragment because it is not tightly wedged inside the capsular bag.

While chopping the hemi-nuclei does partially reduce total ultrasound energy, the majority of sculpting during divide-and-conquer is used to create the first groove. Thus, Stop and Chop does not provide the full benefits of non-stop chopping listed above. The

remainder of this discussion will focus on pure, non-stop horizontal or vertical chop techniques.

## **Horizontal Chop Technique**

The horizontal chopping technique relies on compressive force to fracture the nucleus. This takes advantage of a natural fracture plane in the lens created by the lamellar orientation of the lens fibers. The key initial step is to use the chopper tip to hook the nuclear equator within the epinuclear space of the peripheral capsular bag prior to initiating the horizontally directed chop. Whether one first positions the chopper or the phaco tip is a matter of personal preference. Because chopper placement is the most difficult and intimidating step, many transitioning surgeons find it easier to first position the chopper prior to impaling the nucleus with the phaco tip.

### **Initial placement of the chopper tip**

Following the capsulorrhexis and hydrodissection, hydrodelineation should be performed in order to define and separate the epinuclear shell. This is particularly important for horizontal chopping, because it decreases the diameter of the endonucleus that must be peripherally hooked and divided by the chopper<sup>2</sup>. In addition, the separated soft epinucleus provides a working zone for the chopper. It is because of this epinuclear space that the horizontal chopper can be placed and manipulated peripheral to the endonuclear equator without overly distending and perforating the peripheral capsular bag. Later, after the endonucleus has been evacuated, the epinuclear shell can be flipped and aspirated as the final step.

Prior to placing the chopper, the surgeon should first aspirate the central anterior epinucleus with the phaco tip in order 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 the central endonucleus, and maintains contact as the surgeon passes it peripherally beneath the opposing capsulorrhexis edge. This ensures that the tip stays inside the bag as it descends and hooks 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 not necessary unless the capsulorrhexis diameter is small or the endonucleus is very large. The elongated horizontal chopper tip can be kept in an upright and vertical orientation because the capsulorrhexis will stretch like an elastic waistband without tearing.

Once it reaches the epi/endonuclear junction, the chopper tip must be vertically oriented as it descends into the epinuclear space alongside the edge of the endonucleus. If it has not traveled peripherally enough, lowering the chopper will depress, rather than hook the nucleus equator. The smaller the endonucleus, the larger the epinucleus, and the easier this step will be. Once in position, slightly nudging the nucleus with the chopper confirms that it is alongside the equator, and that it is within, rather than outside the bag. Trypan blue capsular dye improves visualization of the anterior capsule for this step and is a useful teaching adjunct.

## Executing the first chop

Next, the surgeon deeply impales the nucleus with the phaco tip. 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<sup>2</sup>. 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. Although not as essential for horizontal chopping as with vertical chop, high vacuum improves the holding power, which keeps the nucleus from wobbling or spinning during the chop.

The surgeon pulls the chopper tip directly toward the phaco tip, and upon contact, moves the two tips directly apart from each other. This separating motion occurs along an axis perpendicular to the chopping path, and propagates the fracture across the remaining nucleus located behind the phaco tip. The denser and bulkier the endonucleus, the further the hemi-sections must be separated in order to cleave the remaining nuclear attachments. Thanks to the elasticity of the capsulorrhexis, even a wide momentary separation of large nuclear hemi-sections will not tear the capsular bag.

In order for the initial chop to succeed, a substantial amount 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 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 difficult proper positioning of the two instrument tips becomes. Fear of perforating the posterior capsule creates a counterproductive, but natural tendency to elevate the chopper tip during the chop .

The ergonomics and tactile “feel” of the horizontal chop will vary significantly as one advances along the nuclear density scale. A soft nucleus has the consistency of soft ice cream. Simply pressing the phaco tip into the nucleus, without either vacuum or ultrasound, can embed it deeply enough. In addition, no resistance is felt as the chopper is moved. With a medium density nucleus, the chopper encounters slight resistance as the chopping motion is initiated. This indicates that the desired compression is taking place.

This resistance becomes much greater when chopping denser 3-4 + nucleus. As the chopper presses toward the phaco tip, the surgeon recognizes that the nucleus is literally being squeezed in between the two instrument tips. This is followed by a sudden snap as the initial split occurs. Like the forces leading up to an earthquake, the compressive force builds until the nucleus suddenly fractures along its natural cleavage plane, releasing the stored energy. With denser nuclei, the compressive force is evidenced by whitening of the nuclear tissue on either side of the chopper track. Correspondingly more ultrasound power must be used in order for the phaco tip to be able to impale denser nuclei. Deeper

penetration can be achieved by retracting the irrigation sleeve further to expose more of the metal tip.

Another key to developing sufficient compressive force is to move the chopper tip directly toward the phaco tip until they touch before commencing the sideways separating motion. As the instrument tips near each other, some surgeons tend to veer the chopper tip to the left so that the instruments never actually touch. While this may work for softer nuclei, this limits the compressive force and may thwart fracturing a dense lens. This motion will also cause the nucleus to swivel and turn, which also undermines effective propagation of the fracture.

### **Removing the first chopped fragment**

Upon completion of the initial chop, the nucleus should be completely fractured in half. If not, it can be rotated so that a second attempt can be made in a new area. The surgeon next uses the chopper tip to rotate the bisected nucleus 30-45 degrees in a clockwise direction, and the opposite heminucleus is impaled with the phaco tip in a central location. If there is difficulty in occluding the phaco tip, its bevel may need to be aligned parallel to and facing the surface it is about to impale. Repeating the same steps of hooking the equator and chopping toward the phaco tip will now create a small, pie-shaped fragment.

The strong holding force afforded by high vacuum will usually facilitate elevation of this first piece out of the bag. With firmer nuclei, this first piece can be difficult to remove because the pieces may interlock within the capsular bag like jigsaw puzzle pieces. In this case, one should attempt to make the first piece smaller than usual. Insufficient holding force may be the result of inadequate vacuum settings or failure to completely occlude the tip. With brunescient lenses, continuous phaco power tends to core out the tissue alongside the penetrating phaco needle, which breaks the occlusion seal. Single burst mode can enhance the phaco tip's purchase of a firm nuclear piece by better preserving the initial seal around the opening.

Smaller and softer endonuclear pieces can also be difficult to extract because they adhere more to the epinucleus and also tend to crumble. If portions of the fragment break off with attempted aspiration, the phaco tip will need to be advanced closer and closer to the peripheral capsule in order to become re-occluded. In this case, it may be safer to manually tumble the piece out using the chopper. The same maneuver of hooking the endonuclear equator with the horizontal chopper tip is performed. However, instead of immobilizing the piece with the phaco tip, it is allowed to tumble forward into the center of the papillary plane. As the pie-shaped piece somersaults forward, it is pivoting upon its apex. This prevents even a sharp apical fragment tip from coming near the posterior capsule.

Each subsequent chop is a repetition of these same steps. Because of the need to hook the equator during every horizontal chop, it is advisable to remove each wedge-shaped piece as soon as it is created. Once half of the capsular bag is vacated, the phaco tip can impale

and carry the remaining hemi-nucleus toward the center of the pupil. This allows the horizontal chopper tip to be positioned alongside the outer edge under direct visualization, and without having to pass it beneath the anterior capsule. For obvious reasons, the initial chop is the most difficult to execute, and the first fragment is the most difficult to remove. However, utilizing this technique means that if the nucleus is divided into six pieces, the chopper tip passes underneath the capsulorrhexis for only three of the chops.

One advantage of horizontal chopping, in particular, is that larger nuclear pieces can be repeatedly subdivided into smaller and smaller fragments. The size of the pieces should be kept proportional to the size of the phaco tip opening. For example, just as one cuts a steak into smaller portions for a child's mouth, the nucleus should be chopped into smaller pieces if one is using a smaller diameter 20-gauge phaco tip. 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, brunescient nuclei will need to be chopped many more times than soft nuclei.

### **Vertical Phaco Chop**

Hideharu Fukasaku introduced his technique of "Phaco Snap and Split" at the 1995 ASCRS meeting. Vladimir Pfeifer's "Phaco Crack" method of chopping was introduced at the 1996 ASCRS meeting and is a similar technique. This variation was renamed "Phaco Quick Chop" by David Dillman. Abhay Vasavada published his "Stop, chop, chop, and stuff" technique in 1996, and Steve Arshinoff published his "Phaco slice and separate" method in 1999. These are all examples of **vertical** chopping because when the chop is first initiated, the instruments move toward each other in the vertical plane. Whereas the horizontal chopper moves inward from the periphery toward the phaco tip, the vertical chopper is used like a spike or blade from above to incise downward into the nucleus just anterior to the centrally impaled phaco tip.

The most important step in vertical chop is to bury the phaco tip as deeply into the center of the endonucleus as possible. Depressing the sharp vertical chopper tip downward, while simultaneously lifting the nucleus slightly upward imparts a shearing force that fractures the nucleus. This is in contrast to the compressive force produced by horizontal chopping. After initiating a partial thickness split, the embedded instrument tips are used to pry the two hemi-sections apart. Just as with horizontal chopping, this sideways separation of the instrument tips extends the fracture deeper and deeper until the remainder of the nucleus is cleaved in half.

Whereas adequate depth of the chopper tip is the key to horizontal chop, the depth of the phaco tip is the most crucial factor in vertical chop. This is because the phaco tip must completely immobilize the nucleus against the incoming sharp chopper tip in order to generate enough shearing force to fracture it. This need for a strong purchase is also why high vacuum and single burst mode are more critical for vertical than for horizontal chop.

Slightly elevating the impaled phaco tip also prevents the descending chopper tip from pushing a firm nucleus against the posterior capsule. For a brunescent lens, the phaco tip must lollipop into the nucleus as deeply as possible in order to be able to lift it upward. Like spearing a potato with a fork, the phaco tip must aim for the center of the nucleus. Too superficial a tip location will provide insufficient support and leverage.

Much like a chisel would be used with a block of ice or granite, the vertical chopper tip can be used to cleave the nucleus into multiple pieces of variable size. The vertically chopped edges may appear sharp, like pieces of broken glass, because there is none of the crushing force that characterizes horizontal chop involved. The sharp vertical chopper tip generally stays central to the capsulorrhexis. Thus, in contrast to horizontal chopping, it is always visualized and does not pass underneath the anterior capsule or behind the iris.

When learning each of the two different chopping techniques, one should position the more important instrument first. For horizontal chop, this means hooking the nucleus with the chopper tip first. With vertical chop, the nucleus should first be impaled with the phaco tip. 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. In addition, since the vertical chopper is never placed peripheral to the nucleus equator, vacating space within the capsular bag early on provides no real advantage.

### **Comparing Horizontal and Vertical Chop – Which Technique?**

Although the author uses both techniques with equal frequency, they employ different mechanisms that have complimentary advantages and disadvantages. It is worth learning and utilizing both variations for this reason.

Vertical chopping requires a nucleus that is brittle enough to be snapped in half. A lack of firmness explains the difficulty of performing vertical chop or divide-and-conquer techniques in soft nuclei. For example, in order to crack a grooved nucleus in half, there must be sufficient density to the nucleus remaining on either side of the trough. This is why one can snap a cracker in half, but not a piece of bread. The ability of the chopper tip to easily slice through a soft nucleus instead of fracturing it makes horizontal chopping an excellent method for these cases.

Horizontal chopping is also more advantageous for eyes with deeper than average anterior chambers, such as with high myopes or post-vitrectomy cases. In such eyes, one must take measures to prevent or reverse lens-iris diaphragm retro-displacement syndrome (LIDRS). The momentary pupillary block can be reversed or prevented by lifting the pupil edge off of the anterior capsule, so that irrigation fluid can flow into the posterior chamber. Nevertheless, the infusion force sometimes displaces the nucleus more posteriorly so that the phaco tip must approach it from a steeper angle. This can make sculpting a trough more difficult to perform and visualize. In addition, the vertical angle

of the phaco tip makes it harder to lift and support the nucleus from behind for vertical chopping. In contrast, the maneuverable horizontal chopper is easily advanced back far enough to hook the lens equator. Even with a more vertical orientation, the phaco tip can still brace the nucleus against the incoming horizontal chopping motion. The difficulty of securing a strong purchase of the nucleus with the phaco tip because of the steeper angle of approach is less problematic for horizontal than for vertical chop.

Horizontal chop is this author's preference for weak zonule cases, such as traumatic cataracts. Because of the inwardly directed, compressive instrument forces, horizontal chop produces the least amount of nucleus movement or tilt. This characteristic is invaluable when any nuclear tipping or displacement could tear the weakened zonules.

Finally, horizontal chop is more effective for subdividing smaller, mobile nuclear fragments – particularly if they are brunescient. Small mobile pieces are hard to fixate adequately for vertical chopping, because there is insufficient mass for the phaco tip to impale. Attempting to vertically shear such fragments with a chopper will often dislodge the small piece instead. Trapping and then crushing the fragment between the horizontal chopper and the phaco tip will immobilize and divide it most effectively.

The limitation of horizontal chopping is in its relative inability to transect thicker, brunescient nuclei. First, 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. In this situation, forcing the chopper tip into a tightly packed capsular bag risks tearing the capsulorrhexis. Second, the horizontally directed path of the chopper may not be deep enough to sever the leathery posterior plate of an ultra-brunescient nucleus. If this occurs, the pieces may seem freely separated at first, but are actually connected at their apex, like the petals of a flower. In such cases, it is best to try to inject a dispersive viscoelastic through one of the incomplete cracks in the posterior plate to distance it from the posterior capsule. Since a dispersive viscoelastic resists aspiration, the surgeon can attempt to carefully phaco through the remaining connecting bridges that have been visco-elevated away from the posterior capsule.

### **Vertical and Diagonal Chop for Brunescient Nuclei**

Because vertical chop is more consistently able to fracture the leathery posterior plate, it is this author's preference for denser nuclei. Returning to the log analogy, the axe blade is driven into an upright log, but can only penetrate part way. Prying the two hemi-sections apart is necessary in order to extend the split through the remainder of the log. The same is true for the initial horizontal or vertical phaco chop since it is impossible to position the phaco tip externally up against the posterior-most pole of the nucleus. Once the partial split is made by the chopper, it is the sideways separation of the instrument tips that extends the fracture along the natural lamellar cleavage plane through the remaining nucleus. In horizontal chop, this propagating fracture continues horizontally towards the surgeon, but it will not tend to advance further and further posteriorly. In contrast, with vertical chop, as the two halves are pried apart, the advancing fracture propagates downward in the vertical plane until it eventually transects the posterior-most layer.

With an ultra-brunescent lens, one can also slightly alter the angle of the vertical chop. Instead of incising straight down like a karate chop striking a board, the vertical chopper should approach the embedded phaco tip more diagonally. This provides more of a horizontal vector that pushes the nucleus against the phaco tip, while the vertical vector initiates the downward fracture. This “diagonal” chop therefore combines the mechanical advantages of both strategies.

While it is possible to vertically chop a thick brunescent nucleus without doing so, it is generally easier to begin by sculpting a small, deep pit centrally. By starting at the bottom of the pit, the phaco tip can be impaled more deeply than would have been possible without this preliminary de-bulking. Retracting the irrigation sleeve and using single burst mode further maximizes penetration of the phaco tip. Because of the steep angle of the phaco tip, maximal penetration advances the tip into the peripheral nucleus. Initiating the vertical chop in this thinner region better enables it to transect the posterior-most layer of an ultra-brunescent lens. However, this means that the chopper tip must pass peripherally beneath the capsulorrhexis before incising diagonally toward the phaco tip. Because of the poor red reflex, capsular dye helps in visualizing the anterior capsule for this purpose.

Once the diagonal chop commences, the hemi-sections are manually pried apart until the propagating fracture breaks through the leathery posterior plate in the periphery. Each time the separating motion is repeated, the chopper tip is repositioned more and more centrally. The posterior fissure will steadily unzip toward and across the central axis of the posterior plate. One can then rotate the nucleus 180 degrees before repeating the same peripherally located diagonal chop. The nucleus will be completely bisected once the two oppositely initiated fractures connect in the center.

The large hemi-nuclei are diagonally chopped into multiple fragments. As the loosened brunescent pieces are elevated out of the capsular bag, one often finds that they are still quite sizable. As mentioned earlier, horizontal chopping is more effective for subdividing mobile brunescent fragments. This provides another reason to master both chopping variations. Not only do they allow us to better handle the entire spectrum of nuclear density, but also both techniques can be employed for different stages of the same challenging case.

### **Comparative Risk of Complications**

Improper technique can lead to complications with either chopping method. If a firm nucleus is not well supported by the phaco tip, downward force from a vertical chopper can push the nucleus against the posterior capsule. This can displace the bag enough to rupture the zonules. If one loses track of the anterior capsule location, one could perforate it with the vertical chopper. Finally, excessive surge during removal of the final nuclear fragment or epinucleus could cause forward trampolining of the posterior capsule into the sharp vertical chopper tip.

Likewise, because the horizontal chopper tip is not visualized once it passes behind the iris, erroneous placement outside of the bag could occur. If the chop is initiated with the horizontal chopper placed outside the capsular bag, a large zonular dialysis will result. Finally, as stated earlier, the absence of an epinucleus is a contraindication to placing a horizontal chopper tip in the peripheral capsular space.

Too small of a capsulorrhexis diameter increases the risk of tearing the continuous edge with the chopper tip or shaft, and the surgeon must be very cognizant of these risks. One should develop the habit of momentarily taking a mental “snapshot” of the capsulorrhexis shape and diameter once it is completed. This is because following hydrodissection and nuclear rotation, the capsulorrhexis contour will no longer be visible, and the surgeon must remember its location. This is another reason why trypan blue capsular dye is helpful for transitioning surgeons.

### **Comparison of Horizontal and Vertical Choppers**

The plethora of different chopper designs is particularly confusing for the transitioning surgeon. This area can be simplified by categorizing these many variants as either horizontal or vertical choppers. Since each works in dissimilar ways, their design principles are quite different.

Horizontal choppers usually feature an elongated, but blunt-ended tip. A tip length of 1.5 to 2.0 mm length is necessary in order to transect thicker nuclei, and the inner cutting surface of the tip may sometimes be sharpened for this purpose of incising denser lens material. The very end of the tip is always dull, to diminish the risk of posterior capsule perforation. Many horizontal choppers have a simple right-angle tip design. However, this shape does not conform as well to the natural, curved contour of the lens equator and peripheral capsular bag. The author prefers the curved shape of an elongated microfinger because it can wrap snugly around the lens equator without distending or stretching the peripheral fornices of the capsular bag. The microfinger design also allows one to cup the nucleus equator so that it can't slip away as the compression begins.

Vertical choppers feature a shorter tip that has a sharpened point in order to penetrate denser nuclei. If the tip is too dull, it will tend to displace the nucleus off of the phaco tip rather than incising into it. In contrast to horizontal choppers, the length of the vertical chopper tip is shorter because it never encompasses one side of the nuclear segment. The three dimensional motions required of the chopper are much simpler with vertical chop. Compared to horizontal chop, the chopper tip is not placed as peripherally and simply incises downward into the nuclear mass. The tip is always kept vertically oriented and is always visible until it descends into the nucleus. In contrast, the horizontal chopper tip is much longer, must execute a far more difficult set of motions, must pass underneath the capsulorrhexis, and must be blindly positioned behind the peripheral iris before initiating the chop.

Conceptually, the horizontal chopper's shape imitates the surgeon's left arm, hand, and finger. The long extended handle is the "upper arm". The first bend is the "elbow". The next shorter, straight extension is the "forearm". The next bend is the "wrist". Finally, in the case of the microfinger-shaped Chang horizontal chopper, the 1.75 mm long tip is curved like one's left index "finger".

The side-port incision should always serve as the motionless fulcrum for the chopper shaft. In order to avoid displacing or distorting the side-port incision, somewhat counter-intuitive movements must be made with the horizontal chopper in particular. Assuming a right-handed surgeon operating temporally in a right eye, the chopper should be introduced through a paracentesis located 45 degrees to the left of the phaco tip, which is positioned at the 9 o'clock location for a right eye with a temporal corneal incision. To move the chopper tip to the 3 o'clock nasal edge of the capsulorhexis, both the chopper elbow and the surgeon's left elbow must be moved to the right. To drop the chopper tip down alongside the endonuclear equator, both the chopper elbow and the surgeon's elbow must be slightly elevated.

As the chopper is brought through the nucleus directly toward the impaled phaco tip, the chopper elbow should be gradually elevated and moved to the left. This causes the chopper tip's path to deepen slightly as it transects the center of the nucleus. Finally, the surgeon's fingers can be used to roll or rotate the handle to change the orientation of the tip. Although awkward at first, these three-dimensionally coordinated motions will become second nature with time. Until then, one should practice using the horizontal chopper for divide-and-conquer, and perform practice chops in the anterior chamber, as will be described in the next chapter.

In summary, horizontal and vertical chopping are variations that rely upon different mechanisms to provide complementary advantages and common benefits. The Chang double ended combination choppers were designed to provide both a horizontal and a vertical chopper on a single instrument. This reflects the author's regular deployment of both techniques according to nuclear density, and together during the same case with the densest nuclei. The blunt tipped Chang horizontal chopper is an elongated microfinger, with a thinner tip profile to facilitate cutting. At the opposite end, the Chang vertical chopper is like a Sinskey hook with a sharp point to facilitate penetration into brunescient nuclear material. One can switch from using this sharp vertical chopper to the horizontal chopper as nuclear fragments are brought into the supracapsular space. This enables horizontal sub-chopping of large fragments and protects the posterior capsule from ever contacting the sharper vertical tip as the epinucleus is aspirated. The finger shaped tip can also be used to engage and rotate the epinucleus counterclockwise with backhanded motions. The Seibel vertical chopper tip has the profile of a rounded blade. While the latter can vertically incise denser nuclear mass, there is no sharp point to come into contact with the posterior capsule. For this reason, transitioning surgeons often prefer the Chang horizontal/Seibel vertical chopper as their first combination chopper.

## **Transitioning to Phaco Chop – Pearls and Pitfalls**

With both horizontal and vertical chop, the most challenging maneuvers are performed with the non-dominant hand, which must display greater dexterity than is required for divide-and-conquer. For instance, inadvertently distorting the side-port incision with the chopper shaft will impede proper movement of the chopper tip and may compromise visibility and chamber stability. This bimanual skill set is the main reason why chopping is more difficult to master than divide-and-conquer, and why the learning curve is often much longer than surgeons expect.

Being an advanced phaco technique, phaco chop should not be attempted until one has already mastered the divide-and-conquer method. 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.

In divide-and-conquer the second instrument is primarily used while in foot pedal position 1. The surgeon alternates between using the phaco tip (sculpting) and the second instrument (rotating). The only time they are used simultaneously is for the bimanual cracking maneuver, when neither ultrasound nor vacuum is engaged. Thus, in the divide-and-conquer method, the phaco tip is much more active than the spatula and there is far less reliance on bimanual dexterity and timing. In contrast, chopping requires synchronized bimanual instrument maneuvers that are simultaneously coordinated with foot pedal positions 2 and 3.

### ***Which method to learn first?***

While the authors advocate learning both horizontal and vertical chop for maximum versatility, there is no clear-cut consensus regarding which technique to learn first. For many surgeons, vertical chop is the easier technique to learn for two reasons. First, one is always able to visualize the vertical chopper tip because there is no need to place it blindly behind the iris. Second, less dexterity of the non-dominant hand is required for vertical chop. With horizontal chop, the chopper maneuvers are conceptually and mechanically more difficult to execute, and are more likely to deform the side-port incision. However, vertical chop is more difficult to carry out on softer 2+ nuclei, and these otherwise forgiving lenses are not ideal for the transitioning to vertical chop. In our experience with the phaco chop instruction course, transitioning surgeons are most likely to succeed by attempting vertical prior to horizontal chop.

Horizontal chopping, in particular, involves repetition of the same fundamental maneuver over and over again. Once the mechanics of this step are mastered, they can be readily applied to nuclei of all densities. In addition, horizontal chop more quickly teaches one to

recognize the spectrum of nuclear size and density. This is because with horizontal chop, the surgeon must literally encompass one end of the nucleus with the chopper and will experience the tactile “feel” of fracturing progressively firmer nuclei. As with all phaco methods, the chop technique must be tailored according to the size and density of the nucleus. Therefore, one needs to be able to correlate how a nucleus appears at the slit lamp, with how it will behave during surgery. This is true regardless of whether one is performing phaco flip, phaco chop, or divide-and-conquer.

Because of the potential pitfalls while learning either chopping technique, a successful transition requires both preparation and patience. Lacking these, many surgeons become intimidated or discouraged by their lack of success. The purpose of this chapter is to provide a logical, step-wise game plan for transitioning, and to describe the most common mistakes that must be avoided and overcome.

### **Case selection for the transitioning surgeon**

Most surgeons categorize nuclei according to their *firmness* – soft, medium, or dense. As viewed through the slit lamp exam, everyone understands that as the color of the nucleus progresses from yellow to gold to brown, this correlates with increasing firmness and density. However, it is equally important to appreciate the *size* of the endonucleus – small, medium, or large. For example, compared to a medium-sized nucleus, soft lenses will have a smaller diameter endonucleus that is not as thick. A proportionately thicker epinucleus surrounds the small endonucleus above and below, and on all sides. Chopping a small endonucleus is easier because of its reduced dimensions and the ample epinuclear space.

In contrast, the dimensions of brunescient endonuclei can range from small to medium to large. The size can also be determined at the slit lamp. High myopes with oil-droplet nuclear cataracts have only a tiny, central, opalescent endonucleus. Even as it starts to turn golden brown, it usually remains just as small, and most of the lens therefore is epinucleus. In other nuclear sclerotic cataracts, a golden or brunescient fetal nucleus is visible at the slit lamp, but the nucleus peripheral and anterior to it is pale yellow. This indicates an endonucleus of medium diameter and thickness, which is surrounded by a relatively normal sized epinucleus. Finally, there are nuclear sclerotic cataracts in which brunescence extends all the way forward to the anterior capsule when viewed at the slit lamp. This indicates a huge endonucleus with little to no epinucleus. Compared to the medium-sized endonucleus, it has both a larger diameter and a greater anterior-posterior thickness.

The key to differentiating these three endonuclear sizes at the slit lamp is to determine how far forward the brunescient color and opalescence extend from the fetal nucleus. Correctly anticipating the size of the endonucleus permits one to alter and adjust one’s technique. For example, with divide-and-conquer the sculpted trough must extend more peripherally and much deeper than usual in order to crack larger, denser nuclei. With chopping, the chopper and phaco tips must penetrate deeper than usual for a larger nucleus. Otherwise, the chop will be too superficial and will fail to divide it.

Learning any new phaco technique is simplified and facilitated by optimal case selection. Soft to medium density endonuclei have a sizable epinucleus, and are preferable for learning horizontal chop. However, vertical chop is more difficult to perform in soft nuclei. Because they provide little margin for error, large brunescent nuclei should not be attempted until one has mastered chopping the easier cases. In the very beginning, one should avoid uncooperative patients and one-eyed patients. Finally, the transitioning surgeon might initially avoid eyes with problem characteristics such as pseudoexfoliation and loose zonules, excessively deep or shallow anterior chambers, deep-set eyes, small palpebral fissures, small pupils, intraoperative floppy iris syndrome, poor corneal clarity, or a poor red reflex.

## **Transitioning to horizontal chop**

### **Preliminary steps**

Because it is the more difficult variation to master, this chapter will outline a stepwise approach for transitioning to horizontal chop. Like all phaco methods, chopping is easier to perform in the presence of a large pupil, a large capsulorrhexis, and a well hydrodissected and mobile nucleus. Since in horizontal chopping, the chopper tip maneuvers within the epinuclear space, hydrodelineation is particularly important for this method. By demarcating the boundaries of the endonucleus, hydrodelineation also helps one to visualize proper placement of the chopper tip alongside the equator. The technique of hydrodelineation should first be practiced and mastered with divide-and-conquer cases.

The most difficult steps of horizontal chopping are the initial ones - the first chop across the entire un-sculpted diameter of the nucleus, and removal of the first segment. Each subsequent step becomes progressively easier as more and more 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.

### **Stepwise game plan for horizontal chop:**

- **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. Excessive pressure or torsion can cause corneal striae, increased posterior pressure, and lateral displacement of the globe. In preparation for chopping, one can become comfortable and adept with the chopper by using it as the second instrument during divide-and-conquer. Indeed, its shape is well suited

for reaching into the base of the sculpted trough to crack the nucleus in half. Two additional exercises can assist in developing the necessary horizontal chopper skills.

- Step 2: *When performing divide-and-conquer, use the microfinger-shaped chopper to tumble the quadrants out of the capsular bag.* This provides practice hooking the equator of the endonucleus with the chopper. Because of the sculpted grooves, the quadrants are mobile instead of being tightly wedged within the capsular bag. One unnecessary concern raised by this maneuver is the possibility that the sharp apex of the fragment will perforate the posterior capsule. Because the apex serves as the fulcrum about which the fragment flips outward, it never penetrates close enough to the capsule. This identical maneuver can later be used to tumble chopped fragments out of the bag if necessary.

The second exercise is to explore the capsular bag with the horizontal chopper when only the epinucleus is present (following removal of the endonucleus). The elongated tip can be placed in the peripheral capsular fornix to see that it doesn't distend it. It can also be used to palpate the central epinucleus. Surgeons are usually surprised at how deeply the chopper tip must be lowered in order to contact the central posterior capsule. This provides a mental picture of the margin of safety. Since fear of lacerating the posterior capsule with the chopper is something that every transitioning surgeon must overcome, visualizing and understanding this spatial relationship is invaluable.

- Step 3: In divide-and-conquer, the first heminucleus is cracked into two quadrants that are elevated and emulsified in the pupillary plane. Instead of immediately emulsifying them, *use the opportunity to chop each quadrant into smaller pieces.* By holding the quadrant in the center of the pupil, one can visualize executing a horizontal chop in three dimensions without concern for the iris or the anterior or posterior capsule. One can readily envision how best to orient the horizontal chopper tip in order to trap the fragment against the phaco tip. A microfinger chopper should wrap around and cup the posterior slope of the equator. If the end of the tip instead rotates or shies away from the equator, sufficient compression cannot be generated. This subtle three-dimensional concept of how to optimally orient the horizontal chopper tip is critical. Chopping these two mobile quadrants also allows the surgeon to experience the tactile feedback of the chopper as it cuts through nuclei of varying density. Developing this "feel" is helpful as one advances toward chopping firmer and denser nuclei.
- Step 4: After removing the first two quadrants, don't sculpt a groove into the remaining heminucleus. *Instead, impale and carry the heminucleus to the center of the pupil.* A properly hydrodelimited endonucleus should easily separate from the epinucleus at this point. One can proceed to chop it into multiple pieces while directly visualizing the equator, and without having to pass the chopper tip peripherally beneath the anterior capsule.

- Step 5: The next step is to *learn and master “stop and chop”*. As with divide-and-conquer, first sculpt an adequately deep groove in order to crack the nucleus in half. After rotating the endonucleus slightly clockwise, start to chop the remaining halves. For the first time the chopper must be passed peripherally beneath the anterior capsule to hook the equator of the endonucleus. This is still considerably easier than chopping the entire un-sculpted 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 position and depth of the phaco tip is assured. The nucleus will be sandwiched between the phaco tip on one side, and the chopper tip on the other. Finally, the trough provides some vacant space, which helps to mobilize the first chopped fragment.
- Step 6: The next intermediate training step is what this author calls, *“half-trench” stop and chop*. As originally described by Steven Dewey, one sculpts only half a groove (S. Dewey. “Transition to chop: a non-impaling technique”. Video, American Academy of Ophthalmology Annual Meeting, 2003) . The nucleus is spun for 180 degrees and the remaining un-sculpted portion is chopped in the following manner. The phaco tip is first impaled into the remaining ledge of nucleus where the groove ended centrally. The partial groove assures 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. Alternatively, the horizontal chopper can be placed before impaling the nucleus, as will be described later. The ensuing full thickness chop is easier, thanks to the partial groove. This is because after the un-sculpted portion is chopped, the remaining proximal nucleus is thinner due to the sculpting. This minimizes resistance to fracturing of the remaining posterior plate. Unlike Dewey’s original description for vertical chop, this half-trench technique for horizontal chop requires hooking the equator with the chopper. This skill is the key to the final remaining step.
- Step 7: After mastering “classic” and “half-trench” 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. For horizontal chop, softer and smaller endonuclei should be mastered before progressing to firmer and larger endonuclei. Fortunately, if the initial chop fails, one can resort back to sculpting a trench for stop and chop. The remainder of this chapter will discuss pearls for mastering the pure, “non-stop” chopping maneuver.

## **Modifications for vertical chop**

For vertical chopping, one should select 2-3+ density nuclei as initial cases because of the difficulty in using this technique with soft nuclei. , In addition, it is difficult to vertically chop a loose quadrant or fragment without the stabilizing effect provided by the adjacent pieces of nucleus. One should therefore skip steps 2 and 3 from the above transitioning game plan. Finally, instead of using stop and chop as a transition technique, one can sculpt half trench or a central pit prior to attempting the first chop. This variation was discussed in chapter 4 as a strategy for brunescent nuclei, but can be used with 3+ nuclei as well. The centrally sculpted pit ensures deeper penetration of the phaco tip and makes it easier to transect the center of the posterior nuclear plate.

## **Pearls and pitfalls in learning horizontal chopping**

Horizontal chopping fractures the nucleus along a natural cleavage plane defined by the orientation of the lens lamellae. It requires that the bulk of the endonucleus be sandwiched and compressed in between the chopper tip and the phaco tip. If positioned properly, the resulting compression force generated by one instrument moving toward the other initiates the fracture. The denser the nucleus, the greater the compression force required. Accomplishing a successful horizontal chop requires coordinating multiple instrument maneuvers and foot pedal positions.

To achieve a successful chop, there are five interdependent objectives that must be accomplished and coordinated:

1. proper initial placement of the chopper tip
2. proper placement of the phaco tip, utilizing vacuum to stabilize the nucleus
3. keeping the chopper tip adequately deep during the horizontal chop motion
4. optimizing chopper tip orientation and direction during the chop motion
5. manipulating the chopper shaft without deforming the side-port incision

A failed chop is the result of mistakes with one or more of these objectives.

### **Objective 1: Proper initial chopper placement.**

The first and most crucial step is to properly hook the equator of the endonucleus with the chopper. The chopper should pass below the capsulorrhexis edge and into the epinuclear space where it descends alongside the nuclear equator. If the chopper tip passes above the capsulorrhexis edge as it moves peripherally, it will cause a large zonular dialysis during the ensuing chop. This pitfall can be avoided by adhering to the following sequential steps.

The first step is to aspirate the anterior epinucleus. This improves visualization of the capsulorrhexis/anterior capsule location, the underlying endonucleus, and the amount of separation between the two. Some surgeons prefer to keep the horizontal chopper tip in

the same upright, vertical orientation throughout this maneuver. Pressing the dull chopper tip slightly downward as it moves peripherally maintains contact with the anterior endonuclear surface and prevents the tip from passing outside of the capsular bag. As it reaches the edge of the anterior capsule, the upright tip will slightly stretch the capsulorrhexis before it descends into the epinucleus-endonucleus junction. Hydrodelineation helps to define this junction. Trypan blue capsular dye also helps the novice to visually confirm that the chopper is passing beneath rather than over the capsulorrhexis edge.

First impaling the nucleus with the phaco tip prior to placing the horizontal chopper is another option. However, this tends to push the nucleus toward the distal capsular fornix, thereby compressing the epinuclear space. Because horizontal chopper placement is the most intimidating step, positioning it first optimizes visualization of this maneuver. In addition, prior to impaling with the phaco tip, one can test the location of the chopper tip by slightly nudging the nucleus. The anterior capsule should not move if the chopper tip is inside rather than outside the capsular bag. A clear peripheral red reflex would result if the chopper were sitting in the zonular space. If the equator of the nucleus is hooked properly, it should move slightly with this “test” nudge. If it doesn’t, the chopper is not peripheral or deep enough and it will simply deflect over the anterior nucleus rather than compress and penetrate into it.

### **Objective 2: Proper positioning of the phaco tip.**

Because it serves as the chopping block, the phaco tip must impale deeply enough into the nucleus to immobilize it against the incoming chopping motion. With a soft nucleus, the phaco tip can be advanced with manual pressure and vacuum alone. However, with a brunescient nucleus, maximum power and burst mode may be necessary to embed the tip deeply enough. The nucleus is fixated with high vacuum in foot position 2 to prevent it from wobbling or rotating during the chop.

The initial goal in horizontal chop is to position both instrument tips so as to maximize the amount of nucleus in the path of the chopper. The latter must slice through the center point of the nucleus in order to split it entirely. Sculpting habits create an undesirable tendency to advance the phaco tip centrally and superficially while in foot position 3. Instead, one must concentrate on starting the phaco tip just inside the proximal capsulorrhexis edge and aiming it posteriorly toward the optic nerve. The larger and denser the nucleus, the greater the nuclear mass that is initially sandwiched between the chopper and phaco tips must be.

### **Objective 3: Maintaining sufficient tip depth during the chopping motion.**

Fear of puncturing the posterior capsule creates a tendency to elevate the chopper tip as it moves toward the phaco tip. This is understandable because horizontal chop is a forceful, blind maneuver during which the surgeon can neither see the chopper tip nor the posterior capsule. However, the result is that the central core of the endonucleus may not be

compressed and divided during the chop motion. The chopper tip will instead scratch or score the anterior surface of the nucleus, rather than driving through the middle.

One must commit to keeping the chopper tip deep throughout the full course of the horizontal chop. The confidence to execute a deep chop requires an understanding of the thickness of the nucleus, and of just how much posterior capsule clearance there truly is. Because of its convexity, the clearance is greatest centrally. In the crystalline lens, the central distance between the anterior and posterior capsules is approximately 4.0 - 4.5 mm. Even following removal of the anterior epinucleus, it is extremely difficult for a 1.5 mm to 2.0 mm-long chopper tip to reach the central posterior capsule with the nucleus present. As suggested earlier, exploring an empty capsular bag by gently touching the chopper tip to the posterior capsule after removing the nucleus will demonstrate this.

#### **Objective 4: Optimizing chopper tip orientation and direction during the chop.**

As the chop is executed, fear of contact with the posterior capsule causes transitioning surgeons to not only elevate the chopper tip, but to change the angulation of the tip as well. Maximal cutting depth is achieved by having this tip vertically oriented from initiation to completion of the chopping motion. However, inexperienced surgeons may rotate the tip slightly toward or away from the phaco tip. While this provides better visualization of where the tip is, it reduces the depth of the chopping path through the tissue. This has the same counterproductive effect as elevating the tip during the chop.

One should move the chopper directly toward the phaco tip so that compression of the encompassed nuclear material is sustained for as long as possible. During the initial chop, many surgeons tend to veer the chopper tip to the left of the phaco tip at the last moment. This is undesirable because it may create a counterclockwise torsion and rotation of the nucleus. In addition, the posterior-most part of the endonucleus may not fracture if the instrument tips never appose each other. This tendency may result from fear of damaging either the chopper or phaco tip. This should not happen because ultrasound is never utilized during the chopping motion and the two tips merely touch each other lightly.

To better understand this concept, imagine trying to bisect a thin pretzel stick with your thumb and index finger. If the two digits press directly against each other, the middle of the pretzel will be trapped, crushed, and then divided. However, if one were to instead snap their fingers at the last minute, the pretzel stick might spin and slip away without being divided. For denser nuclei, maximizing the compressive force of the initial chop is especially critical because this is the one situation where the phaco tip is not positioned against one side of the nuclear mass.

#### **Objective 5: Avoiding incisional deformation by the chopper shaft.**

As stated earlier, the chopper should be maneuvered like a rowboat oar with the side-port incision serving as the stationary fulcrum. A common error is for the chopper shaft to push the globe away from the surgeon as he attempts to hook the opposite equator. Displacing the globe to the edge of the microscope field compromises visibility. In

addition, tilting the horizontal plane of the iris and endonuclear surface away from the surgeon impedes proper positioning of the phaco tip.

### **Additional Pearls for the Surgeon Transitioning to Horizontal Chop**

Since horizontal chopping requires significant bimanual dexterity, another helpful exercise is to perform some “practice” chops in the anterior chamber above the nucleus prior to initiating the first chop. Much like a golfer’s practice swings, this allows the surgeon to verify proper orientation of the chopper tip and shaft as he practices the full sequence of motions and to develop some muscle memory and rhythm for the upcoming maneuver. For example, the surgeon should try to keep the elongated horizontal chopper tip vertically oriented throughout the entire chopping motion. If the surgeon finds that he is distorting, compressing, or displacing the incision, or that his hand position is awkward or uncomfortable, it is better to correct the problem at this point, rather than after the chopper is inside the capsular bag.

As mentioned earlier, trypan blue dye permits visualization of the capsulorhexis during horizontal chopper tip placement and movement. This not only provides visual confirmation that the tip is inside the capsular bag, but also enables the surgeon to see if the chopper shaft is overly stretching the left side of the capsulorhexis, which is often where the anterior capsule will be torn during horizontal chopping.

Finally, a variation of Dick Mackool’s viscodissection concept can be used to facilitate horizontal chopper placement for the critical initial chop. Rather than cohesive agents, one should use a dispersive ophthalmic viscosurgical device (OVD), such as Viscoat (Alcon) because it spreads evenly and resists aspiration. After the traditional hydro steps, the anterior epinucleus is aspirated. At this point, the dispersive OVD is injected just beneath the nasal capsulorhexis edge until it reaches the equatorial fornix of the bag. This partial viscodissection maneuver widens and maintains the anatomic clearance between the endonucleus and anterior capsule, and the nuclear equator and peripheral capsule. It also dramatically improves visualization by displacing any loosened cortical material that was stirred up by the hydrosteps. The improved visualization and separation of the endonucleus from the capsular bag virtually insures proper intracapsular placement of the horizontal chopper tip. After execution of the first chop and nuclear rotation, there is often enough remaining dispersive OVD to facilitate chopper tip placement for the second chop. Even the most experienced surgeons can resort to this maneuver whenever they encounter difficulty hooking the nuclear equator with a complicated case.

### **Conclusion**

While one shouldn’t be overly aggressive with chopping techniques, neither can one afford to be timid and hesitant. There is a certain pace and rhythm to performing these maneuvers, which can be learned by observing experienced surgeons. Once a surgeon finally accomplishes that first successful chop, he will forever remember and recognize how it should look and feel. This is similar to the learning breakthrough that occurs after one successfully cracks a grooved nucleus for the first time. After one has mastered the

basic horizontal or vertical chopping maneuver, the same step is simply repeated over and over again in order to fragment the remainder of the lens. In addition, whether one has mastered horizontal or vertical phaco chop first, learning the second variation becomes infinitely easier, because the surgeon now possesses greater bimanual dexterity, and a better understanding of the mechanics of chopping.

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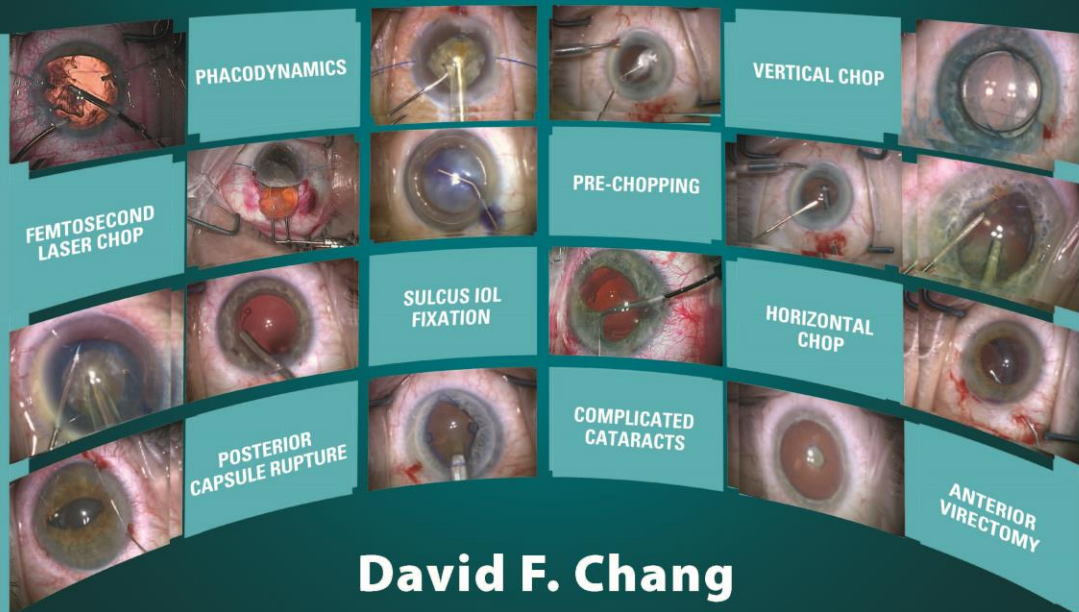
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