The Perfectly Sized Capsulorhexis

Why we should strive to attain it.

BY TAL RAVIV, MD

A properly constructed capsulorhexis, specifically a continuous curvilinear capsulorhexis, is the sine qua non of modern phacoemulsification. The continuous tear affords the anterior capsule strength and a forgiving elasticity to withstand the subsequent stressors of phacoemulsification and the lens' insertion. An early misstep when creating the capsulorhexis can quickly snowball into serious complications.

Although much is known and has been written about the importance of the capsulorhexis' shape, less emphasis has been placed on its size. The reason is probably that surgeons can generally complete phacoemulsification without complications regardless of the capsulorhexis' size. As any novice surgeon can attest, just completing the continuous curvilinear capsulorhexis without extension is usually the targeted endpoint. Likewise, in difficult cases of small pupils, intraoperative floppy iris syndrome, loose zonules, or a shallow chamber, even the experienced surgeon's focus is more on successfully completing the continuous curvilinear capsulorhexis than its final size.

For routine cases, some surgeons prefer a small capsulorhexis, whereas others make it as large as possible. Some surgeons vary the capsulotomy's size arbitrarily from case to case—just maintaining a zone of safety to the iris—no matter the pupil's diameter.

In the past decade, ophthalmologists have learned more about the long-term sequaelae of the capsule/IOL relationship and the factors contributing to posterior capsular opacification (PCO), anterior capsular contraction, late decentration of the optic, the anterior shift of an effective lens position, and the resulting refractive change. Completing a case without an obvious complication is no longer enough in the refractive IOL era; reproducible and stable long-term results are just as crucial. Achieving a consistently sized capsulorhexis is therefore now essential, but what constitutes perfection?

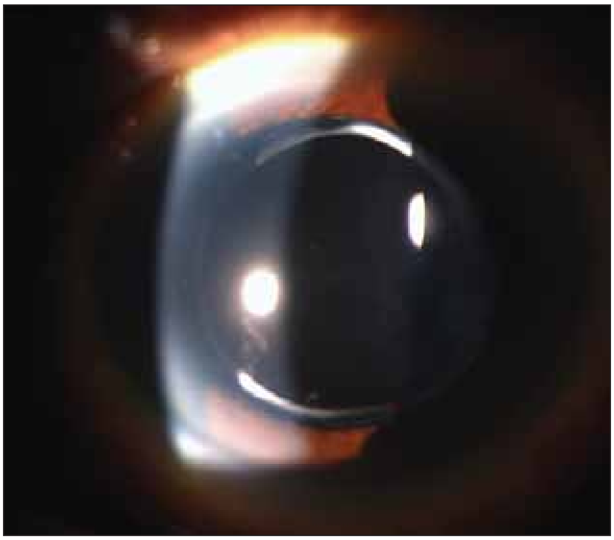

Figure 1. Five years after cataract surgery, the 5.5-mm capsular edge fully overlaps the 6.0-mm IOL for 360º. This barrier effect is critical to mitigating PCO.

THE TARGET SIZE OF THE CAPSULORHEXIS

In the United States, where the dominant size of the IOL's optic is 6.0 mm, a well centered, 360º overlapping capsulorhexis of 5.5 mm achieves the gold-standard scenario in most cases. Studies[1-3] have repeatedly shown that full overlap of the capsulorhexis' edge is the most important determinant of the development of PCO, more so than even an IOL's edge design or material.[4] By creating a "shrink wrap" and a capsular bending effect in the posterior capsule, a 360º overlapping edge on the optic is believed to deter lens epithelial cells from proliferating, the so-called *barrier effect* (Figure 1). In some studies,[3] capsulotomies larger than the IOL's optic were associated with a PCO rate above 50%. The capsulorhexis therefore should not be much larger than 5.5 mm as far as PCO prevention.[3]

BENEFITS OF COMPLETE ANTERIOR CAPSULE/IOL OVERLAP

Anterior capsular overlap locks in the final effective lens position, which affords two critical and beneficial effects. The first is the long-term stabilization of refractive outcomes. Surgeons are familiar with the scenario of a perfect emmetropic result during the early postoperative period that gradually becomes myopic during the first 6 to 12 months. Capsular forces and fibrosis stiffen the posterior capsule and push the IOL forward if it is not stabilized by a 360º anterior overlap.[5] With some large capsulotomies (greater that 6 mm), the anterior capsule can fuse to the posterior capsule, continue to contract, and migrate behind the IOL, all of which generates a significant forward shift, myopia, and a dense double-layered PCO. Clearly, these results are problematic, especially with a multifocal lens.

The second critical effect of 360º capsular overlap is standardization of the effective lens position and thus the A-constants of IOLs, which has huge implications for the accuracy of IOL power calculations. Before the significance of capsular overlap was appreciated, different surgeons with variously sized capsulorhexes would get different refractive results with the same IOL, hence the evolution of the personalized A-constant (a fudge factor). Certainly, different keratometers and A-scan devices were contributing factors. Nowadays, however, with many ophthalmologists' use of the IOLMaster (Carl Zeiss Meditec, Inc., Dublin, CA) for all the measurements, sizing the capsulorhexis becomes the single most critical surgeon variable in achieving consistency in IOL calculations. If all surgeons used a properly calibrated IOLMaster for their measurements and performed a 360º overlapping 5.5-mm capsulorhexis, then their personalized A-constants would likely be identical. If the online User Group for Laser Interference Biometry A-constant database calculated results only from cases with 360º capsular overlap, the need for personalizing A-constants for the IOLMaster would likely become unnecessary, and surgeons would have more consistent results.

THE PROBLEM OF PARTIAL CAPSULAR OVERLAP

Complete 360º coverage is necessary for the prevention of PCO and the IOL's stability. If the overlap is only partial, or the capsulorhexis is decentered, the rate of PCO increases as the barrier effect is lost.[1] Furthermore, the forces of asymmetric capsular contraction can cause a late dislocation of the IOL. Figure 2 illustrates inferior decentration of the optic of an in-the-bag IOL after contraction of a segment of the anterior capsule superiorly that is not overlapped. Although surgeons have gotten away with some decentration and/or tilt with traditional monofocal lenses, current IOLs with

Figure 2. Fibrosis and contraction of an asymmetric capsulotomy leads to late decentration of the IOL's optic in the bag.

negative spherical aberration (aspheric) are very sensitive to decentration, and higher-order aberrations may increase when these lenses are displaced by even 0.3 mm.[6] Sensitivity to decentration applies even more so to (aspheric) multifocal or toric lenses, as patients' postoperatve expectations with refractive premium IOLs are high.

WHEN IS THE CAPSULORHEXIS TOO SMALL?

The evidence for constructing a capsulorhexis smaller than the 6-mm optic is compelling, but surgeons should not make it too small. A small capsular opening makes surgery more difficult and places greater stress on the anterior capsule during nuclear division or quadrant removal. Beyond the operative disadvantages, significant negative consequences can occur during the postoperative period with capsular contraction syndrome.[7] Anterior capsular fibrosis with opacity and shrinkage probably occurs to some degree after every case of cataract extraction.[8] Although extreme capsular phimosis can obscure vision, even a more modest contraction can have adverse effects. Furthermore, a smaller capsular opening can obscure peripheral retinal visibility and treatment.

Studies have shown that, the smaller the capsulorhexis, the more rapidly it contracts postoperatively. The average 5.0-mm capsulorhexis contracted to 4.4 mm within the first 3 months,[9] although most eyes with an initial capsular opening greater than 5.5 mm remained larger than 5.0 mm.[10] One could therefore question whether the final size of the capsular opening matters clinically.

With multifocal lenses such as the AcrySof Restor (Alcon Laboratories, Inc., Fort Worth, TX) and the ReZoom (Abbott Medical Optics Inc., Santa Ana, CA), a smaller capsular opening can have obviously negative consequences by diminishing the light through the peripheral refractive zones.

Figure 3. The Raviv capsulorhexis caliper was designed to facilitate accurate intraocular measurements through the wound or paracentesis.

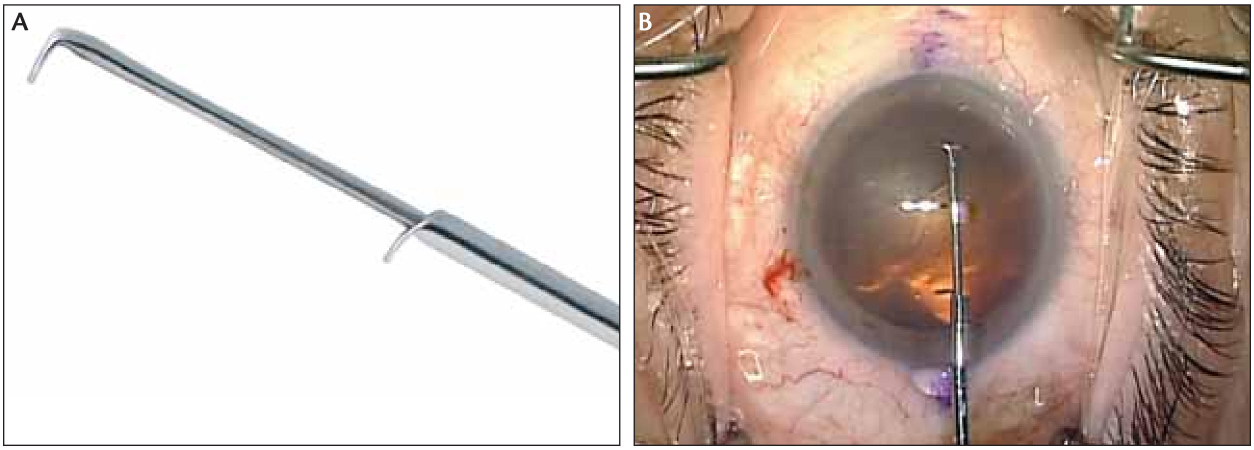

Figure 4. The surgeon uses the caliper (A) intraoperatively to mark the capsule prior to creating a centered 5.5-mm capsulorhexis (B).

Less intuitively however, smaller functional optical zones also negatively affect the results with popular aspheric IOLs. Designed to negate the positive spherical aberration of the cornea, these IOLs lose this property if an opaque anterior capsule occludes their periphery—nullifying their advantage over traditional IOLs. Comparative studies[11,12] between aspheric and spherical IOLs have shown a significant reduction of higher-order aberrations with aspherics when tested with 6.0-mm diameter pupils. When the IOLs were evaluated with 4.0- and 5.0-mm pupils, however, no significant difference was seen between the groups. Thus, to fully attain the benefits of aspheric IOLs, a final anterior capsular opening greater than 5.0 mm is ideal, which, when accounting for capsular contraction, translates once again to about a 5.5-mm capsulorhexis.

EXCEPTIONS TO THE RULE

Although a 5.5-mm capsulorhexis may be the perfect size for the commonly used 6.0-mm optic, some surgical scenarios warrant exceptions. For very dense cataracts, a larger capsulorhexis is preferable for safer intraoperative outcomes. Conversely, cases in which the surgeon anticipates posterior capsular complications (eg, posterior polar cataracts) warrant a slightly smaller capsulorhexis to allow for possible placement of the IOL in the sulcus with optic capture. Accommodating lenses such as the Crystalens HD (Bausch & Lomb, Rochester, NY) are believed to benefit from a capsulorhexis that is slightly larger than the 5.0-mm optic. Some surgeons believe that this larger capsulorhexis allows the accommodative mechanism to function; this activity comes with a higher prevalence of PCO, posterior capsular fibrosis, and an unwanted myopic shift. In my experience these complications can be managed with appropriately timed YAG laser treatment.

EXECUTING A 5.5-MM CAPSULORHEXIS

Ironically, as sophisticated as the latest phaco platforms are, surgeons' ability to reliably size the capsulorhexis is quite inadequate. A majority of ophthalmologists today use a freehand technique. Of the currently available alternatives, most have significant limitations. Using a fixed corneal marker as a guide is unreliable due to varying anterior chamber depth, keratometry, and parallax. A marked capsulorhexis forceps may give a visual cue to sizing but only in one direction and with no help in centration.

Newer concepts may be helpful. Surgeons can insert a flexible 5-mm PMMA ring[13] into the anterior chamber and use it like a stencil to trace the capsulorhexis, as long as it does not move in the middle of the action. A promising technological solution involves overlaying a reference ring on the surgeon's view through the microscope.[14] Carl Zeiss Meditec, Inc., developed an interface module that adjusts the size of the ring appropriately with microscope magnification while keeping it centered within the limbus using real-time eye tracking. Ophthalmic surgeons have such technology on excimer lasers. Why not for surgical microscopes as well? Finally, several companies are developing femtosecond technologies to perform the capsulorhexis.

For the present, I developed a low-tech intraocular caliper (Figure 3), which can be set at the desired capsular diameter and used to indent the capsule at the targeted size (Figure 4). By placing two marks on the capsule through the wound and, if necessary, via a 90º paracentesis, I am able to create an accurately sized capsulorhexis.

IN SUMMARY

Constructing a 5.5-mm capsulotomy is clearly a worthwhile, attainable goal for cataract surgery cases, certainly for all those involving premium IOLs. Surgeons already carefully measure the length and depth of their limbal relaxing incisions, the width of their cataract incisions, and the steep meridians for toric IOLs. Consistently achieving precision in the sizing of the capsulorhexis is the next logical step in improving long-term outcomes. ■

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