CHAPTER 26

Review of Top Phaco Innovations

ROBERT H. OSHER, MD

Every year, Dr. Osher chairs the "What's New" symposium in New York City and the "Cutting Edge" symposium at the AAO Annual Meeting. This article presents Dr. Osher's evaluation of innovations from 2007.

CATEGORY 1: MICROSCOPES

The OPMI Lumera microscope from Carl Zeiss Meditec AG (Jena, Germany) is extraordinary. The resolution is unprecedented, and the depth of field is dramatic. The stereo coaxial illumination provides a brilliant homogeneous red reflex during the capsulorhexis, I/A, the lens' implantation, and the ophthalmic viscosurgical device's (OVD) removal. I would award the Lumera the title of top innovation of the year.

CATEGORY 2: PHACO MACHINES

Both Advanced Medical Optics, Inc. (Santa Ana, CA), and Bausch & Lomb (Rochester, NY) introduced new machines in 2007. The Whitestar Signature System (Advanced Medical Optics, Inc.) features elliptical transverse emulsification, which is in response to the success that Alcon Laboratories, Inc. (Fort Worth, TX), has had with torsional ultrasound. The Stellaris Vision Enhancement System (Bausch & Lomb) has been designed for the transition to sub-2-mm surgery and is compatible with the Akreos lenses (not available in the US; Bausch & Lomb). The wireless foot switch and the option to select either a peristaltic or Venturi pump on the fly are significant innovations.

CATEGORY 3: PHACO TIPS

Two new phaco tips gained attention this past year. The Dewey Radius tip from MicroSurgical Technology (Redmond, WA) has a blunt edge and reportedly offers additional capsular protection. The Osher tip from Alcon Laboratories, Inc., is designed for the surgeon who wants to perform torsional ultrasound but is uncomfortable with the more extreme curve of the Kelman tip. My tip (no financial interest) has a gentle curve, with the bevel opening on the same side as the curve. Takayuki Akahoshi, MD, of Tokyo also independently developed a similar tip. Since 70% of phaco surgeons worldwide prefer a straight tip, this tip should facilitate the transition to torsional ultrasound. The award-winning film from Teruyuki Miyoshi, MD, of Fukuyama, Japan, clearly demonstrates the enhanced efficiency of torsional ultrasound.

CATEGORY 4: IOL INJECTORS

The winner in this category was the Isert Injector from Hoya (not available in the US; Frankfurt, Germany). The lens, preloaded on the reusable injector, never comes into contact with handling instruments or the environment outside the eye. The award-winning film from Hiroko Bissen-Miyajima, MD, of Tokyo emphasizes that the ocular surface is often contaminated during cataract surgery.

CATEGORY 5: IOLs

In the US, Alcon Laboratories, Inc., has swept this category with its introduction of the aspheric AcrySof Restor and the AcrySof Toric lenses. The improved resolution and reduction of the glare circle are impressive on the optical bench. Because the lens can be injected through a 2.2-mm incision, the surgeon does not induce undesirable astigmatism, according to the work of Samuel Masket, MD, of Los Angeles. However, it fails to correct preexisting cylinder, and my European colleagues are fortunate to have the multifocal toric IOLs from Carl Zeiss Meditec AG (which purchased Acri.Tec GmbH) and Rayner Intraocular Lenses, Ltd. (East Sussex, United Kingdom) (both IOLs not available in the US). Refractive cataract surgeons have enthusiastically embraced the introduction of the toric lens, even though the method of identifying the steepest axis leaves room for improvement. Eyeonics, Inc. (Aliso Viejo, CA), with its new Crystalens 5-O, and Visiogen, Inc. (Irvine, CA), with its dual-optic Synchrony (not available in the US), continue to attract an enthusiastic following.

CATEGORY 6: DEVICES

The modification of the Morcher capsular tension ring (CTR; Morcher GmbH, Stuttgart, Germany) by Bonnie Henderson, MD, of Boston to have eight indentations to facilitate cortical removal demonstrates continued innovation in CTR technology. The Capsular Anchor (Hanita Lenses, Kibbutz Hanita, Israel), designed by Ehud I. Assia, MD, of Kfar Saba, Israel, is also exciting. Unfortunately, it may take years for the FDA to approve these products. In 1993, my younger associate, Robert J. Cionni, MD, of Cincinnati and I implanted the first CTRs in the US; it required 11 years before the standard CTR was approved. The other device that created excitement at the 2007 AAO Annual Meeting in New Orleans was the Malyugin ring and inserter (MicroSurgical Technology) for the management of small pupils.

CATEGORY 7: OVDs

As part of the settlement in the lawsuit with Alcon Laboratories, Inc., Advanced Medical Optics, Inc., gained the right to package and market a combination of OVDs. Years prior to the introduction of DuoVisc (Alcon Laboratories, Inc.), I had suggested this idea to Hakan Edstrom, President of the US division of Kabi Pharmacia (Upsala, Sweden). The concept was vetoed in Sweden, and the rest of the story is history. Advanced Medical Optics, Inc., plans to add Healon D, a new dispersive agent, to its existing family of Healon, Healon GV, and Healon5. It is anticipated that the surgeon will be able to select two OVDs in separate carpules for any given case.

CATEGORY 8: SURGICAL KNIVES

Becton, Dickinson and Company (Franklin Lakes, NJ) has set the new standard in blade safety. With increasing concerns about spreading HIV, hepatitis, prion disease, etc., surgeons and OR personnel have rapidly accepted the protective safety shield placed on an assortment of ophthalmic surgical knives.

CATEGORY 9: INSTRUMENTS

Every surgeon has encountered a case in which intraocular scissors or forceps function poorly, because the angle of the blades seems to be in the wrong plane or meridian. For this reason, I designed a unique set of intraocular scissors and forceps with interchangeable tips (no financial interest in the products) with Geuder AG (Heidelberg, Germany) and with Duckworth & Kent, Ltd. (Hertfordshire, United Kingdom) and Bausch & Lomb (Rochester, NY). Compatible with microincisional surgery, the blades have been angled to cut either a vertical or a horizontal plane along different meridia.

Two additional instruments have created much interest. Bong-Hyun Kim, MD, of South Korea has developed an intraocular mirror that allows the surgeon to visualize structures in the angle and in the posterior chamber. Manfred R. Tetz, MD, of Berlin has developed a new device for measuring the anterior chamber diameter and another device for separating the arms of the Artisan and Artiflex (Ophtec, Groningen, the Netherlands; marketed as the Verisyse and Veriflex [Advanced Medical Optics, Inc.] in the US) haptic for easier implantation.

CATEGORY 10: BUGS AND DRUGS

Advanced Vision Care (Woburn, MA) has introduced SteriLid, an antiseptic foam that kills 99% of all bacteria within 1 minute of contact. Two antibiotics drew a great deal of attention at the recent AAO Annual Meeting: AzaSite from Inspire Pharmaceuticals, Inc. (Durham, NC), and Iquix from Vistakon Pharmaceuticals, LLC (Jacksonville, FL). AzaSite is 1% azithromycin, a broad-spectrum topical agent with a dosing regimen of twice a day for the first 2 days and once daily thereafter. Iquix is unpreserved 1.5% levofloxacin, the highest available concentration for a topical fluoroquinolone.

Xibrom, produced by Ista Pharmaceuticals (Irvine, CA), completed its phase 3 FDA clinical trials for a higher-concentration, once-daily formulation of this potent anti-inflammatory agent. As interest in intracameral antibiotics continues to grow, the strong safety performance of moxifloxacin created excitement at the AAO Annual Meeting.[1]

To conclude, 2007 has been a banner year for new products in cataract surgery. Our specialty is predicting continued innovations in 2008. ■

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1. Lane SS, Osher RH, Masket S, Belani SL. Evaluation of the safety of prophylactic intracameral mixofloxacin in cataract surgery patients. Poster presented at: The 2007 AAO Annual Meeting; November 10-13, 2007; New Orleans, LA.

CHAPTER 27

Improving Surgical Safety With Modern Phaco Technology

Strategies With the Whitestar Signature System

DAVID F. CHANG, MD

We cataract surgeons and our patients continue to benefit from ongoing improvements in phaco technology. Because cataract surgery is already such a fast and efficient operation, we are primarily interested in new technologies that can expand our margin of safety—particularly in eyes with dense nuclei and weak zonules. Historically, our three main safety-related concerns with phacoemulsification have been (1) thermal damage to the incision, (2) endothelial trauma associated with prolonged ultrasound time, and (3) capsular rupture due to postocclusion surge.

Incision burns are most likely to occur with the higher power levels and prolonged ultrasound times needed for brunescent lenses. Increasing the stroke length of the vibrating phaco tip generates more frictional heat as well as more phaco power. The thicker nuclear emulsate can admix with a highly retentive ophthalmic viscosurgical device (OVD) to form a viscous plug that clogs the phaco tip or aspiration line. If fluid outflow is blocked, then the gravity-fed inflow of irrigation also ceases. With neither the inflow nor the outflow of fluid to cool it, a phaco tip in continuous mode will instantaneously burn the cataract incision.

The loss of endothelial cells is also much greater with brunescent nuclei, the size and density of which require increased phaco time and energy for emulsification compared with standard cataracts. In my opinion, it is the increased particulate turbulence occurring with brunescent nuclear fragments that causes the most damage to endothelial cells. Rigid nuclear pieces drawn by aspiration to the phaco tip do not mold and conform as well to its opening. This and the added stroke length of higher ultrasound power settings increase the chatter and turbulence of nuclear particles within the anterior chamber.

Finally, there are several reasons why posterior capsular rupture is more common with rock-hard nuclei. The added rigidity and girth of the nucleus more directly transfers instrument-related forces to the capsule and zonules, and there is far less of an epinuclear shell to cushion the movements of the endonucleus. We typically maximize vacuum levels to improve holding power in these cases, but this increases the risk of postocclusion surge. A lax posterior capsule due to weak or deficient zonules will trampoline more easily toward the phaco tip, making even a minor or momentary degree of surge precarious.

Fortunately, all three major manufacturers provide us with bona fide advances in their latest machine platforms that address the

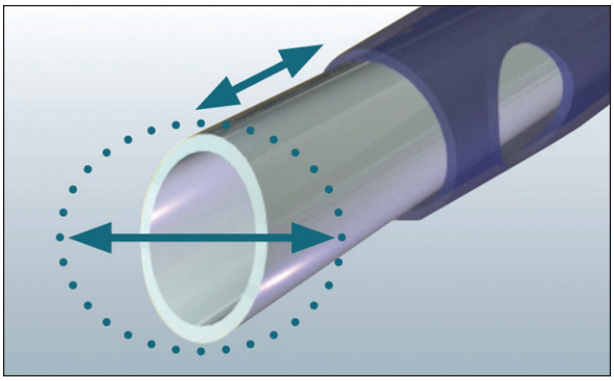


Figure 1. Illustration of the phaco tip's transverse elliptical path combined with some longitudinal axial motion.

three problems I have outlined. This article highlights specific safety features that users of the Whitestar Signature System (Advanced Medical Optics, Inc., Santa Ana, CA) should understand and deploy.

POWER MODULATIONS: WHITESTAR AND ELLIPS

This decade has brought two major advances in ultrasound technology, starting with the launch of Whitestar hyperpulse power modulation with the Sovereign system (Advanced Medical Optics, Inc.) in 2001. Shortening the pulse's duration allows us to significantly increase the frequency of ultrasound pulses. In addition, the ability to decrease the duty cycle produces a major reduction in cumulative ultrasound time. These changes significantly reduce the production of heat and the total ultrasound energy delivered by the phaco tip, and they practically eliminate the risk of wound burn. As well illustrated by the ASCRS award-winning videos of Teruyuki Miyoshi, MD, that used ultra-high-speed digital photography, alternating each ultrasonic pulse with rest periods of "off" time diminishes the repelling force of the vibrating phaco tip. This in turn reduces the chatter and turbulence of small lenticular particles at the phaco tip that would otherwise bombard the corneal endothelium.

The second major advance was the OZil Torsional handpiece (Alcon Laboratories, Inc., Fort Worth, TX), which replaces the axial movement of a traditional phaco needle with the sideways oscillation of a bent Kelman tip. Dr. Miyoshi's videos also showed that eliminating longitudinal repelling forces at the phaco tip dramatically improved followability and reduced the chatter of fragments. Advanced Medical Optics, Inc., has built on this concept by blending some longitudinal movement with a transverse elliptical path of the phaco tip (Figure 1). Ellips Transversal Ultrasound retains some longitudinal motion in order to improve the tip's ability to cut dense nuclear material. Although I have only limited personal experience with torsional phacoemulsification, Ellips seems to provide comparable benefits with a straight phaco tip, which is my strong preference for phaco chop (Figure 2). This is the single most exciting feature of the Whitestar Signature System.

I now routinely combine Ellips with variable Whitestar ICE Technology (Advanced Medical Optics, Inc.), but I use a higher, foot-pedal–controlled duty cycle that I can vary from 60% to 90%. The higher duty cycle compensates for the overall reduction in the tip's axial motion. The enhanced followability that characterizes Ellips Transversal Ultrasound is the most dramatic and obvious when used on dense nuclei. The reduced endothelial trauma in eyes with brunescent lenses is apparent in the form of clearer corneas on postoperative day 1, a well-acknowledged hallmark of phacoemulsification using nonlongitudinal ultrasound.

MICROPHACO TIP

Moving from a 19-gauge to a 20-gauge phaco tip is one strategy that all of us can use to enhance safety regardless of the brand of phaco machine. This single modification reduces the size of the incision, decreases surge, lessens the chance of accidental aspiration of the iris or capsule, and makes it easier to pluck thin or crumbling nuclear fragments from the capsular fornices. The last advantage stems from the fact that the smaller tip becomes occluded without having to penetrate too deeply into the nucleus. The narrower lumen restricts flow, reduces surge, and prevents material from rushing in as fast as through a needle with a shaft of standard diameter. Like an I/A tip with a smaller opening, a microphaco tip provides us with greater control over which tissue is or is not aspirated. Slowing things down in this way helps when we want to guard against snagging the capsule, such as when aspirating epinucleus or thin nuclear pieces abutting the peripheral capsular bag.

Counterbalancing these advantages are several tradeoffs. A microphaco tip increases nuclear chatter because of its smaller "mouth," and its restricted flow lengthens the time needed to remove a bulky nucleus. The smaller surface area of the tip's opening also reduces the effective holding power for any given vacuum level. Fortunately, we can solve the followability problem by chopping the nucleus into smaller pieces and combining Ellips and variable Whitestar power modulations to virtually eliminate chatter. Improved pump technology enables us to safely use higher aspiration flow and vacuum to compensate for the other factors. It is therefore possible to reap the benefits of a smaller phaco tip regardless of whether we perform coaxial or biaxial phacoemulsification, and yet using a microphaco tip is the most overlooked safety modification that we surgeons can make.

ENHANCED FLUIDICS

The Whitestar Signature System's pump is a measurable improvement over that of the Sovereign. Experiments in cadaveric eyes by Randall Olson, MD, were able to measure surge associated with a variety of vacuum levels using different machines with the same experimental eye. These studies have provided quantitative confirmation of the improved chamber stability that we perceive clinically. I also strongly advocate using two optional but important safety features of the Signature's Fusion Fluidics pump: passive automatic reflux and the antisurge algorithm (discussed later).

We are much more likely to aspirate a lax posterior capsule during cortical cleanup in eyes with weak zonules. All phaco machines provide active auto reflux, whereby pressing a foot switch reverses flow in the aspiration line. Doing so expels ensnared material, such as the posterior capsule, from the aspirating port. Passive auto reflux is a safety option of both the Signature and the Sovereign that automatically refluxes the port at every transition from foot position 2 to 1. We surgeons instinctively make this change as soon as the capsule is aspirated, and this wonderful safety feature immediately expels the capsule for us. I select this indispensable option for all cases.

ANTISURGE ALGORITHM

I believe that postocclusion surge is still the most common cause of posterior capsular rupture occurring during nuclear emul-

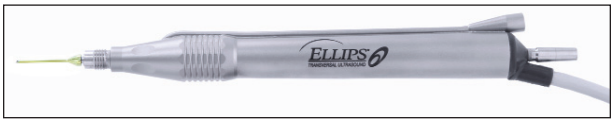


Figure 2. The Ellips Transversal Ultrasound handpiece with a straight 20-gauge phaco tip (infusion sleeve removed).

sification. The Diplomax machine (Advanced Medical Optics, Inc.) was the first to offer the occlusion mode feature, which we could program to automatically change ultrasound and fluidic parameters once the phaco tip became occluded or unoccluded. I always thought, however, that it would be much safer if we could drop the vacuum immediately before a break in occlusion. When using higher vacuum levels, this decrease would significantly reduce surge and improve chamber stability.

In response to this suggestion, the Fusion Fluidics pump technology has an antisurge algorithm to accomplish just this result. The pump's onboard computer recognizes occlusion and proactively reverses the pump to actively step down the vacuum before the break in occlusion occurs. I use the antisurge algorithm during emulsification of chopped fragments, when breaks in occlusion are happening repeatedly. Like a car's antilock braking system, the antisurge algorithm automatically reduces the vacuum level after a predetermined interval to prevent surge as the fragments are evacuated. The algorithm tries to automate and duplicate what an experienced surgeon could do with a dual linear foot pedal once the tip became occluded. High vacuum is first used to maximize holding power, but we would then lower the vacuum with the dual linear foot pedal before delivering phaco power to clear the phaco tip.

CONCLUSION

Advances in phaco technology continue to improve our ability to manage the most challenging cataracts. Although such sophistication comes at the expense of simplicity, understanding and properly configuring our phaco technology deliver better performance while improving safety. ■

Strategies With the Stellaris Vision Enhancement System

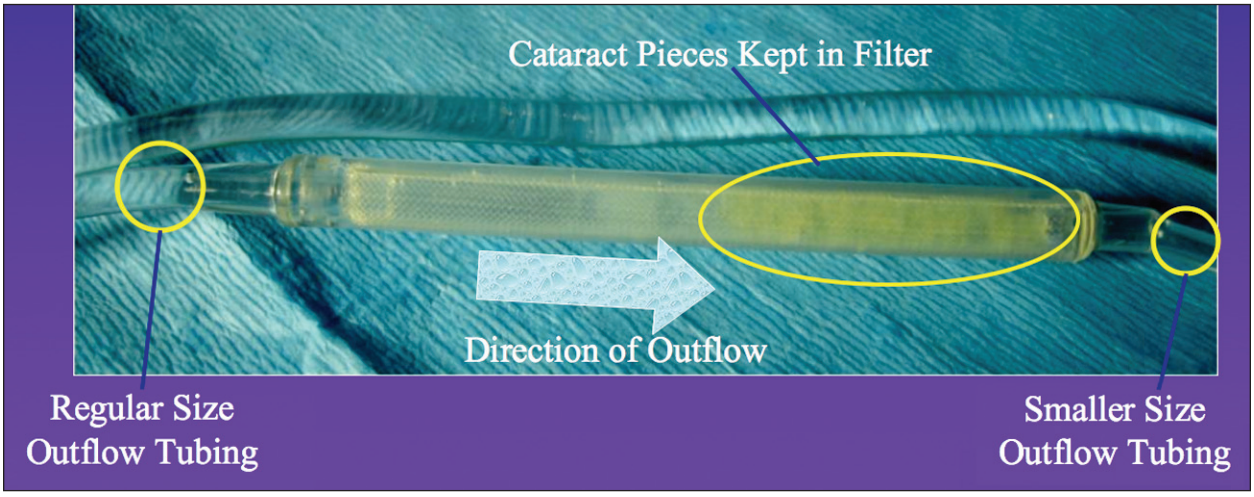
ELIZABETH A. DAVIS, MD

Enhancing safety in phacoemulsification requires optimizing fluidics and reducing the amount of ultrasound energy delivered. Several new phaco systems represent improvements in these areas over previous platforms. This article focuses on the Stellaris Vision Enhancement System (Bausch & Lomb, Rochester, NY).

TRANSITION TO MICROINCISIONAL CATARACT SURGERY

I have been performing cataract surgery with the Stellaris Vision Enhancement System for approximately 2 years. I had been a longtime user of Bausch & Lomb's Millennium microsurgical system, with which I performed coaxial surgery through an incision of 2.8 to 3.0 mm. One of the factors motivating my switch to the Stellaris was that it has several new features that enhance surgical safety and efficiency. Additionally, the system is capable of microincisional cataract surgery, which I was anxious to incorporate into my practice. The significance of the benefits of smaller incisions (reduced astigmatism, enhanced chamber stability, and a lower risk of leaking wounds and infection) was clear to me. Based upon many of my colleagues' experience, however, I was not enthusiastic about bimanual microincisional surgery for numerous reasons. The procedure seemed fraught with challenges in fluidics, chamber stability, and prolonged surgical time. It also demanded a significant change in technique. Although the Stellaris Vision Enhancement System may be used for biaxial surgery, the opportunity to perform microincisional surgery in a coaxial fashion was what I found particularly attractive.

I started with a standard 3.0-mm coaxial procedure but then was pleasantly surprised to experience a seamless transition to 1.8-mm coaxial surgery. I did not have to make any substantial changes to my surgical technique aside from adjusting to the use of a microincisional capsulorhexis forceps instead of a Utrata model.



(Courtesy of Uday Devgan, MD.)

Figure 1. The Stellaris Vision Enhancement System's restrictive outflow tubing.

HIGH VACUUM AND TUBING

In terms of enhancing my technique, I have found the Stellaris' high vacuum settings (up to 600 mm Hg) beneficial. I usually employ very high vacuum for supracapsular surgery, and, even at 600 mm Hg, the chamber remains extremely stable. This technology can be combined with flow-restrictive tubing that prevents postocclusion surge at high vacuum levels (Figure 1). A mesh filter located in the tubing traps particles and prevents clogging.

A simple but ingenious new feature of the Stellaris Vision Enhancement System is the connection of the infusion tubing to the handpiece via a luer lock. This setup prevents the dangerous loss of inflow and chamber collapse that can occur if the tubing disengages from the handpiece during surgery.

FLOW MODULE

Although I prefer the vacuum module, the Stellaris Vision Enhancement System has a flow module available that can function in either a flow or vacuum mode. This feature not only allows multiple surgeons with different pumping preferences to use the same machine, but it also permits a single surgeon to toggle between flow and vacuum mode during a single case to enhance efficiency at various stages of nuclear removal. The flow module also uses an electrical pump, which eliminates the need for external compressed gases and the associated tanks.

POWER MODULATION

The Stellaris' power modulation represents another improvement on the Millennium. Because the former delivers up to 250 pulses per second with adjustable duty cycles, the surgeon may use waveform modulations in pulse or burst modes. The ultrasound power can also be turned on for as little as 2 milliseconds at a time. I like the Stellaris' power modulation, because it can adapt to the type of cataract or the stage of the phaco procedure.

PHACO HANDPIECE AND FOOT PEDAL

The new titanium handpiece features six crystals versus four in most other systems. As a result, the Stellaris' handpiece is more ergonomic and comfortable, and it has spared me a fatigued wrist at the end of a long surgical day.

As with the Millenium cataract extraction system, the Stellaris' foot pedal is dual linear, which gives me on-the-fly control of power and either vacuum or flow. I have particularly enjoyed this feature, which allows me to alter surgical parameters instantaneously as events occur intraoperatively. Additionally, the foot pedal is now wireless, which eliminates one of the cords across the OR floor.

CONCLUSION

The Stellaris Vision Enhancement System's enhanced fluidics, chamber stability, and power modulation improve efficiency and reduce the use of phaco energy. I encourage other surgeons to try microincisional cataract procedures on this system. They can perform bimanual or coaxial surgery and use either the vacuum or flow module. I am convinced they will not face a difficult transition but will, like me, find their surgical performance and efficiency enhanced. ■

Strategies With the Intrepid Micro-Coaxial System

TERRY KIM, MD

The goals of microincisional cataract surgery are to minimize surgically induced astigmatism, hasten wound healing, and reduce the risk of a leaking wound and infection. The Intrepid Micro-Coaxial System, using both the Infiniti Vision System and the OZil Torsional handpiece (all from Alcon Laboratories, Inc., Fort Worth, TX), represents a fully integrated line of equipment and instruments specifically designed to maximize the safety and efficiency of microincisional coaxial phacoemulsification through a 2.2- or 2.4-mm incision.

OZIL TORSIONAL TECHNOLOGY

Systems that use conventional longitudinal ultrasound incorporate the forward and backward motion of the phaco tip, analogous to the movement of a jackhammer, to emulsify the lens. OZil Torsional ultrasound represents a breakthrough. The side-to-side oscillatory motion of the phaco tip is amplified to shear lenticular material, which results in more efficient emulsification by almost eliminating the repulsion caused by the cutting of nuclear tissue. As a result, the surgeon will notice less repulsion and increased followability of lenticular material, which mean a lesser dependence on the high vacuum levels needed with longitudinal ultrasound to overcome repulsion. Surgical efficiency also increases. Moreover, whereas 50% of the stroke (ie, the backward stroke) is wasted energy with longitudinal ultrasound, torsional ultrasound uses 100% of the stroke to shear nuclear material while also reducing frictional movement within the incision. As a result, torsional ultrasound achieves higher thermal safety than modulated longitudinal ultrasound.

For microincisional coaxial phacoemulsification, the Intrepid's MicroSmooth Ultra irrigation sleeve (Alcon Laboratories, Inc.) protects the wound against thermal/mechanical stress and provides sufficient flow that the bottle need not be excessively high, as with some other phaco systems.

THE INTREPID FLUID MANAGEMENT SYSTEM

The Intrepid Fluid Management System (Alcon Laboratories, Inc.) uses very low-compliance aspiration tubing to minimize the risk of postocclusion surge and to increase the stability of the anterior chamber without requiring additional irrigating flow. Stable fluidics is essential during both routine and complex cataract surgery through a small incision, because surge and increased turbulence in the anterior chamber can heighten the risk of intraoperative complications. The Intrepid Fluid Management System allows the surgeon a sufficient range of vacuum levels during microincisional coaxial phacoemulsification with incisions as small as 2.2 mm and a bottle less than 110 cm high. The bottom line is a safer cataract procedure.

MONARCH III IOL DELIVERY SYSTEM

The Monarch III IOL delivery system with the D Cartridge (Alcon Laboratories, Inc.) completes the microincisional system by permitting the IOL's safe, controlled implantation through an unenlarged 2.2-mm incision. Compared with the C cartridge, the D cartridge has a nozzle with a 33% smaller tip and a 0.5-mm larg-

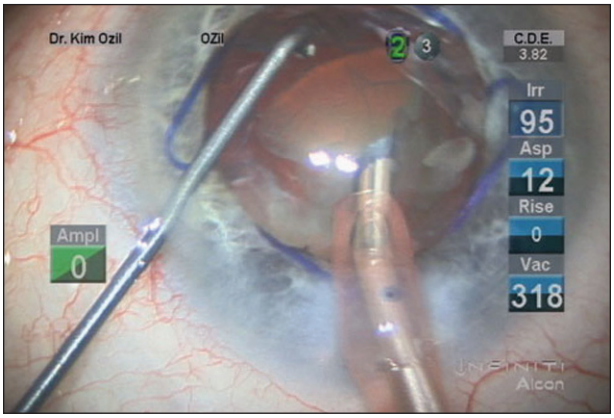


Figure 1. Using the OZil Torsional handpiece with a Malyugin ring (MicroSurgical Technology, Redmond, WA), Dr. Kim performs phaco chop on a dense nucleus.

er opening. The aspheric design and material properties of the AcrySof IOLs (Alcon Laboratories, Inc.) complement this injector; their thin optics are made of high-quality hydrophobic acrylic material, and their single-piece design facilitates in-the-bag implantation. Easier, more consistent delivery of the IOL decreases stress on the corneal incision.

PERSONAL EXPERIENCE

I have been using the Alcon Intrepid Micro-Coaxial System routinely for all of my phaco procedures for more than 2 years. The incision's proper construction and architecture are increasingly important as they grow smaller. Shorter tunnels and shallow wounds (resulting in tears at their edges) leave the incision more vulnerable to mechanical stress during phacoemulsification and I/A, and they increase the likelihood of a leaking wound that will require suturing.[1]

One of the steeper learning curves in transitioning to a 2.2-mm incision occurs during the capsulorhexis. The smaller incision limits the movement of a standard capsulorhexis forceps. As a result, the surgeon must grasp the capsulorhexis' edge more frequently and torque/angulate the forceps more often to complete the tear. After a few cases, I became accustomed to these maneuvers and found the need to switch to a microcapsulorhexis forceps unnecessary.

With the 0.9-mm Mini-Flared Kelman tip with a 45° bevel (Alcon Laboratories, Inc.), I routinely use 100% torsional ultrasound with a vacuum setting of 350 mm Hg, an aspiration flow rate of 35 mL per minute, and a bottle height of 100 cm. I particularly notice the benefits of torsional ultrasound with denser lenses: the enhanced followability and decreased anterior chamber turbulence have been impressive (Figure 1).

I have used the Monarch III IOL delivery system with the D cartridge to implant the full line of single-piece AcrySof IOLs, including the AcrySof IQ, the AcrySof Toric, and the AcrySof Restor Aspheric as well as high-powered spherical IOLs such as a 34.00 D monofocal AcrySof IOL. Regardless of the lens used, its delivery through a 2.2-mm incision has been consistently easy with a wound-assisted technique, which is my preference (Figure 2). I have found that these incisions seal completely after stromal hydration without the need for a suture, even in atypical cases such as after trabeculectomy or pars plana vitrectomy, and they are astigmatically neutral.[2]

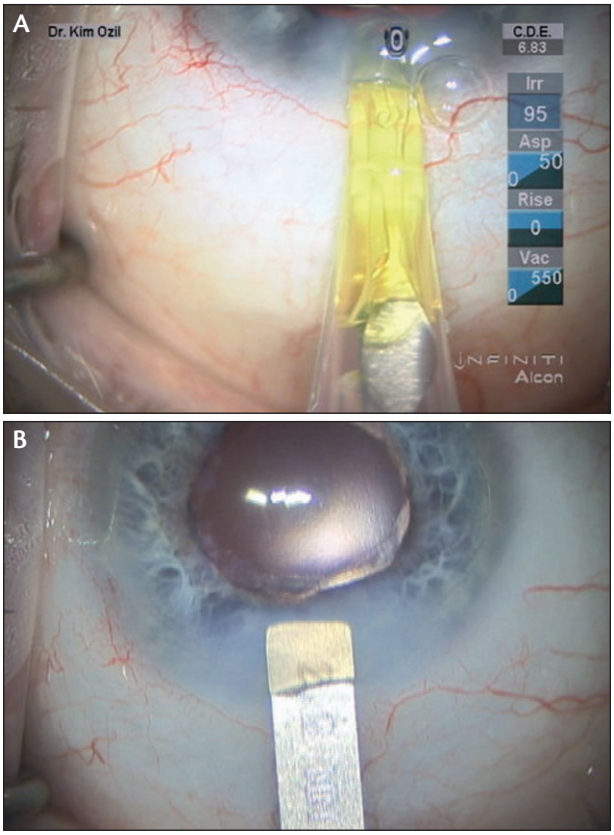


Figure 2. Dr. Kim inserts an AcrySof Restor Aspheric lens with the Monarch III IOL delivery system with a D cartridge (A). He confirms a 2.2-mm incision size with an incision gauge at the conclusion of the case (B).

LABORATORY AND CLINICAL STUDIES

A number of studies have confirmed the safety and efficiency of the Intrepid Micro-Coaxial System using the Infiniti Vision System, OZil Torsional technology, and the Intrepid Fluid Management System.[3-6] My colleagues and I conducted a series of laboratory and clinical studies examining the wound's architecture and integrity after phaco procedures performed using the Intrepid system. The results of these investigations have consistently supported the positive safety profile of phacoemulsification with a 2.2-mm microincision and torsional ultrasound.[7,8]

In an ex vivo study using human eye-banked eyes, my colleagues and I analyzed the effects of different OZil settings (ie, 100% torsional ultrasound or 70% torsional/30% longitudinal ultrasound) through a 2.8- or 2.2-mm incision. Surgical parameters—including vacuum, aspiration, and bottle-height settings—were constant for all procedures. Gross and histopathologic examination as well as findings on optical coherence tomography and scanning electron microscopy revealed no differences in the corneal wound's architecture or integrity among all groups. Compared with longitudinal ultrasound, torsional and mixed torsional/longitudinal ultrasound did not adversely affect these incisions.[7]

We recently performed a contralateral eye study in 30 human patients with bilaterally similar cataracts in order to compare the differences in various intraoperative and clinical parameters after phacoemulsification using 100% torsional ultrasound.[8] The procedure was performed through a 2.8-mm incision

in subjects' right eye (with a 0.9-mm tapered Kelman tip with a 30° bevel and the standard Infiniti Fluid Management System) and a 2.2-mm incision in their left eye (with a 0.9-mm Mini-Flared Kelman tip with a 45° bevel and the Intrepid Fluid Management System). We chose these tips to maximize the fluidic performance for the corresponding size of incision. The surgical techniques (ie, prechop, horizontal chop, etc.) and settings (ie, vacuum, aspiration, and bottle height) were similar for each patient. The parameters we studied included the accumulated usage of ultrasound energy, the usage of balanced salt solution, the change in central corneal thickness (on postoperative day 1), and the change in endothelial cell count (at postoperative month 6). Of these, the only two that showed a statistically significant difference in favor of the 2.2-mm incision were the amount of ultrasound energy used (cumulative dissipated energy) and the change in the endothelial cell count. Based on these results, we concluded that microincisional phacoemulsification with a 2.2-mm incision, the 45° beveled Mini-Flared Kelman tip, 100% torsional ultrasound, and the Intrepid Fluid Management System is a safe and effective procedure that may offer favorable clinical and intraoperative benefits to our patients.

CONCLUSION

The Intrepid Micro-Coaxial System includes the 2.2-mm ClearCut metal keratome blades, OZil Torsional ultrasound, the Intrepid Fluid Management System, the Monarch III IOL delivery system with the D cartridge, and the line of AcrySof Aspheric IOLs. This platform offers the latest integrated technology specifically designed to enhance the safety and efficacy of modern cataract surgery. ■

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CHAPTER 28

The Influence of New Technology

WILLIAM J. FISHKIND, MD; STEVEN DEWEY, MD; ROBERT J. CIONNI, MD; ALAN S. CRANDALL, MD; AND UDAY DEVGAN, MD

WILLIAM J. FISHKIND, MD

The past few years have brought the introduction of noteworthy new phaco technologies that have altered the way we surgeons analyze and execute the procedure. To better understand these advances, we must partition phacoemulsification into its components of power and fluid. The former is characterized as the combined effect of cavitational and jackhammer energy (the debate over the role of cavitational energy is beyond the scope of this discussion).

The fluidic element of the procedure includes the management of vacuum and flow. When the fragment is adjacent to the phaco tip during emulsification, it obstructs the inflow of fluid and allows vacuum to increase to the preset maximum (defined as occlusion). The instant of occlusion is a critical dividing point in the procedure. The act of removing the fragment can therefore be divided into preocclusion phacoemulsification, occlusion, and postocclusion phacoemulsification (Figure 1A).

In the past, we performed the majority of the procedure with occlusion inevitably followed by postocclusion phacoemulsification. Every occlusion resulted in a surge, which we came to accept, albeit unhappily.

Micropulse phacoemulsification is a revolutionary power modification composed of extremely short bursts of phaco power, for use even with hard nuclei. This technology and torsional phacoemulsification have shown us that we can emulsify the fragment near the tip without total occlusion. As a result, there is rarely an occlusion or surge. If we perform phaco chop, we create multiple fragments early in the procedure. We remove these fragments with low amounts of power in stable anterior chambers (Figure 1B).

If we take an expansive look at the new phaco technologies, their major effects are to permit the phacoemulsification of fragments in the preocclusion phase and therefore avert postocclusion surge.

STEVEN DEWEY, MD

Six years ago, the introduction of the original Whitestar micropulse technology (Advanced Medical Optics, Inc., Santa Ana, CA) ushered out the remnants of traditional longitudinal phacoemulsification by significantly reducing chatter, turbulence, and instability of the chamber seen with older phaco systems. With the latest Whitestar ICE technology (Advanced Medical Optics, Inc.) upgrade, three features now transform the micropulse power delivery: micropulse shaping; variable duty cycle power delivery; and chamber automated stabilization environment (CASE; Advanced Medical Optics, Inc.).

The benefits of the original Whitestar Technology in reducing effective phaco time are well known.1 My own measurements

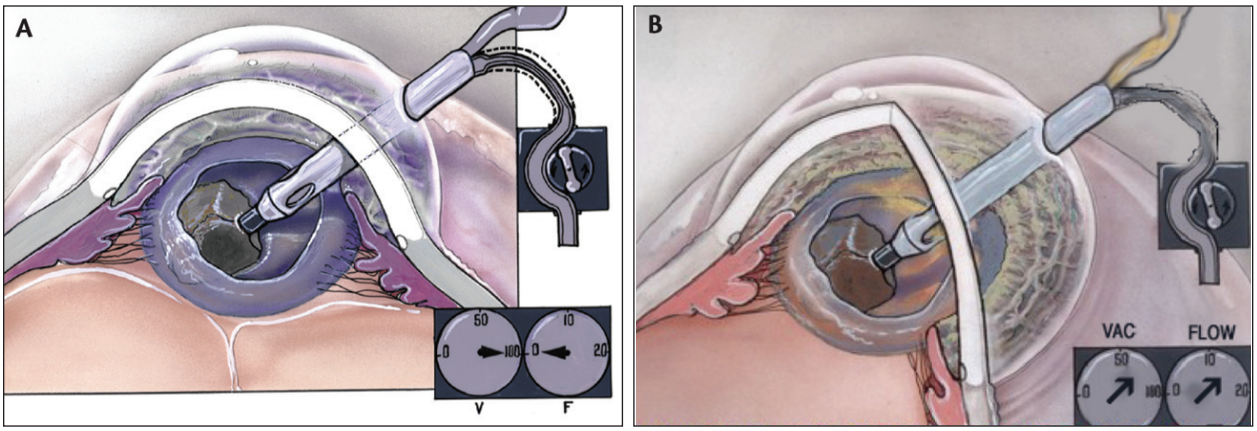

Figure 1. The fragment occludes the phaco tip.There is full vacuum and no flow.When phaco power is energized, the fragment is emulsified, resulting in greater outflow through the phaco tip than inflow, a situation that inevitably leads to surge (A).The fragment is near the phaco tip but does not occlude it.There is always partial vacuum and flow.Without occlusion, there is no surge, and the anterior chamber remains deep (B). (Reprinted with permission from Fishkind WJ, ed.Complications in *Phacoemulsification: Avoidance,Recognition,and Management*.1st ed. New York,NY:Thieme Medical Publishers; 2002.)

comparing Whitestar generations show further gains with the ICE technology. Using a nonstop horizontal chop, my effective phaco time has decreased by 40% for a 2+ nuclear sclerotic cataract and by 20% for a 3+ cataract. By reviewing digital video, I can measure the time from the phaco needle's insertion to its removal. I find my phaco needle is a few seconds more efficient with the Whitestar ICE technology than the original technology.

To understand how my surgical efficiency improved, I wanted to evaluate how the equipment interacted with my technique. While reviewing hundreds of surgical videos using the Whitestar ICE technology, I observed virtually no surge, turbulence, or chatter; far less bouncing of the chamber; and impressive followability of particles.

I believe the Whitestar ICE technology allows me to attack the point of occlusion instead of hesitantly engaging the material. I use vacuum much more effectively to shear the nucleus apart and achieve occlusion prior to applying power. As occlusion breaks, I no longer depend on my response with the foot pedal to release vacuum and prevent surge or on my placement of a second instrument against the capsule to prevent its engagement with the tip. Instead, I work as comfortably with the last quadrant as I did the first. This technology allows me to remove the nucleus efficiently without having to anticipate the limitations of the equipment.

ROBERT J. CIONNI, MD

Just when I think that cataract removal technology cannot improve further, something revolutionary knocks my socks off. The introduction of Ozil torsional phacoemulsification (Alcon Laboratories, Inc., Fort Worth, TX) is one of the most impressive advances that I have witnessed during the last decade.

Traditional phacoemulsification is characterized by a longitudinal motion of the phaco tip along its long axis. The forward striking movement of the sharp metal tip emulsifies the nucleus of the cataract. This force, however, also encourages the movement of nuclear material away from the tip, thereby requiring higher vacuum levels and aspiration rates as well as power modulations to keep nuclear material from chattering away. Additionally, because the tip only cuts with a forward movement, the 50% of the time that it is moving backward is wasted energy that generates potentially harmful heat.[2]

Torsional phacoemulsification is characterized by an oscillatory motion around the long axis of the phaco tip. This motion generates sufficient energy to emulsify the nucleus but has several advantages over traditional longitudinal ultrasound. First, the oscillatory motion does not encourage the chattering of lenticular material.3 Followability is therefore markedly improved. Second, torsional phacoemulsification emulsifies in both the to and fro directions and thereby does not waste energy. The rotational movement induces less frictional heat at the incision as well. The net result is lower energy delivered and less risk of thermal damage to the incision (data on file with Alcon Laboratories, Inc.).

I have found that the best-performing tip for Ozil torsional ultrasound is the tapered Kelman tip (Alcon Laboratories, Inc.) through a 2.7- to 3.0-mm incision. With traditional longitudinal ultrasound, a strong holding force is needed to prevent lens chatter, and a high aspiration rate is needed to improve followability. With Ozil torsional phacoemulsification, I decrease the vacuum from 500 to 350 mm Hg and the aspiration rate from 40 to 25 mL/min. Because the vacuum level and aspiration rates are lower, I can also decrease the bottle's height to 90 cm without inducing volatility in the chamber. Finally, I no longer need to rely on power modulations and simply set the torsional amplitude on linear continuous control. These settings work well with chopping or dividing techniques.

Torsional ultrasound has increased my safety profile for cataract removal while simplifying my technique so much that it feels like cheating.

ALAN S. CRANDALL, MD

Phacoemulsification has progressed since its introduction more than 40 years ago by Charles Kelman, MD. Technical advances such as the continuous curvilinear capsulorhexis have improved outcomes. Understanding the lens' anatomy led to different techniques of disassembly (including divide and conquer and various forms of chopping) that have improved the safety of the procedure and reduced the risk of capsular rupture.

New phaco software to increase surgical safety has included measures to reduce surge and pulse and burst modes to decrease the energy delivered. A better understanding of the combination

of aspiration flow, vacuum, and ultrasound power with all the available phaco units has increased procedural safety and improved outcomes. Research into alternate methods for removing the lens (eg, lasers and water jets) has yet to replace traditional phacoemulsification, however.

Traditional phacoemulsification uses longitudinal motion of the phaco tip to emulsify the lenticular material. The frequency of the tip varies with different units from the middle 20,000s to 46,000 cycles per second. Heat is produced with this motion, and fluid is used to lower the risk of burns to the cornea and iris. With the longitudinal motion of the tip, there is a repulsive force that can decrease the efficiency of the procedure. Part of the art as well as the science of the phaco procedure is using various modes, flows, and phaco powers to effectively remove cataracts of different hardness safely and with the least amount of energy and fluid. Alterations to phaco tips have allowed further variations in technique.

In the 1990s, the Neosonix tip (Alcon Laboratories, Inc.) had a 2° oscillation along with longitudinal phacoemulsification, but the oscillation was very slow at a few oscillations per second. The theory was that the movement would help prevent occlusion, so it was helpful in divide and conquer techniques or anytime that nuclear material was being removed due to improved flow.

Torsional phacoemulsification involves an ultrasonic torsional motion (33,000 cycles/sec) that significantly improves the followability of nuclear material. The technology can use variations such as pulse and burst modes to further reduce potential heat-related complications and surge. The Ozil handpiece permits surgeons to use longitudinal (traditional) phacoemulsification for hard nuclei or for their comfort during the transition to full-time torsional phacoemulsification.

The torsional motion reduces friction at the incision,4 which should lower the risk of wound burn. The small phaco tip (0.9 mm) and the torsional motion work well for 2.2-mm microincisional phacoemulsification.

I currently use Ozil torsional phacoemulsification almost exclusively. The followability of nuclear fragments allows me to reduce vacuum to 300 mm Hg and aspiration flow to 38 mL/min. I am still learning about the intricacies of the new technology and how to use the system most efficiently.

UDAY DEVGAN, MD

The current phaco platforms have successfully made the use of phaco power modulations the standard of care. This decrease in phaco energy has resulted in less endothelial cell damage, a near-zero rate of phaco wound burns, and patients happy with their clear corneas and minimal inflammation immediately after surgery. The new machines have not significantly decreased the rate of posterior capsular complications, however, because the inadvertent rupturing of the capsule is most often due to issues of fluidics and not ultrasonic power.

The next frontier for safety and efficiency in cataract and IOL surgery is the delicate balance of fluidics within the confines of the anterior segment. As surgeons transition to refractive cataract surgery, they require an increased level of stability, followability, efficiency, and, most importantly, safety to deliver the expected outcomes for patients. Fluidic balance is the key.

The Stellaris Vision Enhancement System (FDA approved; Bausch & Lomb) delivers a superb balance of fluidics. The system includes new-generation fluid pumps, customized control software, options for advanced surgical control, and high-vacuum restrictive phaco tubing. The results are rock-solid stability of the anterior chamber during surgery, an efficient phaco procedure with magnetic followability, and a large margin of safety. I have found that the fluidic control and balance are outstanding and fully integrated into a true next-generation system. Whether the surgeon favors a bimanual or coaxial approach, flow-based or vacuum-based surgery, a divide-and-conquer or phaco chop technique, the Stellaris Vision Enhancement System delivers the performance and fluidic control that empowers ophthalmologists and benefits the patient. ■

This article originally appeared in the March 2007 issue of CRSToday.

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CHAPTER 65

Severe Scleritis, Weak Zonules, and a Rock-Hard Cataract in a One-Eyed Patient

DAVID F. CHANG, MD

I always approach surgery on a complex eye by mentally rehearsing a backup plan in the event of a complication. My most challenging case ever was also my most terrifying, because I could not envision what my backup plan would be.

THE PATIENT'S HISTORY

I first saw this 61-year-old woman in 1997. She had a long history of uveitis and scleritis since the age of 12, which is when she was first diagnosed and managed by Phillips Thygeson, MD. This was complicated by severe secondary uveitic glaucoma. Her left eye underwent cataract surgery in 1984 by one of the leading phaco surgeons in the country. Unfortunately, complications had led to corneal decompensation and severe secondary glaucoma that progressed to optic atrophy and blindness despite all treatment. Her functioning right eye had undergone a successful trabeculectomy in 1977 by H. Dunbar Hoskins, Jr, MD, who, according to the patient, called hers the worst case of scleritis he had ever seen. Her IOP was well controlled in the single digits. As her right cataract became increasingly brunescent and mature, she consulted one of the country's leading phaco surgeons in 1995. His consultation letter described the "formidable anatomic obstacles" and concluded, "There is nothing to be lost by waiting, because the cataract is nearly as hard and fully developed as it will be."

The patient was referred to me by her general ophthalmologist in 1997, because, as a resident of Northern California, she wanted to have her cataract surgery performed close to home. I learned that she was a nationally syndicated writer and an accomplished author of many books who was well known in her field. Although hoping to delay surgery for as long as possible, she was struggling to read and work with 20/400 vision in her only sighted eye.

CLINICAL FINDINGS

Examining this eye with extensive scleromalacia at the slit lamp made my heart stop. The entire superior one-fourth of the cornea had thinned seemingly to the thickness of Descemet's membrane. The corneal and scleral thickness looked to be no more than 100 µm all along the superior 8 clock hours of her limbus. There was a large, thin-walled bleb inferiorly that was rather bullous and encroached onto the peripheral cornea. There was only approximately 3 mm of normal corneal thickness at the inferior-temporal limbus adjacent to the bleb. The pupil did not dilate to more than 3 mm in diameter, and it remained eccentric due to broad inferior posterior synechiae. An ultrabrunescent lens obscured any view of her fundus.

Of the two of us, I am not sure who was more scared, but it might have been me. Because of the limited limbal space, which could barely accommodate a phaco incision, I had no backup plan if there was damaged or inadequate capsular support. Converting to a large incision would be impossible if I encountered complications. The tiny 3-mm wide island of nearly normal peripheral corneal thickness would not allow me to insert an ACIOL. Furthermore, there was insufficient tissue to create a scleral flap anywhere else to suture fixate a PCIOL. Suturing both haptics of a PCIOL to the iris had not yet been described, and it would have been difficult because of her eccentric pupil. Wearing an aphakic contact lens was not an option because of the bullous, thin-walled inferior bleb.

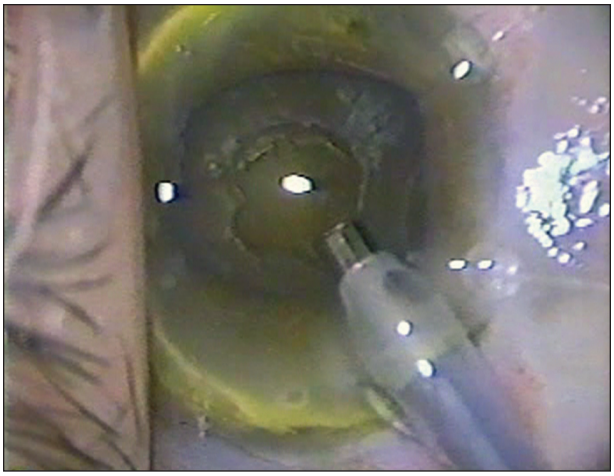

Figure 1. Surgeon's view of the patient's right eye with an inferior bleb, two inferior iris retractors, and the phaco tip placed through an inferotemporal clear corneal incision. There is no red reflex, making visualization of the capsulorhexis extremely difficult. Normal corneal thickness disappears at the whitish areas that involve most of the peripheral cornea, beyond which the cornea looks to be no more than 100 µm thick.

There were other potential nightmarish scenarios that I could envision. I knew that a penetrating keratoplasty would be impossible if her corneal endothelium decompensated, and I doubted that a pars plana vitrectomy/lensectomy could be performed in the event that any lens fragments dropped posteriorly. I wondered how I would close the eye if there were any thermal damage to the phaco incision. I was not even sure I could close a sideport incision because of the severe peripheral scleral/corneal thinning.

After we discussed the many risks, I was somewhat relieved when she elected to postpone surgery until she could no longer read with low-vision aids. She returned 12 months later and again 6 months after that before she finally decided to proceed with

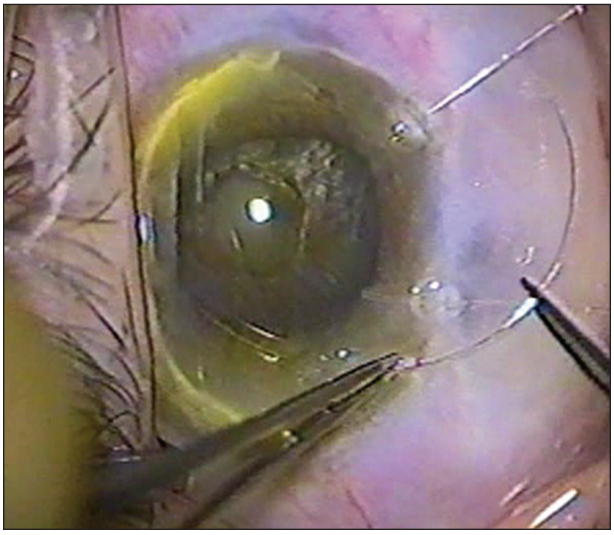

Figure 2. A capsular tension ring (CTR) is manually inserted without an injector. The inability to see the margin of the capsulorhexis makes it difficult to tell whether the CTR is entering the capsular bag. Note the position of the sculpted area showing that the insertion of the CTR is decentering the entire loose lens complex superiorly.

cataract surgery. I had this case on my mind for the ensuing 4 weeks leading up to the date of her surgery in October 1998. Other than a prayer, my only backup plan was to give her aphakic spectacles if the posterior capsule ruptured, and I explained this to her in advance.

SURGERY

Her referring ophthalmologist came to observe her surgery, and she appreciated the moral support. Assuming the posterior sclera to be equally thin as the anterior sclera, I used topical anesthesia to avoid the risks of a retro- or peribulbar injection. I made the 2.6-mm clear corneal incision in the only place possible before encountering the first major problem. Despite lysing the posterior synechiae, inserting two iris retractors inferiorly, and maximizing the microscope's illumination and zoom, I simply could not get enough of a red reflex to see the anterior capsule (Figure 1). Capsular staining with trypan blue dye had not yet been described. The difficulty in puncturing her anterior capsule and the excessive mobility of her lens as I maneuvered the capsular flap indicated that her zonules were extremely loose. I had not expected this. After struggling along at a snail's pace, I thought that I had successfully completed a capsulorhexis, but I could not be absolutely sure.

Following hydrodissection, I was unable to rotate the bulky nucleus within the loose capsular bag. As I began to sculpt a central trough through the brunescent nucleus, I was confronted with a surprising degree of phacodonesis. Despite proceeding very slowly, I got increasingly nervous as the lens jiggled with each phaco stroke. I decided to stop to regroup and ponder my options. After becoming a subinvestigator in Morcher's expanded investigational device exemption study, I had earlier purchased a single CTR (Stuttgart, Germany) from the company to be used in an emergency. Reasoning that desperate times required desperate measures, I decided that now was the time to implant my first CTR. Doing so proved to be extremely difficult, because the pupil was small, I did not have an injector, and I really could not visualize the margins of the capsulorhexis (Figure 2). It was extremely hard to tell if the ring was even entering the bag, and I nervously released the trailing eyelet with mixed feelings of hope and trepidation.

I had heard others speak about how helpful CTRs were for eyes with abnormal zonules. To my dismay, however, there was no reduction in phacodonesis when I resumed sculpting. The idea of using capsule or iris retractors to support the bag had not yet been described, and I did not understand at the time that a CTR can only redistribute instruments' forces to areas of healthy zonules—of which this patient had none. Nevertheless, the naïve notion that the CTR was somehow going to fortify the capsular bag gave me just enough confidence to continue.

After what seemed like an eternity, I eventually succeeded in chopping and removing her nucleus. I accomplished cortical cleanup in the presence of the CTR with great difficulty. I was drenched in perspiration but elated. I filled the loose capsular bag with an ophthalmic viscosurgical device and prepared to inject a foldable IOL. To my dismay, the zonules were so lax that the entire bag bobbed posteriorly away from the approaching IOL. I doubted that I could get the IOL into such a mobile capsular bag and elected to leave it in the ciliary sulcus instead.

OUTCOME

Postoperatively, the eye displayed a large choroidal detachment that persisted for many years, as the IOP remained in single digits. The IOL was slightly decentered within the sulcus but was optically well tolerated thanks to the patient's small pupil. Her BCVA improved to 20/70, and she could happily read J3 with a simple magnifier!

LESSONS LEARNED

No. 1.

As a surgeon, it is much better to be lucky than good. For example, a CTR does not really stabilize the capsular bag intraoperatively if there are 360° of zonular deficiency. Although it probably did nothing to enhance intraoperative safety in this case as I had intended, the CTR fortuitously prevented postoperative capsular contraction with the IOL positioned in the sulcus.

No. 2

We should endeavor to master new technologies. Were I to do this case now (10 years later), I would use VisionBlue dye (DORC International BV, Zuidland, the Netherlands) and a Malyugin pupil expansion ring (MicroSurgical Technologies, Redmond, WA) to avoid the need for multiple paracenteses. Microcoaxial phaco instrumentation would have been ideal for this case, and I would certainly use hyperpulse power modulation with OZil Torsional Ultrasound (Alcon Laboratories, Inc., Fort Worth, TX) or Ellips Transversal Ultrasound (Advanced Medical Optics, Inc., Santa Ana, CA) to minimize heat and endothelial trauma from particulate turbulence.

Finally, I would use polypropylene capsule retractors (eg, Mackool Capsule Support System [FCI Ophthalmics, Inc., Marshfield Hills, MA]) once severe capsulodonesis became apparent. Then, I would implant a CTR (using an injector) in the bag after cortical cleanup to prevent postoperative capsular contraction. I prefer a 13.5-mm long STAAR AQ2010V foldable three-piece IOL (STAAR Surgical Company, Monrovia, CA) for placement in the sulcus. I would consider anchoring one haptic to the iris with a

10–0 Prolene (Ethicon Inc., Somerville, NJ) McCannel suture or suturing both haptics to the iris if the posterior capsule were ruptured. In the event of a dropped nucleus, 25-gauge vitrectomy microinstrumentation would most likely be used.

POSTSCRIPT

I saw this patient several times during her first postoperative year but only twice thereafter. During that second visit in the summer of 2007, we congratulated each other on her 9 years of good visual function and reminisced about how scared we had both been while approaching her cataract operation. Ironically and tragically, she apparently tripped and hit her head on a curb 1 month later, causing a ruptured globe with a spontaneous expulsion of the IOL and much of her iris and vitreous. Her globe was repaired, but she remained limited to counting fingers vision and became very depressed. While preparing this article, I was heartbroken to learn that she had passed away in September 2008 of a possible suicide. Her story is a tragic and sobering reminder of the grave risks we and our patients face whenever we operate on someone's only seeing eye. ■

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CHAPTER 66

Combined Cataract and Glaucoma Surgery

RICHARD L. LINDSTROM, MD

A monocular patient with concurrent cataract and glaucoma and a reluctance to undergo ocular surgery not only presented a challenge; her case also led me to significantly change my practice patterns.

THE CASE

Presentation

A 71-year-old white female presented to my office with a complaint of painless, progressive visual loss in her right eye. She was unable to read in bright light with a magnifier and had abandoned driving years ago. She still lived independently, but her family was considering placing her in a nursing home.

The BCVA of her right eye was 20/200 at distance with a refraction of +3.00 +0.75 X 92 and J10 at near with a +3.00 D add. Her pupil and motility and confrontation fields were normal. The IOP in her right eye was 22 mg Hg. A slit-lamp examination revealed dense nuclear and cortical lenticular opacity. She had pseudoexfoliation, and her pupil dilated to only 5 mm. There was no phacodonesis, and gonioscopy exposed an open angle with increased pigmentation. The fundus was normal on direct and indirect ophthalmoscopy except for an enlarged cup. The view on direct ophthalmoscopy was estimated at 20/200.

The patient had a well-fit ocular prosthesis in her left eye socket. The eye had been enucleated some 10 years earlier.

Her laser interferometry visual potential was 20/30 OD. To control her IOP, the patient was taking Travatan Z (Alcon Laboratories, Inc., Fort Worth, TX) at bedtime in addition to Cosopt (Merck & Co., Inc., Whitehouse Station, NJ) and Alphagan P (Allergan, Inc., Irvine, CA) twice daily. Her past medical history was significant for a combined phacoemulsification and trabeculectomy with injections of 5-fluorouracil 10 years earlier. The procedure had been complicated by early hypotony, an inadvertent bleb leak, and, eventually, endophthalmitis that had resulted in the enucleation.

The patient had been followed for years by a skilled comprehensive ophthalmologist. She also saw a glaucoma specialist, who recommended that she undergo phacoemulsification with lens implantation combined with filtering surgery in her left eye. She steadfastly refused additional surgery due to the negative outcome in her right eye.

Surgical Options

The patient and I discussed her options. I advised her that many patients, especially those with pseudoexfoliation and a narrow angle, achieve a significant reduction in IOP simply from the removal of the cataract and placement of a PCIOL. I believed this procedure was an appropriate choice for her. After consulting with her family, she elected to undergo phacoemulsification with lens implantation under topical anesthesia.

The Procedure

After stretching the pupil with Kuglen hooks, I performed phacoemulsification using a tilt-and-tumble subcapsular technique. I injected Viscoat Plus (Alcon Laboratories, Inc.) and Amvisc Plus (Bausch & Lomb, Rochester, NY) twice during the nuclear emulsification. I removed the cortex and placed a capsular tension ring. I then positioned an aspheric lens implant in the capsular bag.

The surgery was uncomplicated, and the patient saw 20/40 1 day postoperatively with mild corneal edema, flare, and cells. Her IOP was 17 mm Hg. The patient eventually achieved 20/30 UCVA and 20/20 BCVA with a manifest refraction of -0.50 +0.25 X 95. Her IOP stabilized at a range of 15 to 18 mm Hg on Travatan Z alone at bedtime, which allowed the patient to discontinue two of her glaucoma medications.

STUDY

This case cemented in my mind that cataract surgery with the implantation of a PCIOL effectively lowers the IOP in many patients. My colleagues and I were motivated by this patient's results and many other similar experiences to study the issue further. Thomas Samuelson, MD; Brooks Poley, MD; Richard Schulze, Sr, MD; and Richard Schulze, Jr, MD; and I decided to look more

carefully at the impact of cataract surgery with PCIOL implantation on IOP.

In a retrospective review of 588 patients without glaucomatous damage and another 129 with confirmed glaucoma, we found that patients with preoperative IOP between 23 and 29 mm Hg achieved a 6- to 8-mm Hg reduction in IOP on average after cataract surgery and PCIOL implantation.[1] In addition, cataract surgery with the placement of a PCIOL reduced patients' need for topical glaucoma therapy by 23% among subjects who had been taking antihypertensive medications preoperatively.

Based on the results of our review as well as our clinical experience, we now recommend cataract removal with lens implantation alone to nearly all patients who have cataract and glaucoma. We utilize a clear corneal incision, which spares the conjunctiva for future filtration or tube shunt surgery, if needed.

CONCLUSION

During the past 5 years, my use of combined phacoemulsification and trabeculectomy has fallen to nearly zero from more than 10% a decade ago. The case described herein inspired my more careful evaluation of cataract surgery alone in the glaucoma suspect and glaucoma patient. The result is a significant change in my practice pattern. I now believe that cataract surgery with PCIOL implantation may well be the best glaucoma procedure available today. ■

This article originally appeared in the November 2008 isue of CRSToday.

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CHAPTER 67

Combined Glaucoma Procedures

THOMAS W. SAMUELSON, MD

The presentation of coincident cataract and glaucoma is one of the most common clinical challenges facing the anterior segment surgeon. Although the only effective therapeutic intervention for a cataract is surgical, glaucoma may be effectively managed either medically or surgically. When you decide to perform a cataract procedure on patients with glaucoma, therefore, you must also determine whether to continue the medical management of their glaucoma or to perform combined cataract and glaucoma surgery.

Cataract surgery performed alone lowers IOP, at least transiently, in a significant percentage of cases,[1] and the decrease may be more significant than previously appreciated.[2] In addition, recent advances in the medical management of glaucoma have significantly reduced the number of combined glaucoma procedures performed. Despite these considerations, the combined glaucoma procedure remains an extremely important option for some patients, and surgeons must determine the best approach.

WHEN IS A COMBINED PROCEDURE APPROPRIATE?

Although there are exceptions, I prefer coincident cataract and glaucoma surgery in cases of visually significant cataract and

- glaucoma that is poorly controlled despite medical therapy;
- progressive glaucoma in patients who do not comply with prescribed therapy or cannot afford medications;
- progressive glaucoma in patients who are intolerant of medications;
- stable or progressive glaucoma in patients taking three or more glaucoma medications;
- stable, medically controlled glaucoma in patients who choose to reduce or eliminate their need for glaucoma medications;
- far advanced disease with a very aggressive target IOP.

In such cases, the cataract is the primary indication for surgery. That is, an individual with glaucoma has a visually significant cataract requiring surgery. You therefore must decide how to manage the glaucoma. There are also situations in which glaucoma surgery is indicated, and you must decide how to manage the patient's crystalline lens. In many instances, the decision is clear-cut. For example, an obviously cataractous lens in the setting of a planned glaucoma surgery calls for combined surgery. In general, my indications for removing the lens are more liberal in patients scheduled for planned glaucoma surgery. For example, I will remove a marginally significant cataract during a planned trabeculectomy, because I know that the lenticular opacification will likely progress following the glaucoma surgery.

TRABECULECTOMY

After deciding to proceed with combined cataract and glaucoma surgery, you must make several choices regarding management. Although phacoemulsification is clearly the procedure of choice for the lensectomy, there are several options for the surgical management of glaucoma. Each can be combined with cataract surgery.

Coincident phacoemulsification and trabeculectomy remain the gold standard for combined glaucoma procedures. Modern small-incision cataract surgery is an ideal adjunct to trabeculectomy. Debate continues over one-site, single-incision surgery versus separate sites for the trabeculectomy and cataract procedures. Most published studies suggest that one- and two-site surgeries are equally efficacious.[3] I commonly use both strategies, depending on the clinical situation. For example, I consider single-site surgery for eyes with excellent exposure and well-dilated pupils, because this approach is efficient and efficacious and it obviates the need for a corneal suture. I favor two-site surgery, however, for most of my combined procedures. This approach is advisable when exposure is more difficult or if you simply feel less comfortable with cataract surgery from a superior approach.

I also prefer two-site surgery when the pupil fails to dilate well, as with patients taking systemic alpha-1 blockers such as tamsulosin (Flomax; Boehringer Ingelheim Pharmaceuticals, Inc., Ridgefield, CT), those with exfoliation syndrome, or those who have bound-down pupils. In such cases, the clear corneal incision provides a frontal entry into the anterior chamber, and the iris is less likely to prolapse into the wound. When performing clear corneal surgery in the setting of trabeculectomy, I place a suture in

the corneal wound, because I cannot be certain that the early postoperative IOP will be sufficient to seal the corneal incision.

Although the early-to-midterm results of trabeculectomy are excellent, the bleb remains vulnerable to the healing whims of the conjunctiva, which often results in late failures. The conjunctiva in its natural state is prone to scarring and contraction, ultimately leading to a failed bleb. Although antimetabolites such as mitomycin C and 5-fluorouracil greatly enhance the success of trabeculectomy, the weakened conjunctiva is more prone to late bleb leaks, hypotony, and, perhaps of greatest concern, late infection of the bleb.

BLEBLESS GLAUCOMA SURGERY

Surgery that lowers IOP independent of a filtration bleb is highly desirable. Such a procedure would eliminate much of the risk and morbidity inherent to traditional bleb-based, transscleral filtration procedures. Viscocanalostomy and nonpenetrating deep sclerectomy are based on this concept. Stegmann inspired a resurgence of interest in viscocanalostomy in the late 1990s.[4] Although his viscocanalostomy is a truly "blebless" procedure, most versions of nonpenetrating deep sclerectomy rely on the presence of a filtering bleb.

Both viscocanalostomy and nonpenetrating deep sclerectomy rely on the flow of aqueous through an exquisitely thin trabeculo-Descemet's membrane. The procedures are technically difficult to perform and, like trabeculectomy, may be prone to late scarring. Accordingly, they have not been widely adopted by surgeons. Nonetheless, nonpenetrating surgery is an acceptable, safe, and effective means of lowering IOP.[5] Procedures of this sort combine well with phacoemulsification.

TRABECULAR BYPASS DEVICES

Renewed interest in procedures involving Schlemm's canal has paved the way for novel, more technologically sophisticated devices that bypass the trabecular meshwork and facilitate the flow of aqueous directly into the canal itself. These stents and shunts are investigational devices that represent the most recent efforts toward blebless glaucoma surgery. Such procedures are based on the premise that the pathology in the physiological outflow system is in the juxtacanalicular portion of the meshwork or within the inner wall itself. By bypassing the proximal trabecular meshwork, these procedures facilitate the flow of aqueous into Schlemm's canal by shunting (Eyepass Glaucoma Implant; GMP Companies, Inc., Fort Lauderdale, FL) or stenting the canal itself (iStent; Glaukos Corp., Laguna Hills, CA).

Another method that is increasingly employed to enhance flow directly into Schlemm's canal is an internal filtration surgery or ab interno trabeculectomy, which uses a device that ablates and aspirates the trabecular meshwork and the inner wall of Schlemm's canal using micro-cautery (Trabectome; NeoMedix Corporation, Tustin, CA). Performed through a clear corneal incision, the procedure combines easily with phacoemulsification.

Other devices such as the Solx Gold Micro-Shunt (not available in the US; Solx, Inc., Waltham, MA) divert aqueous into the suprachoroidal space. During excimer laser trabeculotomy, the excimer laser ablates trabecular tissue to promote the direct communication of aqueous into Schlemm's canal. Although currently investigational, such procedures can be performed at the time of cataract surgery, and they may play an increasingly important role in this setting.

PHYSIOLOGICAL OUTFLOW AND POTENTIAL PITFALLS

The decision to proceed with trabeculectomy or another procedure that completely bypasses the physiological outflow system should not be made lightly. In general, once you choose to bypass the natural outflow system, there is no going back. In all likelihood, such procedures are detrimental to physiological outflow due to underperfusion of the system. For mild or moderate glaucoma, I therefore either perform cataract extraction alone or choose a procedure to enhance conventional outflow. If such a procedure fails, I can then perform a more complete bypass such as trabeculectomy.

Although the concept of bypassing the trabecular meshwork is intriguing and promising, much work remains to be done. Some investigators have expressed concern over the lack of circumferential flow within Schlemm's canal. That is, even if a stent or shunt successfully bypasses the trabecular meshwork, it is generally accepted that the enhanced outflow may be limited to several clock hours surrounding the bypass or perhaps to a single quadrant. As a result, multiple stents or shunts may be needed to lower the IOP adequately. Alternatively, the circumferential flow may be enhanced by microcannulation of the canal with newly developed, investigational techniques such as 360º viscocannulation (iTrack microcatheter; iScience Interventional, Menlo Park, CA). Canaloplasty is gaining acceptance as a viable procedure to lower IOP without the creation of a filtering bleb. Midterm data were recently reported on canaloplasty as a stand-alone procedure and as an adjunct to cataract surgery.[6,7]

ENDOSCOPIC CYCLOPHOTOCOAGULATION

Endoscopic cyclophotocoagulation is another option for the coincident management of cataract and glaucoma. The procedure utilizes a clear corneal incision and is tailor made as an adjunct to cataract surgery, because access to the ciliary processes is greatly enhanced in pseudophakic eyes. Although a prospective randomized trial is not available, the technique has become popular for the management of early, less complex glaucoma as a way of reducing the burden of medical therapy. Although I prefer to lower IOP by enhancing outflow, there may be a role for endoscopic cyclophotocoagulation in the reduction of pressure in select patients.

SUMMARY

The field of glaucoma is in a period of transition, and the surgical options for the simultaneous presentation of cataract and glaucoma continue to evolve and improve. Individualize your decisions on management to the patient and your skill set in order to maximize outcomes and minimize risk. ■

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CHAPTER 68

Combined Procedures

BRADFORD J. SHINGLETON, MD

Cataract and glaucoma commonly coexist and present special problems for the ophthalmologist. The risks and rate of complications of cataract surgery are greater in glaucomatous than nonglaucomatous eyes due to miotic pupils, posterior synechiae, peripheral anterior synechiae, the presence of preexisting blebs, and pseudoexfoliation. The lack of consensus as to the best surgical approaches for coexisting cataract and glaucoma is therefore not surprising. Should ophthalmologists perform combined cataract and glaucoma surgery or separate the procedures? If the latter, should phacoemulsification precede glaucoma surgery, or vice versa? If combined surgery is a superior option, is one site or two preferable?

The development of nonfiltering surgeries for IOP control increases the number of glaucoma procedures that can be performed in tandem with cataract surgery. The timing and long-term outcomes of cataract surgery in the setting of glaucoma also remain controversial. This article assesses the benefits and drawbacks of combined cataract and glaucoma surgery, its indications, and its performance.

PROS AND CONS

Among its advantages, combined cataract and glaucoma surgery involves a single trip to the OR and restores patients' vision relatively promptly compared with separate procedures. Compared with cataract surgery alone, patients often require fewer glaucoma medications after combined surgery, and early and long-term postoperative IOP control is often better.[1] In addition, surgeons can administer antimetabolites to enhance the probability of lower IOP postoperatively. Finally, removing the cataract facilitates their assessment of the optic nerve and visual fields.

Unfortunately, combined surgery is associated with more postoperative complications than cataract surgery alone. The problems of a shallow anterior chamber, bleb leak, choroidal effusion and/or hemorrhage, hypotony, infection, dellen, and astigmatism can all be more serious as well. Compared with cataract surgery alone, a combined procedure is more time consuming and is associated with more intense requirements for postoperative care.

INDICATIONS

There are no rigid standards for when combined cataract surgery should be performed, and one cannot be dogmatic about the indications for this approach. Because combined procedures result in better IOP control and reduced requirements for glaucoma medication than phacoemulsification alone, I favor a combined procedure when patients require more than two medicines for satisfactory IOP control. I am similarly inclined if their use of medication is limited by allergy or medical contraindications. I also may choose a combined procedure in young patients and those who have sustained significant glaucomatous visual field loss and cupping. In addition, I tend to prefer this approach in monocular patients or individuals with significant risk factors for glaucoma such as pseudoexfoliation, pigment dispersion, or angle recession. Lastly, combined cataract and glaucoma surgery is indicated in patients unable to tolerate two separate operations due to medical problems limiting the number of trips to the OR.

Cataract surgery alone may be appropriate for an individual whose IOP is adequately controlled and who has sustained no significant glaucomatous visual field loss or cupping. Many patients experience a small but significant reduction in IOP after clear corneal phacoemulsification.[2] A two-staged procedure, with a glaucoma operation preceding the phaco procedure, may be indicated when glaucoma is an immediate threat to vision (eg, markedly increased IOP in patients with active uveitis or neovascularization). Even in the presence of a visually significant cataract, an IOL may not be indicated in patients with high IOPs and active inflammation. The fact that the phacoemulsification performed after glaucoma surgery is often successful makes this approach a reasonable option for certain patients.

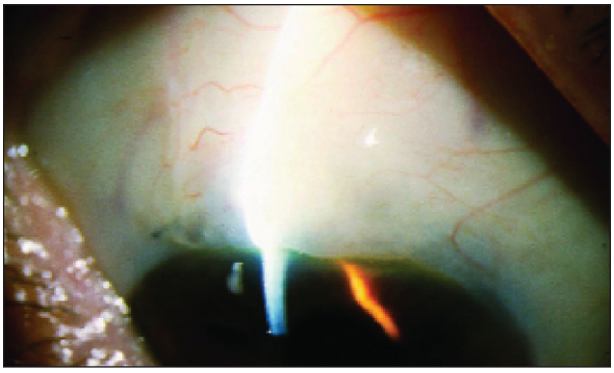

Figure 1. An excellent filtering bleb developed after separate-site combined phacotrabeculectomy.

SEPARATE SITES

Theory

Weitzman and Caprioli have argued that performing phacoemulsification and trabeculectomy at separate sites enhances the development of effective filtration[3] (Figure 1). It also permits cataract surgeons to perform phacoemulsification from a position that most find comfortable—a temporal approach.

Technique

First, the ophthalmologist performs phaco/IOL surgery. A small, clear corneal/limbal incision and foldable IOL are preferable to minimize conjunctival manipulation. I favor a single, buried, 10–0 nylon suture to facilitate early digital pressure and supplemental 5-fluorouracil (5-FU), if needed, during the early postoperative phase.

Next, the surgeon shifts to the superior axis to perform the trabeculectomy. The conjunctival flap is mobilized according to his preference, and intraoperative antimetabolites may be used. The surgeon performs his standard trabeculectomy.

Results

Via an evidence-based review, Friedman et al reported better IOP control with a combined procedure performed at separate sites versus a single one.[1] When comparing single- and two-site combined procedures, my colleagues and I found an equal reduction of IOP, degree of visual improvement, and reduction in medication.[4]

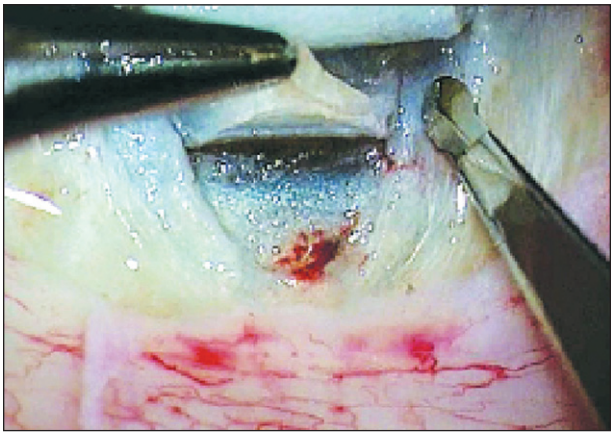

Figure 2. The surgeon mobilized the deep scleral flap to expose Schlemm's canal during combined phacoemulsification and viscocanalostomy surgery.

SINGLE SITE

Theory

A single-incision approach is simple, fast, and effective although potentially less comfortable for the temporally oriented phaco surgeon. An ophthalmologist's choice to perform a single- or separate-site procedure is a matter of preference, but, in all cases, he should make an effort to minimize the manipulation of and trauma to ocular tissue.

Technique

This procedure involves a superior approach, and I favor an inferior, limbal, 6–0 silk positioning suture to facilitate superior exposure of the limbal area. A paracentesis incision permits bimanual phacoemulsification and also enables the testing of filtration outflow at the end of the case. A conjunctival flap is mobilized via a limbus- or fornix-based approach. My colleagues and I found that both limbus- and fornix-based conjunctival flaps are effective for reducing the IOP, developing a bleb, improving vision, and reducing the number of glaucoma medications postoperatively.[5] Most importantly, with a fornix-based flap, one may anticipate more anterior bleb leaks and should closely check for them postoperatively and provide treatment as necessary.

Intraoperative antimetabolites facilitate the reduction of IOP. One may apply topical mitomycin C (0.2 to 0.5 mg/mL) or 5-FU (50 mg/mL) to reduce fibrous proliferation and scarring of the bleb postoperatively.

Scleral flaps can be mobilized in any shape, and the most important factors for IOP control are the thickness of the flap and the tightness of its closure. If I anticipate performing laser suture lysis postoperatively, I favor 10–0 nylon sutures with the knots buried. Releasable sutures are also effective for regulating and modulating aqueous outflow and the development of a bleb.[6-8]

Multiple suture needles and materials can be used for conjunctival closure. For limbus-based flaps, I favor 9–0 Vicryl (Ethicon Inc., Somerville, NJ), 10–0 BioSorb (Alcon Laboratories, Inc., Fort Worth, TX), or 10–0 nylon. Incorporating Tenon's tissue in the closure may enhance its seal. Fornix-based flaps can be closed with wing sutures, horizontal mattress sutures, or running sutures such as those described by Wise.[9] Wing sutures with denudation of the limbal corneal epithelium reduce the number of sutures in the sclerectomy area and may minimize inflammation, but they also may be associated with more leaks and anterior migration of the bleb. Running sutures utilizing a limbal remnant or the Wise closure reduce bleb leaks and the anterior migration of the bleb, but they may be associated with more inflammation because of suture material near the sclerectomy site.

It is important to test filtration and the elevation of the bleb by injecting balanced salt solution via the paracentesis at the conclusion of the procedure. Topical 2% fluorescein strips or a Weck-Cel sponge (Medtronic ENT, Jacksonville, FL) can be used to test for bleb leakage.

Results

In my hands, a single-incision combined procedure without antimetabolites produced a mean IOP reduction of approximately 5 mm Hg at 1 year and decreased the number of glaucoma medications by approximately 75%.[10] The IOP reduction has been sustained for 3 years in these patients, but their need for medication has tended to increase slightly. Intraoperative antimetabolites are associated with lower IOPs postoperatively but also with more postoperative complications. Subconjunctival 5-FU administered postoperatively can also enhance the bleb's development.

OTHER POSSIBLE COMBINATIONS

A host of other glaucoma procedures can be combined with cataract surgery. Surgeons may couple phacoemulsification and the implantation of a tube shunt such as the Ex-Press mini glaucoma shunt (Optonol Ltd., Neve Ilan, Israel), which creates an external filter. Many new shunting devices are currently under development that will permit the surgeon to perform a trabeculectomy with an internal tube shunt, silicone drainage tube, or a gold implant (Solx Gold Micro-Shunt; Solx, Inc., Waltham, MA) in the suprachoroidal space.

Alternatively, one might perform endoscopic cyclophotocoagulation (ECP) along with phacoemulsification. ECP produces modest postoperative reductions in patients' IOPs and needs for glaucoma medication.[11,12] Moreover, ECP does not appear to be associated with the significant inflammation that occasionally occurs after external cycloablative procedures.[11]

Another option is to combine a nonpenetrating deep sclerectomy procedure with cataract surgery (Figure 2). Park et al reported a reduction in IOP of 3.4 mm Hg at 1 year and 3.6 mm Hg at 3 years with viscocanalostomy and cataract surgery.[13] It would be interesting to read an evaluation of the potential combination of phacoemulsification and 360º canaloplasty with the microcannula developed by iScience Interventional (Menlo Park, CA). The device expands the dilation of Schlemm's canal beyond that normally achieved with standard viscocanalostomy and, like the latter procedure, minimizes bleb development. Techniques utilizing collagen (AquaFlow Collagen Glaucoma Drainage Device; STAAR Surgical Company, Monrovia, CA) or hyaluronic acid actually facilitate the egress of aqueous into the subconjunctival space and can be coupled with deep sclerectomy procedures to facilitate bleb development. Surgeons may use antimetabolites intraoperatively with the nonpenetrating deep sclerectomy procedures aimed at creating blebs.

European ophthalmologists have combined cataract surgery with excimer laser trabeculotomy via an *ab interno* approach, although this technology is not approved in the US. Standard trabeculotomy is another option.[14]

It is also worth noting that goniosynechiolysis can be coupled with cataract surgery and chamber-deepening procedures to open preexisting angle closure. My colleagues and I showed this approach to be effective for angle closure of up to 12 months'

duration.[15] Finally, Terry described coupling phacoemulsification and holmium laser sclerostomy,[16] and Montgomery and Gills reported combining cyclodialysis with cataract surgery in 1980.[17]

SUMMARY

There have been tremendous advances in combined surgery during the past 4 decades. In the 1970s, intracapsular surgery with a filter was the most common approach, with the filtration procedure typically occurring first. In the 1980s, the trend became extracapsular procedures with simultaneous trabeculectomies. Improvements in viscoelastics and IOLs along with laser suture lysis and releasable sutures enhanced success rates. In the 1990s, phacotrabeculectomy came into its own with the use of small incisions, foldable IOLs, and antimetabolites. In the new millennium, surgeons have become more interested in separating the sites for the combined cataract and glaucoma procedure, and they have a greater appreciation for the effect of phacoemulsification alone on IOP. The use of nonpenetrating deep sclerectomy procedures, some of which avoid a bleb, has also grown extensively.

As cataract incisions shrink further, one may imagine a future in which IOLs enhance the visual field or continuously monitor IOP intracamerally, implants release glaucoma medication, antimetabolites are more effective and safer, photodynamic therapy of the conjunctiva modulates fibroblastic proliferation, and novel nonfiltering surgical procedures reduce bleb-associated problems. ■

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CHAPTER 85

Is Endophthalmitis on the Rise?

MEHRAN TABAN, MD

Of the numerous advances in the field of cataract surgery during the last half of the 20th century, the introduction of sutureless phacoemulsification using clear corneal incisions has affected the field most significantly. With its efficient technique, minimal rate of surgically induced trauma, shortened operative times, low induction of astigmatism, limited postoperative inflammatory response, and fast postoperative recovery, sutureless, clear corneal cataract extraction has steady gained acceptance among cataract surgeons since its introduction in 1992.[1] In the most recent survey of ASCRS members, Leaming et al[2] reported that the clear corneal incision and the sutureless techniques are preferred by 72% and 92% of US surgeons, respectively.

During the last decade, however, reports have indicated that the incidence of endophthalmitis after cataract surgery may be on the rise, and some have speculated about whether the complication is associated with clear corneal incisions.[3,4] Although the greater rate of infection may primarily be due to increased antibacterial resistance, the absence of a reported increase in endophthalmitis following other intraocular surgeries (penetrating keratoplasty, trabeculectomy, etc.) during this period and the proliferation of aseptic surgical techniques challenge this argument. Other factors therefore must be carefully investigated, and the sutureless clear corneal incision technique remains a possible candidate.

LITERATURE REVIEW AND LABORATORY INVESTIGATION

In 2000, Colleaux and Hamilton[3] reported a two-and-a-half times greater incidence of endophthalmitis following cataract extraction with a sutureless, clear corneal incision relative to a scleral tunnel incision. More recently, Nagaki et al[4] reported an almost sixfold greater risk in endophthalmitis associated with clear corneal incisions compared with sclerocorneal incisions. A recent review of the English-language literature presented at the 2003 AAO annual meeting analyzed more than 200 studies (comprising over 3 million cataract surgeries) that addressed endophthalmitis after cataract extraction between 1963 and 2003.[5] When the study period was split into two sets, prior to and after 1992, a gradual but noticeable increase was apparent after 1992, when the technique of clear corneal incision was introduced. In a comparison of types of incision from 1992 to 2003, a significantly higher risk of endophthalmitis occurred with clear corneal incisions compared to either scleral or limbal incisions (an increase in relative risk of two-and-a-half and three times, respectively).

Two studies conducted in cadaveric rabbit and human eyes may help to explain the etiology of the apparent association between endophthalmitis and clear corneal incisions. One using optical coherence tomography showed the possibility of corneal wound gaping secondary to IOP variations in both human and rabbit eyes.[6] Similarly, investigators using the Miyake viewing technique in cadaveric human eyes showed an ingress of extraocular India ink or fluid following IOP variations.[7] In the latter study, four of seven eyes showed the intraocular presence of ink, after standard external manipulation in three eyes and after IOP variation alone in the fourth. These studies demonstrated a possible mechanism by which microorganisms gain access into the intraocular space during the critical early postoperative period, when the wound has not yet healed.

CONCLUSION

Endophthalmitis remains one of the most feared complications of ocular surgery. Although this review of the literature suggests that the pattern of endophthalmitis after cataract surgery is associated with the introduction and increased use of the clear corneal incision, there is no proof of a causal relationship, and inevitable bias (positive or negative) is evident in the literature. Only a large, multicenter, prospective, randomized study can answer the question of the cause of endophthalmitis after cataract surgery. In the meantime, careful wound construction with a minimal tolerance for wound leakage, the placement of sutures whenever necessary, and continued vigilance in the surveillance of infection are necessary. ■

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CHAPTER 86

Clear Corneal Incisions and Endophthalmitis

I. HOWARD FINE, MD; RICHARD S. HOFFMAN, MD; AND MARK PACKER, MD

There is no doubt that the incidence of infectious endophthalmitis after cataract surgery has increased. Most frequently quoted are the retrospective study by Cooper et al[1] and the prospective study by Nagaki et al.[2] Another certainty is that the use of clear corneal incisions has risen recently. The transition from scleral tunnel to clear corneal incisions involves a learning curve, during which time the surgeon may experience an increased rate of complications. The question to be addressed, therefore, is whether the rising use of clear corneal incisions is causing the increase in cases of endophthalmitis following cataract surgery.

BACTERIAL RESISTANCE

It is important to take into account the change in bacterial resistance to antibiotics (Figure 1). Gram-positive organisms are overwhelmingly responsible for postoperative endophthalmitis: 69% of patients with bacterial endophthalmitis were culture positive, and 94% of the infectious agents were gram-positive organisms.[3] In 1997 and 1998, 100% of the organisms associated with postcataract surgery endophthalmitis were sensitive to the fluoroquinolones then available (Figure 2). By 1999, only 20% remained sensitive, and 100% of those organisms were resistant to the existing fluoroquinolones by 2001.[4] The growing resistance of microorganisms to antibiotics certainly has some bearing on the increased rate of endophthalmitis.

Two Swedish reports[5,6] in 2002 cited the lowest level of endophthalmitis ever despite an increased use of clear corneal incisions. The findings are probably a result of the use of prophylactic intracameral cefuroxime at the close of surgery. These reports provide further evidence of the significant role that antibiotics play in the prevention of bacterial endophthalmitis.

PERSONAL EXPERIENCE

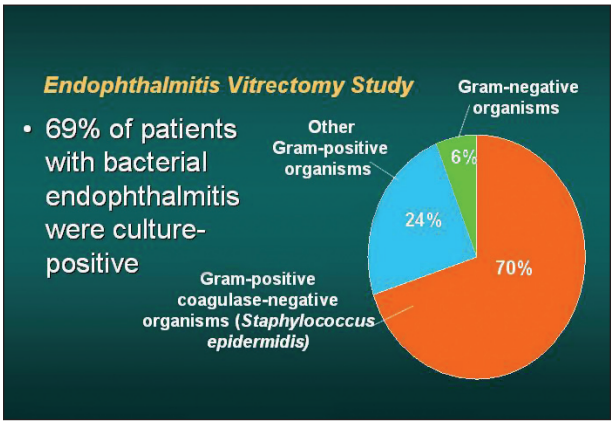
Although we use only clear corneal incisions, we have not encountered a single case of infectious endophthalmitis in more than 9 years and 8,000 cases. Rather than good luck, we believe our experience is due to our attention to detail.

A recent dye study by McDonnell et al[7] in cadaver eyes demonstrated that, in the presence of hypotony, clear corneal incisions tend to draw India ink into the incision. Shingleton et al[8] reported that 20% of the patients examined 2 hours postoperatively had IOPs of less than 10mmHg. Dr. Fine found a 15% similar incidence in his own practice (unpublished data). Of extreme importance is the fact that neither Shingleton et al nor Dr. Fine have experienced an increased incidence of endophthalmitis in spite of immediate postoperative hypotony, which McDonnell et al[7] hypothesized was the cause of an increased incidence of endophthalmitis.

DETAILS THAT MATTER

Preparing the Eye

We apply 5% povidone-iodine (Betadine; Purdue Frederick, Stamford, CT) to the ocular area, and we use Steristrips to evert the eyelashes so that they are flush against the skin and the meibomian gland's orifices are exposed. After draping the eye, we place a wick in the lateral canthus to disallow the pooling of fluid.



(Courtesy of James McCulley, MD.)

Figure 1. This chart illustrates the types of endophthalmitis encountered after cataract surgery.[3]

Creating the Incision

Rather than incising the steep axis, we create incisions at the temporal corneal periphery in order to address astigmatism and postoperatively neutralize the pressure effects of blinking and gravity. When indicated, limbal relaxing incisions address preoperative astigmatism.

Replacing aqueous with viscoelastic stabilizes the eye and firms the anterior chamber. This technique also permits us to construct incisions reproducibly, because the eye does not become unpredictably distorted due to hypotony.

To create the incision, we applanate the trapezoidal knife against the surface of the globe with the point just anterior to the conjunctival insertion. The knife is advanced in the plane of the cornea for 2 mm and then directed through Descemet's membrane, into the anterior chamber. We then advance the knife until the internal incision's width is the appropriate size, usually indicated by the width of the shoulders of the tip.

We prefer single-plane incisions, which create better architecture for valve structure than do grooved incisions and maximize endothelial pumping, because there is no opening in the corneal-epithelial fluid barrier. We use trapezoidal incisions, which we can enlarge for IOL implantation by advancing the trapezoidal knife farther into the eye without compromising the architecture of the incision. We avoid side-cutting knives, which can alter the incision's architecture and are frequently inaccurate with respect to the final width of the incision. All cataract incisions should be at least 2 mm long and no more than 2.5 to 3.5 mm wide.

Surgical technique is crucial to the incision's integrity. We never

(Courtesy of Francis Mah, MD.)

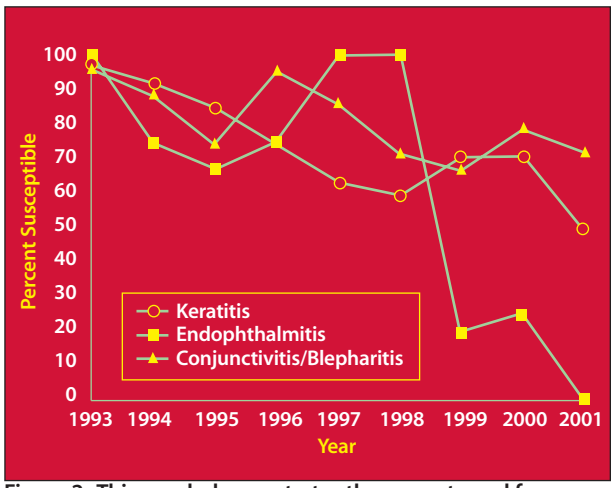


Figure 2. This graph demonstrates the current need for fourth-generation fluoroquinolones and focuses on the in vitro susceptability of *Staphylococcus aureus*.[4]

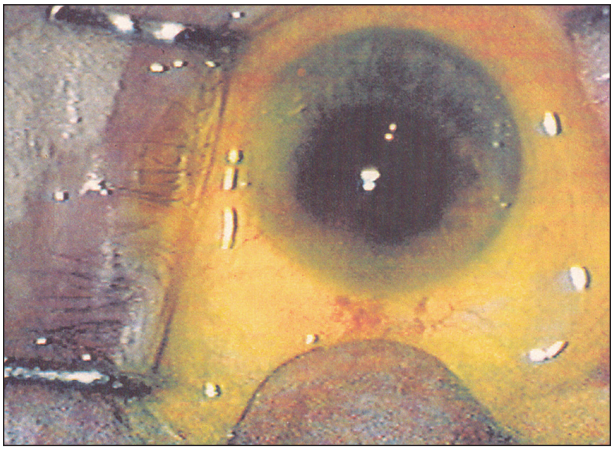


Figure 3. One of the authors tests the seal of a clear corneal incision at the conclusion of surgery.

grasp the superior lip with a forceps, because this instrument can abrade the epithelium and cause a loss of the fluid barrier. Instead, we lift the roof of the incision from its floor with a cannula in order to insert an instrument such as a pupil dilator or an injector for a capsular tension ring. We prefer beveled phaco tips, which we insert bevel down by pushing against the floor of the incision and insinuate into the eye. During phacoemulsification, power modulations protect the eye against thermal injuries, which can compromise the integrity and sealing of the incision.

Implanting the IOL

IOL implantation should occur through adequately and precisely enlarged incisions. Stretching the incision aggressively can negatively affect its ability to seal. When stabilizing the eye with a fixation ring, injection systems are far superior to folding forceps, which require a larger incision and distort the wound further.

Sealing the Incision

We perform stromal hydration of the main and sideport incisions by filling the eye to physiologic pressures or slightly higher without ever overpressurizing the eye. The patient wears a soft contact lens if the epithelium located over the incision is abraded. We suture the incision whenever necessary and always test for leakage. It is important to recognize the importance of endothelial pumping and proper architectural features that allow for mechanical stability. To test for leakage, we place fluorescein stain on the eye and press the posterior lip of the incision with a finger (Figure 3). Many of the studies showing an incision's inability to seal are based on pinpoint pressure.[9,10] This technique is completely nonphysiologic and irrelevant; a patient would have to press on his eye with something the size of a pencil's point. Moreover, pinpoint pressure can cause a paracentesis, although hypersquare, to leak, but no one questions the safety of this type of incision.

Using Antibiotics

Our patients receive a fourth-generation fluoroquinolone q.i.d. for 3 days preoperatively, at least q.i.d. on the surgical day, and q.i.d. for 10 days postoperatively. We believe it would not be unreasonable to administer this antibiotic q2h on the day of surgery and perhaps even on the first postoperative day.

CONCLUSION

Clear corneal incisions offer many benefits, including safety and efficacy, but successful outcomes require a surgeon's attention to detail, as described herein. That stated, ophthalmologists should use the incision that they can perform with the most reproducibly safe results. ■

This article originally appeared in the February 2005 issue of CRSToday.

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CHAPTER 87

Preventing Endophthalmitis

RANDALL J. OLSON, MD

After a perfectly performed cataract procedure with excellent results on the first postoperative day, it is disheartening when the patient returns with signs of increased inflammation likely to be endophthalmitis (Figure 1). Although cataract surgeons have come a long way in treating endophthalmitis, severe organisms such as *Streptococcus* and *Pseudomonas* species still routinely devastate final visual acuity. Even more benign bacteria will often negatively affect results.

As clear corneal surgery became common practice, the incidence of endophthalmitis increased. Because new approaches or technology are so often greeted by pessimism, it is easy to dismiss critics' complaints as a normal reaction to change. My colleagues and I adopted clear corneal surgery with great enthusiasm, and it became our predominant technique by mid-1996. Clear corneal surgery in combination with topical anesthesia allows for a prompt return of vision without sutures.

Our experience with endophthalmitis is no different than others' in that the complication is rare but often occurs in clusters, making it nearly impossible to gauge the actual incidence. As a result, we began a prospective, quality-control study on endophthalmitis in 1997.

In early 2001, we concluded that our incidence of endophthalmitis was increasing dramatically from a historical rate that we calculated as less than 1 in 1,000 cataract surgeries. We had enough data to know this increase was not simply a cluster of events. Furthermore, we had no cases of endophthalmitis in patients who had corneal-scleral incisions. All of the incidents of endophthalmitis occurred in patients with clear corneal incisions. Nevertheless, we know many ophthalmologists across the country, myself included (I have not had a single case of endophthalmitis after cataract surgery), who state that they have not had a problem with clear corneal surgery during their career. How to make sense of the seeming conflict of data and personal reports was a major and important research step that we decided we must undertake.

CAUSES OF ENDOPHTHALMITIS

Choice of Surgery and Lens

Many studies have suggested an increase in endophthalmitis with clear corneal incisions. Nagaki et al[1] conducted a prospective, randomized, clinical trial comparing the difference between clear corneal and corneal-scleral incisions, the difference between using silicone and acrylic lenses, and the relation of incision and lens type to the incidence of endophthalmitis. This study, which included more than 12,000 surgeries, is definitive in addressing both surgical and lens choices. The results showed a statistically significant increase in the incidence of endophthalmitis in association with clear corneal surgeries (0.29% vs 0.05%; *P*=.037), but the investigators did not find a difference between silicone and acrylic lenses. It is virtually impossible to refute their study, and the only conclusion that I can make is that clear corneal surgery can dramatically increase the incidence of endophthalmitis. The operative word is *can*, not will.

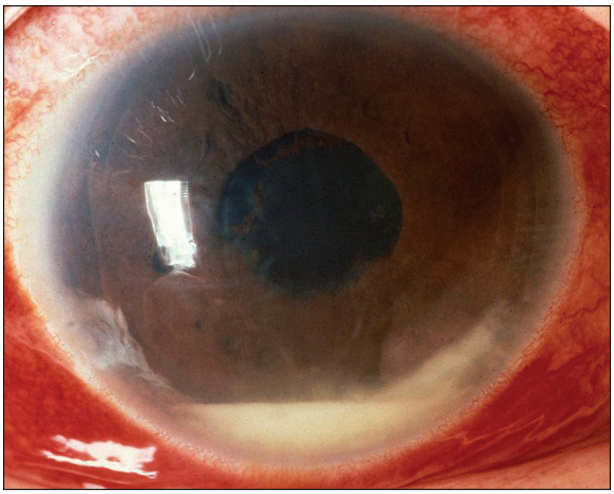

Figure 1. A patient presents with endophthalmitis after cataract surgery.

Cataract Surgery Incisions

In their landmark work, Taban et al[2] studied how wounds behave under pressure using eye-banked eye preparations. They demonstrated that a long incision, which my colleagues and I have always considered the strongest, is very resistant to elevated IOP. However, long incisions can sometimes gape and leak with a low IOP compared with incisions that are more perpendicular to the surface of the eye. The latter type of incision, or short incisions, will leak with an elevated IOP, but they actually seal better with a low IOP. Taban et al[2] studied further and used India ink as a bacterial model because its particle size is similar to that of bacteria. They found that, as the IOP increased, even long incisions resistant to leakage gaped externally and allowed the India ink to enter the wound. Additionally, as the IOP dropped, there was the potential for an internal gape that theoretically could result in bacteria's entering the anterior chamber, although the IOP never dropped to zero and there was never obvious leakage (Table 1). One criticism of this study is that the investigators used dead tissue without living endothelial cells; certainly, if the endothelial pump had been intact, it would have secondarily sealed the wound and possibly avoided some of the leakage associated with their findings.

Clear Corneal Surgery

The study by Taban et al[2] combined with our own results as well as those of Nagaki et al[1] point to the fact that microleaks after cataract surgery are more common in patients who undergo clear corneal surgery, at least some of the time. In addition, the increased risk of leakage with attendant contamination is why some ophthalmologists are seeing more cases of endophthalmitis. A definitive study to prove that thesis would be extremely difficult to create, but the circumstantial evidence seems sufficient.

It is important for ophthalmologists to understand that the risk of endophthalmitis is not guaranteed to be higher with clear

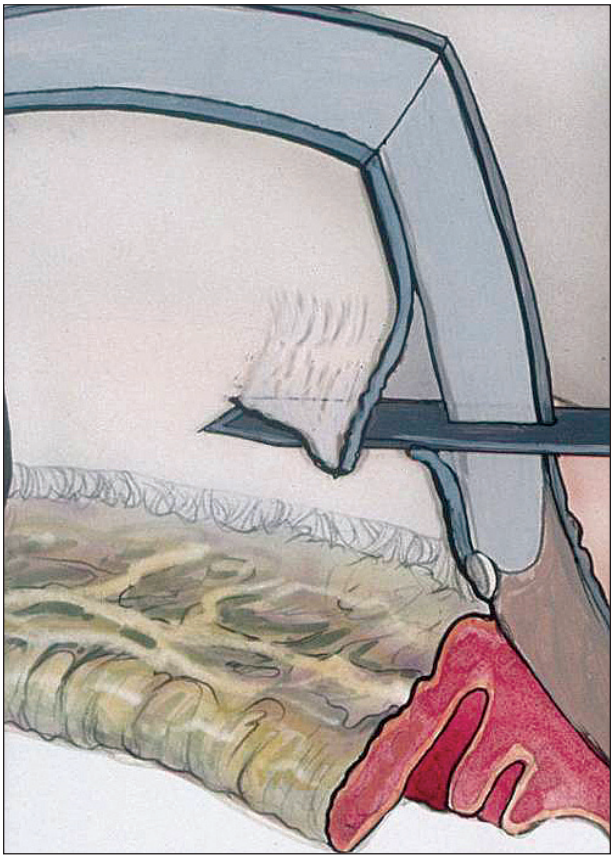

Figure 2. A dull keratome can induce a small, single tear of Descemet's membrane.

corneal surgery but that the incisions themselves are very unforgiving. I believe the reasons why some ophthalmologists have not encountered a rise in their rates of endophthalmitis are their careful attention to detail and their suturing of any marginal wounds, which are more likely to leak than those that are well constructed.

Wounds

Marginal wounds require careful scrutiny. In my experience, they are generally related to a small tear in Descemet's membrane, overstretching and internal tearing, or an external tear, all of which dramatically decrease the IOP/leakage curve.

A small tear in Descemet's membrane can occur at any time during cataract surgery and usually starts at the wound internally and runs back toward the limbus. The tear will leave a portion of Descemet's membrane and endothelium that can flap back and forth during irrigation, but, because it is located under the wound, the tear can often go unnoticed (Figure 2). I always irrigate through the stab incision, because I can often see the torn flap moving as the irrigation passes. Irrigation can frequently bring the torn flap into apposition with the cornea. I believe that all such cases require a suture.

Although some cataract surgeons may consider it overkill, I feel that the closure of the wound requires both a mechanically correct incision and the secondary sealing action of the endothelial pump. As outlined by Taban et al,[2] relying on the mechanical nature of the wound alone is risky. Even though ophthalmologists worry about early elevated postoperative IOP, Shingleton et al[3] clearly showed that significant hypotony (frequently 5 mm Hg) often occurs after surgery. Low pressure is as much a concern as high pressure. A well-constructed wound without an active endothelial pump is a risk I am not willing to take.

Internal tearing or stretching of the wound typically occurs when cataract surgeons force instruments or a lens through a wound that is too small. At the conclusion of surgery, some of the structures may be torn, and the wound may not come together nicely. I do not believe that these indications necessarily require the placement of a suture. If I can easily cause leakage with a little stromal hydration, inflation of the eye, and pressure applied directly behind the wound as well as 180º away, then I will place a suture.

A third problem is an external tear on either side of the incision. This is easily done during the creation of the incision with a diamond blade, either due to torquing or lifting one side of the keratome such that one edge is much shorter than the desired 2.0- to 2.5-mm length. I am convinced that the wound is only as strong as its weakest part. If one side is torn due to surgical maneuvers inside the eye or cut at the beginning of the procedure, then a suture is necessary. As mentioned earlier, if this wound does not automatically and easily seal, I recommend placing a suture.

Stromal hydration can be used to seal the incision. For the wound to seal and the endothelial pump to work, everything must remain in apposition for a period of time. Otherwise, the profound leakage through the wound will overwhelm the endothelial pump, and the wound will continue to leak. Still, surgeons cannot rely too much on stromal hydration, which forces otherwise marginal wounds to close that can leak later. Stromal hydration is a temporary fix.

STUDY

In another study, my colleagues and I randomly analyzed 10% of more than 15,000 consecutive cataract surgeries and compared these with 27 cases of endophthalmitis after cataract surgery during the same timeframe.[4] We found that, if the wound were frankly leaking on the first postoperative day, the risk of endophthalmitis increased more than fortyfold. In fact, with sutureless, clear corneal incisions that leak on the day after surgery (often as a patient blinks), we can see the tears moving in and out of the anterior chamber. I consider such leakage a mandatory reason to put in a suture. These patients need frequent dosing of topical fourth-generation fluoroquinolones and require close observation for the earliest sign of increased inflammation, which should be considered a presumptive diagnosis of endophthalmitis (Table 2).

Eyes with torn capsules or zonules were about 15 times more likely to develop endophthalmitis. This incidence was four times higher than described in the classic study by Javitt et al,[5] who showed that vitreous loss increased endophthalmitis fourfold back when it was standard to suture the incision. Torn capsules and zonules, therefore, warrant a sutured incision and increased surveillance.

The other statistically significant findings of our study relate to the type of antibiotic, when antibiotics were used, and the use of a collagen shield. We switched to fluoroquinolones from aminoglycosides and used only Ciloxan (Alcon Laboratories, Inc., Fort Worth, TX) and Ocuflox (Allergan Inc., Irvine, CA.). We found that the use of Ciloxan increased the risk of endophthalmitis three- to fivefold, which may be related to the inability of ciprofloxacin to penetrate into the anterior chamber. Fortunately, such is not the case for ofloxacin, levofloxacin (Quixin; Santen, Inc., Napa, CA), or

TABLE 1. ATTRIBUTES OF A WOUND LIKELY TO LEAK

Torn and/or detached Descemet's membrane
An unusually stretched wound
A wound difficult to seal
A short distance to the opening at either end of the wound

any of the new fourth-generation fluoroquinolones. This is the first study of which I am aware to give strong, presumptive evidence that antibiotics are important in the prevention of endophthalmitis. It is important to remember that culturing the anterior chamber after cataract surgery will result in a positive endophthalmitis culture 20% to 60% of the time, statistics that have been shown in many studies. Most notable is that the anterior chamber can clear a fairly good sized bacterial inoculum, but the vitreous cannot. Our study results strongly suggest that, if there is enough antibiotic in the eye to eliminate the bacterial inoculum, endophthalmitis can be prevented.

Starting antibiotics on the day of surgery versus waiting until the next day also decreased the risk of endophthalmitis by a factor of three to five. The use of a collagen shield decreased the risk of endophthalmitis three- to fivefold.

All of our findings stood up to the rigor of a multivariate regression analysis and were independently important. In addition to facilitating the delivery of antibiotics to the eye, a collagen shield may provide some support to the wound, much like a bandage contact lens, and may help prevent early leakage. My colleagues and I performed a series of studies, which have been submitted for publication, looking at the use of fourth-generation fluoroquinolones with a collagen shield for the prophylaxis of endophthalmitis. With this approach, gatifloxacin and moxifloxacin demonstrated excellent penetration into the anterior chamber.

CONCLUSION

Clearly, antibiotic prophylaxis as well as the integrity of the cataract incision are important to the prevention of endophthalmitis. Marshall[6] found that the new Atomic Edge silicon chip blade (BD Ophthalmic Systems, Franklin Lakes, NJ) creates a wound with much greater bursting strength than that created by a diamond. The silicon blade is an example of innovative technology to strengthen sutureless wounds. Other ophthalmologists argue we simply need to go back to using sutures. What is needed are good dialogue and solid studies so we can make progress and minimize this scourge. At the least, we should suture all questionable wounds and frequently use antibiotics that can achieve therapeutic levels in the eye starting right after surgery. ■

TABLE 2. SIGNIFICANT RISK FACTORS ASSOCIATED WITH ENDOPHTHALMITIS IN THE JOHN A. MORAN EYE CENTER ENDOPHTHALMITIS STUDY[4]

Clear corneal incisions
Leaky wound on the first postoperative day
Capsular or zonular trauma
Topical antibiotic that penetrates poorly into the eye
Starting topical antibiotics the day after surgery
Not using a collagen shield

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CHAPTER 118

Highly Accurate IOL Calculations

WARREN E. HILL, MD

Accurate IOL calculations begin with identifying the patient's visual goals. No one needs to explain this concept to a LASIK surgeon, but cataract surgeons all too often overlook this basic starting point. With patients' expectations continuing to increase, it is becoming more important to follow the lead of our refractive colleagues and take the time to agree upon a refractive goal with each patient prior to cataract surgery. It may come as a surprise that your patients will often give you an answer other than emmetropia. For example, a patient of mine is a well-known chef who told me that his world exists mainly at arm's length. We agreed before surgery that -1.50 D would be our refractive target. Conversely, for a pilot, the refractive goal would undoubtedly be plano. Ascertaining individual preferences, especially if a specific occupational concern is important, can convert those patients who clearly know what they want into a small army of ambassadors for your practice.

THE COMPONENTS OF ACCURATE CALCULATIONS

For normal eyes, using the best aspects of today's technology makes it possible to consistently achieve highly accurate postoperative results. As always, however, the devil is in the details, meaning that we have to execute all components of the exercise correctly. Patient selection, accurate keratometry, the method of biometry, the IOL power formula selected, and even the surgical technique all play important roles. To concentrate all of our attention on biometry is to miss the point. For example, if the keratometry is off by 0.75 D, then the final postoperative refraction will be off by that same amount. Using the SRK/T formula in the setting of high-axial hyperopia will probably produce a hyperopic result. If the capsulorhexis is much larger than the optic of the IOL, a myopic shift may occur following the contraction of the capsular bag. Finally, knowing when to repeat a measurement that does not fall within an established set of validation criteria is as important as knowing how to carry out the measurement correctly in the first place. Highly accurate IOL power calculations are the result of a collection of many nuances, all linked together and each needing optimization.

AN EXCITING TIME

Refractive surprises have occurred ever since Sir Harold Ridley implanted the first IOL in 1949. With steady technological advances, the overall accuracy of our refractive outcomes has generally doubled every 5 to 10 years. With the introduction of the IOLMaster (Carl Zeiss Meditec Inc., Dublin, CA) in North America in 2000, refractive outcomes within 0.25 D of the targeted refraction became a reality for the first time. This milestone allows us to set our sights on far more sophisticated endeavors, such as allowing our patients to fully enjoy the correction of spherical aberration. We are clearly entering a very exciting time in the history of IOL power calculations.

There are several patient groups for whom it is not always possible to deliver a highly accurate refractive result, however. At present, consistently accurate refractive outcomes remain elusive for those with prior keratorefractive surgery, keratoconus, extreme axial myopia with posterior staphyloma, nanophthalmic eyes, or eyes with silicone oil.

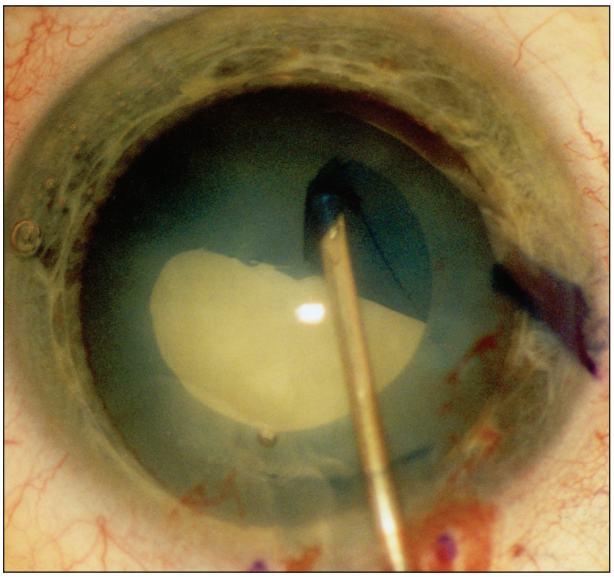

Figure 1. In terms of highly accurate refractive outcomes, the proper construction of the capsulorhexis is the defining portion of the surgical procedure.

BASIC KERATOMETRY

When was the last time you calibrated all of the keratometers in your office? If your office has more than one keratometer, or employs several different methods of corneal power measurement (eg, simulated keratometry, automated keratometry, and manual keratometry), multiple instruments will introduce another variable into the process. I strongly recommend assigning a single instrument that was recently calibrated against a set of standard calibration spheres to the task of all pre- and postoperative keratometry.

It is also helpful for each office to establish a set of keratometry validation guidelines. In my office, if the Ks are very flat (less than 40.00 D) or very steep (greater than 48.00 D), a second person double-checks the measurements and signs the chart. If the total keratometric power between eyes is greater than1.50 D, a second staff member repeats the measurements. If the mires are distorted, or the total astigmatism for either eye is greater than 4.00 D, we will typically obtain a topographic axial map to screen for keratoconus. Lastly, if there are any difficulties in obtaining the measurements that cannot be resolved, we ask the patient to return for repeat keratometry on another day.

BIOMETRY

There are currently four methods available for ophthalmic biometry: applanation A-scan; immersion A-scan; immersion A/B-scan; and optical coherence biometry using the IOLMaster.

Surgeons interested in highly accurate outcomes have mostly abandoned applanation biometry, which yields a falsely short axial length due to variable amounts of corneal compression. It is also highly operator dependent and often leads to corneal irritation. Of the ultrasound-based biometric methods, immersion biometry is a much better choice. Although it has the same 10-MHz resolution as the applanation method, it is much more consistent because there is no corneal compression and the measurement displayed is closer to the true axial length. Contrary to popular belief, the immersion technique is actually quite simple to perform, especially when used in conjunction with the Prager shell. Moreover, because immersion biometry is far more consistent than applanation biometry, it often takes less time.

The main limitation to accuracy with 10-MHz A-scan ultrasound is that it uses a relatively broad, low-resolution sound wave to measure the distance from the corneal vertex to the vitreoretinal interface. Moreover, the region surrounding the fovea has a variable retinal thickness, with the foveal center being thinner than the area immediately adjacent to it. Typically, both of these areas are included in an A-scan biometric measurement.

The most sophisticated form of ultrasound-based biometry is a combined immersion vector A/B-scan. By this technique, familiar to our retinal colleagues, a horizontal immersion B-scan is carried out with a simultaneous vector A-scan that can be manually positioned to measure from the center of the corneal vertex to the location of the fovea.[1] The disadvantages of A/B biometry are that the equipment is generally somewhat expensive and a higher level of operator skill is required. In my office, if we are not able to use the IOLMaster due to the presence of a dense axial opacity, immersion A/B biometry is our method of choice.

THE IOLMASTER

In my opinion, the IOLMaster represents the single most important advance in IOL power calculations since the introduction of ultrasound biometry 3 decades ago. Interestingly, the technological foundation of this instrument is based on principles laid down during the 19th century by the German-American physicist Albert Michelson.[2] More than 100 years after its invention, the Michelson interferometer was introduced to ophthalmology via our colleagues in astronomy and physics. It is likely that, in the future, similar technological advancements will come to us from other unrelated disciplines and will have an equally important impact.

One of several reasons why the IOLMaster has a much higher resolution than ultrasound is that the axial-length measurement is based on a very short 780-nm light wave, rather than a much longer 10-MHz sound wave. By optical coherence biometry, the IOLMaster measures the distance from the corneal vertex to the retinal pigment epithelium (not affected by variations in retinal thickness) and then subtracts the foveal thickness. This approximation to an axial length by immersion ultrasound is based on a comparison to the exquisitely accurate Grieshaber Biometric System (Alcon Grieshaber AG, Schaffhausen, Switzerland), an ultra-high–resolution ultrasound biometer that employs four 40-MHz counters and is capable of an astonishing accuracy of 20µm.[3] In essence, the IOLMaster is the equivalent of an upright, noncontact, immersion A-scan but with a fivefold increase in resolution.[4]

There are four situations in which the IOLMaster is best suited for accurate biometry: (1) nanophthalmia or extreme axial hyperopia, because small errors in axial length are important; (2) extreme axial myopia, especially in the presence of a peripapillary posterior staphyloma; (3) prior retinal detachment with silicone oil; and (4) pseudophakia, polypseudophakia, and phakic IOLs. Ophthalmologists are now starting to measure eyes that develop cataracts after phakic IOL implantation, and the IOLMaster can measure straight through the phakic IOL on the phakic setting with excellent results.[5]

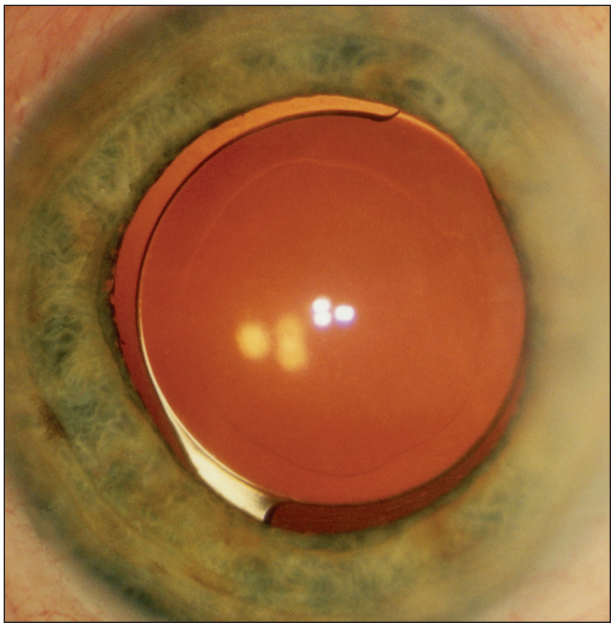

Figure 2. The capsulorhexis should be round, centered, and smaller than the optic of the IOL.

When the IOLMaster debuted, it was presented mostly as a point-and-shoot device with which the axial-length display with the highest signal-to-noise ratio was considered the best choice. Unfortunately, it is not quite that simple. Using the IOLMaster requires the correct interpretation of the axial-length display, with the signal-to-noise ratio being helpful but not the most important determiner of the overall quality of the axial length measurement. Ideally, the axial-length display should have tall and slender primary maxima, with a thin and well-defined termination, much like the familiar silhouette of the Chrysler building in New York City.[4] Careful attention to the axial-length display will avoid double peaks and other problems that could lead to potentially inaccurate measurements.

VALIDATION GUIDELINES FOR AXIAL LENGTH

If the preoperative refraction and keratometry are equal between both eyes, but one eye measures 28mm and the other eye measures 26 mm, something is obviously wrong. A 27-mm axial length displayed for a patient with a +4.00 D refractive error suggests an error. As originally suggested by Holladay,[6] it is important to follow a set of axial-length validation guidelines as the basis of a protocol to double-check any measurements that may not correlate with the overall clinical picture. In my office, if the difference between eyes is greater than 0.33 mm, a second person independently verifies the results. If the axial length is less than 22 mm or greater than 26 mm, a second person reviews or repeats the measurements. We do likewise if the axial length correlates poorly with the refractive data or if there is any difficulty in obtaining consistent measurements.

IOL FORMULAE

In North America, the three commonly used, theoretical IOL power calculation formulas (Hoffer Q, Holladay 1, and SRK/T) are derived from the same mathematical backbone. The main difference between these third-generation, two-variable formulas is the way in which they calculate the final position of the IOL, commonly known as the *effective thin-lens position*.[7]

Limitations of all third-generation, theoretical, two-variable formulas are that they work best near schematic eye parameters, apply a number of broad assumptions to all eyes, and, apart from the lens constant, predict the final position of the optic of the IOL based solely on central corneal power and axial length. For example, some formulae assume that the anterior and posterior segments of the eye are mostly proportional, or that there is always the same relationship between central corneal power and the effective lens position, which is not always true, especially in axial hyperopia.[7,8]

By the late 1980s, the Holladay 1 formula was available, which works well for eyes with normal and long axial lengths. This formula was followed in 1990 by the SRK/T formula, which works well for normal-to-moderately long axial lengths. Several years later, the Hoffer Q formula was added, which works well for eyes with short and normal axial lengths. Presently, regression formulae such as Binkhorst II, SRK I, and SRK II are now mostly of historical interest only. Interestingly, SRK II is still widely used by many in spite of its obvious limitations.

In 1991, Wolfgang Haigis, MS, PhD, the head of the Biometry Department of the University of Würzburg Eye Hospital in Germany, published the Haigis formula. Using the same mathematical backbone as other theoretic formulas, the Haigis formula approaches the problem of IOL power accuracy with three constants (a0, a1, and a2) and adds a measured anterior chamber depth for a third required variable. With the a0 constant optimized in a manner similar to SRK/T, and the a1 and a2 constants based on schematic eye parameters, the formula performs as if it were a very good third-generation two-variable formula. When all three constants are optimized by regression analysis based on surgeon-specific IOL data, however, the range of the Haigis formula can be extended greatly to cover both high-axial hyperopia and high-axial myopia. The main limitations to using the Haigis formula for all axial lengths are that only Dr. Haigis and I presently carry out the required regression analysis and a patient database of approximately 200 cases containing a wide range of axial lengths is required.

The Holladay 2 formula, available since 1998, is considered by many to be the most accurate of the theoretic formulas currently offered. The formula is easy to optimize and works well across a wide range of axial lengths. Its main limitations are that it requires the manual input of seven variables and it is relatively expensive to purchase. Surgical practices serious about their refractive outcomes will typically use the Holladay 2 formula.

Because most biometric equipment already comes with several theoretic formulas, a simple rule to follow is to use the Holladay 1 formula for normal-to-long eyes and the Hoffer Q formula for normal-to-short eyes. However, it should eventually be the goal of every surgical practice to use a more modern formula such as Haigis or Holladay 2.

What are useful IOL power calculation validation guidelines? Of course, both eyes should be measured at the same time to serve as a basis for comparison. If the IOL power difference between eyes is greater than 1.00 D, or if there is any question about the accuracy of the axial length or keratometry, the results should be double-checked. Also, if the calculated IOL power does not match what you expected to see, such as a +28.00-D IOL recommended for an axial myope, repeating the measurements is mandatory.

SURGICAL TECHNIQUE

For highly accurate refractive outcomes, the capsulorhexis should be considered the defining portion of the surgical procedure (Figure 1). Ideally, the capsulorhexis should be round, smaller than the optic, and centered. If carried out correctly, the optic of the lens implant should remain at the plane of the zonules. If the capsulorhexis is much larger than the optic, the forces of capsular bag contraction may shift the optic anteriorly, inducing a myopic shift late in the postoperative course. Also, at the conclusion of the case, the optic of the IOL should be centered directly beneath the capsulorhexis so that the capsular bag can uniformly shrink-wrap around it (Figure 2). This approach is another important step for ensuring consistent refractive outcomes. A failure to pay close attention to the capsulorrhexis can impact on the refractive outcome more than ultrasound-based biometry or keratometry.

SUMMARY

Understand the current limitations of technology. There are some patients to whom you cannot promise a highly accurate outcome. Assign a single instrument for the task of keratometry for added consistency. Use the IOLMaster or immersion biometry rather than an applanation technique. Develop a set of validation criteria for each part of the measurement process and have a second person carefully review and/or repeat any part that falls outside of these guidelines. Consider switching to one of the newer IOL power calculation formulae for improved accuracy. Optimize your surgical technique by making the capsulorhexis round, smaller than the optic, and centered. By embracing current technology and paying careful attention to details, every ophthalmologist can achieve highly accurate refractive outcomes. ■

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CHAPTER 119

Spherical Aberration 101

LISA MARTÉN, MD; TRACY SWARTZ, OD; AND MING WANG, MD, PHD

Spherical aberration is an imperfection in an image that is due to the spherical shape of the lens or mirror used to create that image. There is an intrinsic defect in spherical mirrors that prohibits the mirror from focusing light toward a single point. Light rays that strike the outer edges of the mirror focus at a different point than those rays that strike the inner portions of the mirror, and the result is a blurry image. The image of a point formed by a lens with a spherical aberration is usually a bright dot surrounded by a halo of light. Spherical aberration softens the contrast and blurs the details of images[1] as if looking through a fog. This article provides a short, basic review of spherical aberration.

The quantity and sign of spherical aberrations relies on the wavelength of light. A spherical aberration depends upon the focal length, aperture, shape, and distance of an object from the visual axis. The resulting amount of aberrant light, or image blur, is relative to the diameter and inversely proportional to the focal length of the lens/mirror. Spherical aberration is responsible for the blurred form at negative distances and a smoother appearance at positive distances.[2] Off-axis rays of light are focused closer to the lens than the paraxial rays. In simple terms, as one moves away from the center of the lens, the refractive (light-bending) power of the lens increases. When a light bundle strikes at a lens position farther from the lens' center, it will be bent more than when the light bundle strikes at a lens position closer to the center. Hence, along the radial direction, the farther away the point on the lens at which a light bundle strikes, the more powerful refractively the lens becomes. Depending on the focal point at which someone is looking, the center of the image will be clearly focused, while the edges of the field appear fuzzy and dim.

HOW TO DECREASE SPHERICAL ABERRATION

Because rays of light spread across several points on the z plane along its axis, the intensity of the light as well as its lateral and axial resolution are decreased. As someone views an image through different points along the focal axis, the image can lose detail and become distorted.[3]

Spherical aberration is important to the clarity of images produced through photography, microscopes, telescopes, and the human eye. Various methods can minimize spherical aberration and improve an image's quality. Corrective factors are employed, for example, in the Hubble telescope. Mathematical formulae are used to calculate an appropriate series of lenses that will reduce spherical aberration. Scientists can apply the Coddington shape and position factors to minimize the bending of light into its best form, thereby reducing spherical aberration.

Spherical mirrors cause most spherical aberrations and are commonly corrected with a parabolic mirror. Parabolic optics correct the aberration, because their outer edges have a different curvature than the center, resulting in sharp, clear images. In microscopy, common methods used to minimize spherical aberration include decreasing the size of the aperture and using collared water or oil immersion. The system must be adjusted, however, for different focal planes. Newer, self-adjusting programs have been developed for microscopy to automatically set the optics to minimize spherical aberration.[3]

SPHERICAL ABERRATION OF THE HUMAN EYE

Corneal asphericity (Q-value) has a value of -0.50 in an ideal visual system. This value is indicative of a prolate shape and results in zero spherical aberration. Unfortunately, a zero Q-value is not anatomically possible due to the necessary framework of the junction between the cornea and the sclera. Instead the human Q-value averages -0.26 due to the limbal transition. The human visual system therefore suffers from a small amount of spherical aberration, which rises as the pupil's size increases.

The natural curvature of the cornea induces positive spherical aberration, although the relaxed natural lens induces negative spherical aberration.[2,4] The spherical aberration of the posterior corneal surface is negative when a person is young and becomes positive with age, thus making the posterior corneal measurement important for calculating the total spherical aberration of the entire eye.[2]

The anterior surface of the cornea, internal optics of the posterior

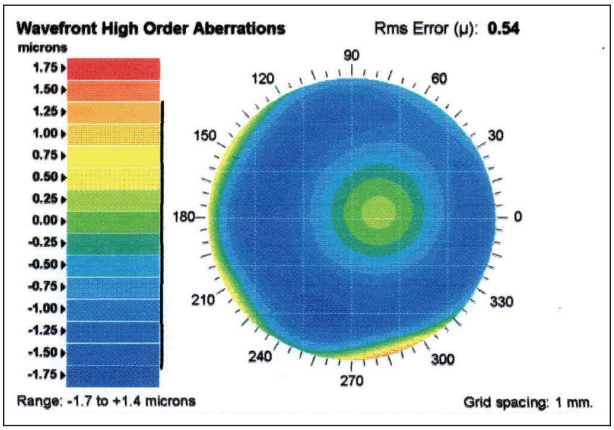

Figure 1. Pictured is a wavefront aberrometry map of a patient after myopic LASIK.

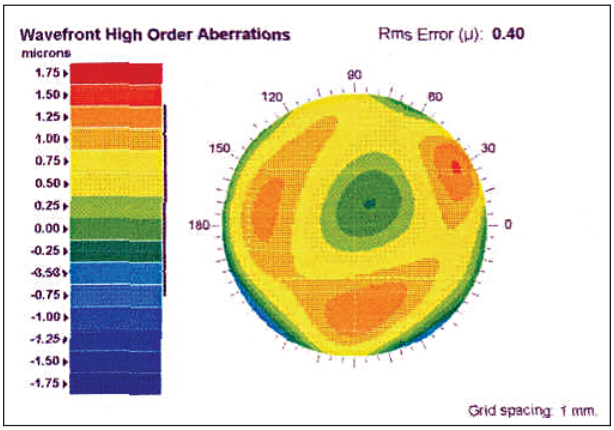

Figure 2. Pictured is a wavefront aberrometry map of a patient after hyperopic LASIK.

cornea, and crystalline lens all contribute to the aberration of a wavefront passing through the eye.[5] It is possible to measure the lower and higher optical aberrations with a wavefront aberrometer. By shining a small spot of light onto the retina and observing the amount that is reflected from within the eye, one can quantify the amount of lower-order aberrations (eg, astigmatism, myopia, hyperopia) and higher-order aberrations (eg, coma, spherical aberration). The Hartmann-Shack sensor, which was originally developed for measuring the aberrations of optical instruments and general refracting surfaces in astronomical telescopes, is now used to measure aberrations of the human eye. The Hartmann-Shack sensor sends information to a computer software program, which decomposes wavefront aberrations into a set of Zernike polynomials.[6] Other techniques include ray tracing and instruments based on the Tscherning principle.

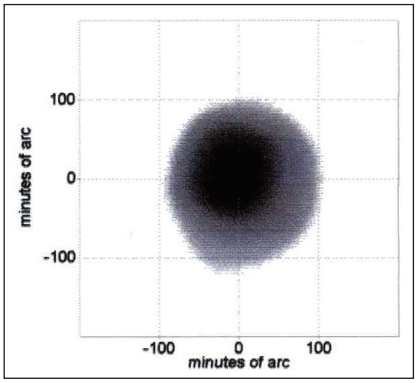

Figure 3. Pictured is a simulated image of a point of light as seen by a patient with increased spherical aberration.

In the human eye, it is difficult to insert lenses of different sizes and powers to minimize spherical aberration. Given the dynamic change of spherical aberration, many would argue against such a procedure. Contact lenses can be easily changed and are one option for correction. The design of regular soft contact lenses of high negative or positive power should aim to produce -0.07 D/mm of spherical aberration. Patients can usually tolerate an interval between -0.15 and +0.01 D/mm of spherical aberration for a 6-mm pupil.[7,8] After cataract surgery, specially designed aspheric contact lenses can compensate for the cornea's positive spherical aberration that tends to increase with age.

Wavefront aberrometry may identify patients who have significant amounts of spherical aberration prior to elective keratorefractive surgery, and wavefront systems to program computerized ablation may prevent an increase in visual symptoms related to corneal properties. Spherical aberration may result from large changes in the corneal curvature such as that induced by myopic or hyperopic LASIK. Note the effect of the flattening of the central cornea with myopic treatments (Figure 1) and that of a hyperopic treatment (Figure 2). The aberrations are in opposite directions. The effect of spherical aberration can be simulated using Snellen E representation as well as in the point of light as shown in Figure 3.

Advances in keratorefractive and IOL technology have incorporated the reduction of spherical aberration into the optical correction. IOLs with negative spherical aberration can negate or offset the positive spherical aberration of the cornea.[9] Future technologies will increasingly consider both the lens' and cornea's aberration, to yield optimal overall optical performance.

IN SUMMARY

Understanding spherical aberration in the human eye is important in modern-day refractive surgery procedures. It is present in the cornea as well as the crystalline lens in their native states. Furthermore, spherical aberrations can be created iatrogenically by keratorefractive or lenticular surgeries. The pupil's size, the lens' shape, and the cornea's curvature and shape all influence spherical aberration. New technologies, including wavefront imaging, have ushered in a new era of understanding the human eye's higher-order aberrations. Technologies such as wavefront-driven or corneal topography-based treatments are being developed to minimize the spherical aberration created by surgeons. ■

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CHAPTER 120

Maximizing Optical Quality

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The youthful, accommodating, emmetropic, and minimally aberrated eye is the standard by which the results of cataract and refractive surgery are evaluated.[1] The erosion of accommodation and the decline in functional vision that occur with age[2] are linked to changes in the crystalline lens.[3,4] Cataract and refractive lens exchange surgery offer an intuitive avenue for correcting presbyopia as well as for reversing increased lenticular spherical aberration. Because the optical wavefront of the cornea remains essentially stable throughout life,[5] refractive lens exchange represents a permanent solution to the challenges of restoring accommodation and achieving a youthful quality of vision.

The positive spherical aberration of a spherical pseudophakic IOL tends to increase total optical aberrations, a problem that has led to the development of aspheric IOLs.[6] These designs may reduce or eliminate ocular spherical aberration and improve functional vision compared with a spherical pseudophakic implant.

Three aspheric IOL designs are currently marketed in the US: the Tecnis Z9000 IOL (Advanced Medical Optics, Inc., Santa Ana, CA); the Acrysof IQ IOL (Alcon Laboratories, Inc., Fort Worth, TX); and the Sofport AO IOL (Bausch & Lomb, Rochester, NY).

ASPHERIC IOLS

Tecnis IOL

The Tecnis IOL was designed with a modified prolate anterior surface to compensate for the average corneal spherical aberration found in the adult eye. This lens introduces -0.27 µm of spherical aberration into the eye. The results for clinical studies of the Tecnis IOL, which were submitted to the FDA, showed that the IOL eliminated patients' mean spherical aberration and significantly improved their functional vision compared with a standard spherical IOL.[7]

Acrysof IQ IOL

The Acrysof IQ IOL incorporates both the ultraviolet- and blue-light–filtering chromophores found in the single-piece acrylic Acrysof Natural IOL (Alcon Laboratories, Inc). The Acrysof IQ lens, however, has a posterior, aspheric surface designed to compensate for spherical aberration by addressing the effects of overrefraction at the periphery. It adds -0.20 µm of spherical aberration to the eye.

Sofport AO IOL

The Sofport AO IOL is an aspheric IOL that has been specifically designed with zero spherical aberration so that it will not contribute to any preexisting higher-order aberrations. This lens' silicone, sharp-edged optic design incorporates haptics with zero angulation to permit atraumatic placement in the capsular bag.

STUDIES COMPARING DIFFERENT ASPHERIC IOLS

According to the literature, the Tecnis IOL has demonstrably reduced spherical aberration and provided superior contrast sensitivity and contrast acuity in comparison to a variety of spherical IOLs (as of press time, there were no peer-reviewed publications evaluating the clinical results with either of the other two aspheric IOLs available in the US).[8-15] Data show that the mean spherical aberration in the eyes implanted with the Tecnis IOL is, as stated by executives from the FDA, "not different from zero."[16] Subjects in the FDA-monitored night driving simulation study of the Tecnis IOL performed functionally better in 20 of 24 driving conditions (and statistically better in 10 conditions) when using BSCVA with the eye implanted with the Tecnis IOL compared to BSCVA with the eye implanted with the Acrysof IQ.[6] These findings represent the basis for the FDA labeling indicating that the Tecnis IOL improves functional vision and enhances highway safety "for elderly drivers and those with whom they share the road."[6] Optical laboratory studies' results nevertheless have cast doubt on the efficacy of IOLs with negative spherical aberration (eg, the Tecnis and Acrysof IQ) due to the range of tilt and decentration of pseudophakic lenses in general[17,18].

MULTIFOCAL IOLS

Array Lens

From 1997 until 2005, the only FDA-approved multifocal IOL available was the Array IOL (Advanced Medical Optics, Inc.) This zonal progressive lens has five concentric zones on its anterior surface. Zones one, three, and five are distance dominant, whereas zones two and four are near dominant. The lens has an aspheric component whereby each zone repeats the entire refractive sequence corresponding to distance, intermediate, and near foci. This configuration provides patients with vision over a range of distances.

The lens uses 100% of the incoming available light and is weighted for optimum light distribution. With typically sized pupils, approximately half of the light is distributed for distance, one third for near vision, and the remainder for intermediate vision. Because the lens utilizes a continuous surface construction, there is no loss of light through diffraction and no degradation of image quality as a result of surface discontinuities.[19] The lens has a foldable silicone optic that is 6mm in diameter, PMMA haptics, and an overall diameter of 13mm. It can be inserted through a clear corneal incision that is 2.8mm wide by means of the Unfolder injector system (Advanced Medical Optics, Inc.).

Rezoom Lens

In 2005, the FDA approved two new multifocal designs, the Rezoom IOL (Advanced Medical Optics, Inc.) and the Acrysof Restor IOL (Alcon Laboratories, Inc.). The former represents new engineering of the Array platform, including a hydrophobic acrylic material and a shift of the zonal progression. Zones one, three, and five are all distance dominant, whereas zones two and four are near dominant. The large, distance-dominant, central zone one is designed to provide vision in bright light (eg, for daytime driving). The Rezoom IOL's expanded zone three facilitates distance vision in moderate-to-low light when the pupil is more fully dilated, and zone five is designed to supply distance vision in low light (eg, for nighttime driving). Zone two, the large zone immediately peripheral to zone one, is intended to give near vision in moderate-to-low light. Zone four serves to provide near vision for lower-light situations. Aspheric transitions between the zones offer intermediate vision. The near-dominant zones provide +3.50 D of add power at the IOL's plane for near vision, yielding approximately +2.57 D of add power in the spectacle plane. This power addition translates to a near point of vision of 39cm or 16 inches.

Optiedge technology (Advanced Medical Optics, Inc.) inhibits the migration of lens epithelial cells without causing visual disturbances or glare (sata on file with Advanced Medical Optics, Inc.). Buehl et al[20] demonstrated low rates of posterior capsular opacification (PCO) in cataract patients implanted with an IOL that has a modified, sharp, posterior optic edge design.

The Rezoom IOL reduces the amount of light that goes to the near foci in low-light conditions (ie, larger pupils) and reallocates it to the distance foci. The intermediate power of this lens allows the formation of images on the retina, even if the distance and near powers form slightly out-of-focus images. The intermediate power should theoretically reduce the unfocused light on the retina, leading to fewer halos and less glare. Reduced photic phenomena (such as internal reflections and edge glares) and minimized PCO are the goals of the IOL's Optiedge design.

Acrysof Restor Lens

The Acrysof Restor IOL employs a central apodized diffractive area surrounded by a purely refractive outer zone. This lens has a central 3.6-mm diffractive optic region. Twelve concentric diffractive zones on the anterior surface of the lens divide the light into two diffractive orders to create two lens powers. A region that has no diffractive structure over the remainder of the 6.0-mm–diameter lens surrounds the central 3.6-mm zone. The near correction is calculated at +4.00 D at the lens' plane, resulting in approximately +3.20 D at the spectacle plane. This add power provides a defocus curve of 6.00 D of pseudoaccommodation at the 20/40 level.

The apodized diffractive structure of the Acrysof Restor IOL provides a gradual centrifugal decrease in step height of 12 diffractive circular structures. This design creates a transition of light between the foci and theoretically reduces disturbing optical phenomena like glare and halos. The results of a current study of the Acrysof Restor IOL show excellent near visual acuity and no compromise of subjects' distance vision, with approximately 80% not needing spectacles for near, distance, or intermediate vision.[21]

With the Acrysof Restor lens, the logic of placing the diffractive element centrally depends upon the near synkinesis of convergence, accommodation, and miosis. As the pupil constricts, the focal dominance of the lens shifts from almost purely distance to equal parts distance and near. This approach conserves efficiency for mesopic activities when the pupil is larger (eg, nighttime driving) but reduces near vision under mesopic conditions (eg, reading a menu by candlelight).

Comparative Studies

Many investigators have evaluated both the objective and subjective qualities of contrast sensitivity, stereoacuity, glare, and photic phenomena following the implantation of multifocal IOLs. Refractive multifocal IOLs such as the Array are better than diffractive multifocal IOLs in terms of contrast sensitivity and glare.[22] Recent reports comparing refractive and diffractive IOLs, however, revealed similar distance-vision qualities evaluated by modulation transfer functions but better near vision for the diffractive lens.

In terms of contrast sensitivity testing, the Array produces a small loss of contrast sensitivity that is equivalent to one line of visual acuity at the 11% contrast level using Regan contrast sensitivity charts.[23] This loss of contrast sensitivity at low levels of contrast is only present when the Array is implanted monocularly. It is not seen in patients with bilateral implants and binocular testing.[24] Regan testing, however, is not as sensitive as sine wave grating tests that evaluate a broader range of spatial frequencies. With the latter approach, reduced contrast sensitivity occurred in eyes implanted with the Array in the lower spatial frequencies compared with monofocal lenses when a halogen glare source was absent. When a moderate glare source was introduced, no significant difference in contrast sensitivity between the multifocal or monofocal lenses was observed.[25]

Practitioners implanting the Array have noted a period of neural adaptation in patients.[26] Similarly, researchers have shown that contrast sensitivity normalizes over a 6-month period.[27]

According to recent reports, there is a reduction in tritan color contrast sensitivity function in refractive multifocal IOLs compared with monofocal lenses under conditions of glare. These differences were significant for distance vision in the lower spatial frequencies and for near vision in the low and middle spatial frequencies.[28] A newer aspheric multifocal IOL, the Progress 3 (Domilens Laboratories, Lyon, France; not available in the US), also significantly lowers mean contrast sensitivity with the Pelli-Robson chart when compared to monofocal IOLs.[29]

Ultimately, these contrast sensitivity tests reveal that, in order to deliver multiple foci to the retina, there is always some loss of efficiency with multifocal IOLs when compared with monofocal IOLs. Contrast sensitivity loss, random-dot stereopsis, and aniseikonia improve, however, when multifocal IOLs are placed bilaterally versus unilaterally.[30] A recent publication evaluating a three-zone refractive multifocal IOL showed an improvement in stereopsis, less aniseikonia, and a greater likelihood of spectacle independence with bilateral versus unilateral implantation.[31] There is also evidence that contrast sensitivity with multifocal IOLs improves over time, approximating the levels found with spherical monofocal lenses by 6 months postoperatively.[25]

Disadvantages

One of the persistent drawbacks of multifocal lens technology has been the potential for patients to see glare or halos around point sources of light at night in the early weeks and months following surgery.[32,33] A meta-analysis of the peer-reviewed literature on multifocal IOLs shows a greater incidence of glare and halos with the multifocal than monofocal IOLs.[34] According to a clinical investigation of the Acrysof Restor IOL, 23.2% of subjects implanted bilaterally complained of moderate halos at night, although 7.2% complained of severe halos, versus 1.9% and 1.3%, respectively, of subjects implanted bilaterally with a control monofocal IOL.[35] Severe halos were reported by 15.3% of subjects bilaterally implanted with the Array IOL, the Rezoom IOL's precedecessor.[36] Fortunately, most people learn to disregard halos with time, and bilateral implantation appears to improve these subjective symptoms.[37]

ASPHERIC MULTIFOCAL IOL

The Tecnis Multifocal IOL (Advanced Medical Optics, Inc.) is a wavefront-designed, diffractive, foldable IOL with a modified prolate anterior surface. It has received CE Marking for the treatment of presbyopia, and clinical trials in the United States are ongoing. Optical bench studies reveal a superior modulation transfer function at both distance and near compared with standard monofocal IOLs with a 5-mm pupil and equivalence to standard monofocal IOLs with a 4-mm pupil. When compared to the Array multifocal IOL, the Tecnis Multifocal IOL performed better in the presence of a 2-mm pupil at near and a 5-mm pupil at distance and near. From these laboratory studies, it appears that combining diffractive multifocal optics with an aspheric, prolate design may enhance the functional vision of pseudophakic patients.[38]

Huetz et al[39] performed a prospective, randomized study comparing three bilaterally implanted multifocal IOLs: the Array; the Acrysof Restor; and the Tecnis Multifocal. They found faster uncorrected and best distance-corrected reading speeds among patients with the Tecnis Multifocal than the other lenses under both photopic and mesopic conditions. The reading speed with the Tecnis Multifocal was significantly faster with near correction under photopic conditions, and it was significantly better than in patients with the Acrysof Restor (but not the Array) under mesopic conditions. The latter finding probably reflects the fact that the larger pupil under mesopic conditions benefits near vision with the zonal progressive Array but reduces near vision with the apodized diffractive Acrysof Restor. Anecdotally, our patients, after receiving refractive multifocal lenses (Array and Rezoom), have remarked that they read more easily in dim versus bright light.

ONE SIZE DOES NOT FIT ALL

The availability of presbyopia-correcting IOLs, refractive lens exchange, and customized aspheric IOLs is changing ophthalmic practice. Informed consent takes on a new meaning when the surgeon and the patient decide together which IOL technology best fits his lifestyle and visual demands. Customizing the selection of IOLs is now essential to the practice of refractive lenticular surgery. ■

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