Uses for Intraoperative Wavefront Aberrometry

Ophthalmologists discuss the use of the ORA system for improved surgical outcomes.

BY MICHAEL G. WOODCOCK, MD; WILLIAM F. WILEY, MD; KERRY ASSIL, MD; AND STEPHEN S. LANE, MD

Intraoperative Wavefront-Guided Cataract Surgery

By Michael G. Woodcock, MD

Cataract surgery has become the new LASIK of the baby boomer generation. That is, as the population matures, having developed the attitude that healthy bodies and perfect UCVA should be expected, there is increasing demand for cataract surgery to be more than restorative. In order to meet patients' heightened expectations, I have made every effort to perfect biometry and institute new technologies to maximize precision and outcomes. In my experience, the adoption of intraoperative wavefront-guided cataract surgery has led to the greatest improvement in the past 10 years.

The Optiwave Refractive Analysis (ORA) System (WaveTec Vision; Figure 1) is a diagnostic device that allows me to take wavefront aberrometry measurements intraoperatively. The system provides the ability to refract the eye in phakic, aphakic, and pseudophakic states at any time during cataract surgery. In addition to providing this raw information, the software also assists in IOL power selection and recommendations for toric IOL positioning before and after implantation. My observations regarding ORA are primarily using one-piece acrylic IOLs.

The first utility of the ORA System is in IOL power prediction. Prior to adopting ORA, my routine had primarily been to rely on the Holladay IOL Consultant professional edition and the Holladay II formula. In the past 2 years, I have found good correlation with this software but have achieved better outcomes with the ORA System. It is likely that the outcomes are improved for two reasons. First, the power measurement taken during ORA calculation is under my direct observation of the tear film quality; therefore, technician errors are eliminated. Second, I take an additional reading after IOL implantation and

Figure 1. The ORA System is used for intraoperative wavefront analysis.

can eliminate outcomes that result from patients whose anatomy does not allow for any formula to accurately predict the power. I simply exchange the IOL immediately, avoiding months of unhappiness while the patient waits for a LASIK enhancement.

The second application for which I find ORA useful is implanting toric IOLs. Keratometry only estimates astigmatism based on surface curvature. Unless topography is based on true corneal power from ray tracing, these metrics can lead to significant toric power errors. Without intraoperative wavefront measurement, achieving accurate toric IOL alignment, toric power selection, and spherical power are more difficult. ORA not only provides more accurate measurements, but it also does the math after implantation to guide IOL rotation, minimizing residual astigmatic error. Additionally, any significant residual myopia or hyperopia is identified.

Perhaps the most valuable function of the ORA System is in performing cataract surgery in post-LASIK

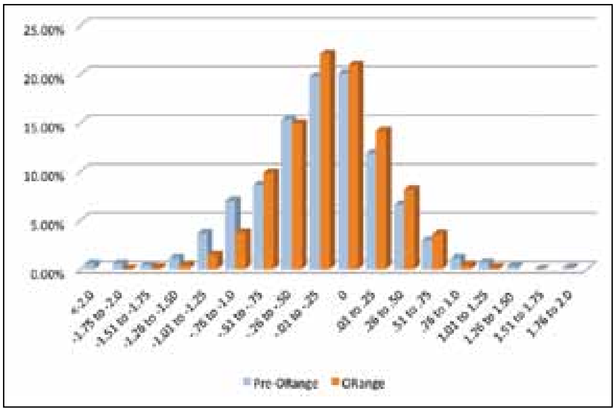

Figure 2. Comparison of refractive accuracy before and after implementation of intraoperative wavefront analysis.

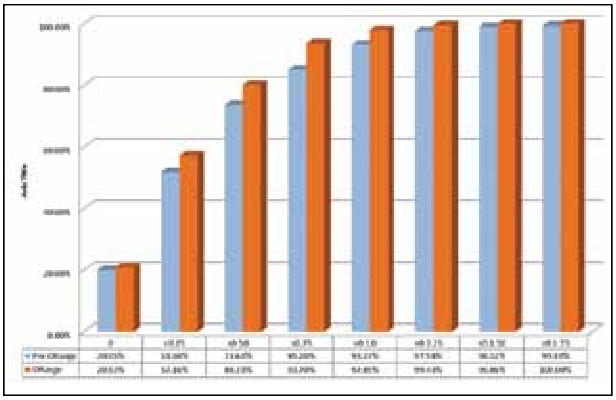

Figure 3. Refractive outcomes achieved before and after implementation of intraoperative wavefront analysis.

patients. This technology has proven to be so useful that I ask patients who decline the use of intraoperative aberrometry to seek another physician to perform their surgery. The amount of time and expense needed to perform all of the additional tests and estimates is simply not justifiable when compared with using ORA. The IOL power predictions have proven to be more accurate, and when a surprise occurs, I am able to identify and correct the error while the patient is still in the operating room.

The latest use of the ORA System in my practice has been as an adjunct to laser cataract surgery. I use the ORA reticle to confirm that the arcuate incisions and the intraoperative refraction correlate. Then I use the refraction to determine if the arcuate incisions should be opened to maximize their effect. The integration of the two technologies has been well accepted by patients who desire the most precise surgical care for their eyes.

Over the past 2 years, I have made intraoperative wavefront-guided custom cataract surgery my standard of care. I have performed more than 3,500 cases using either WaveTec's first intraoperative wavefront aberrometer, the ORange, or the new ORA System. Outcomes from immediately before I adopted intraoperative wavefront analysis compared with after (Figures 2 and 3) have shown:

- The percentage of patients within ±0.50 D spherical equivalent (SEQ) target increased by 7%;
- The percentage of patients more than ±0.75 D from SEQ target decreased by 61%;
- The percentage of patients with phakic IOLs who need enhancements decreased by 75%; and
- No returns to the operating room for rotation of a toric IOL in the past 2 years.

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The ORA System for Astigmatism Correction

By William F. Wiley, MD

I work in a relatively high-volume cataract and corneal refractive surgery practice. Intraoperative aberrometry is the perfect tool for bridging refractive surgery and cataract surgery. For refractive surgery, we are accustomed to achieving the precise and accurate outcomes that the excimer laser can deliver. Traditionally, however, cataract surgery has fallen short in delivering the same level of precision and accuracy. Particularly, cataract surgery has been less effective in treating patients with astigmatism or presbyopia and eyes that have previously undergone refractive surgery. Intraoperative aberrometry can deliver improved results for these patients.

In my practice, intraoperative aberrometry is most useful for astigmatism correction and treating eyes after refractive surgery. Figure 4 shows the intraoperative results for the first 50 toric IOLs I implanted using the ORA System. The average intraoperative aphakic cylinder is 1.83 D, and the final pseudophakic cylinder is less than 0.50 D with low standard deviation. For astigmatism correction, we have been able to achieve near-excimer accuracy for both toric IOLs and limbal relaxing incisions (LRIs).

Our demanding postrefractive surgery patients have also benefited from the use of intraoperative aberrometry; these patients expect near-perfect visual results, and it is rewarding to have a tool to help meet their expectations. With intraoperative aberrometry, we have reduced our enhancement rates in postrefractive eyes to less than 5%.

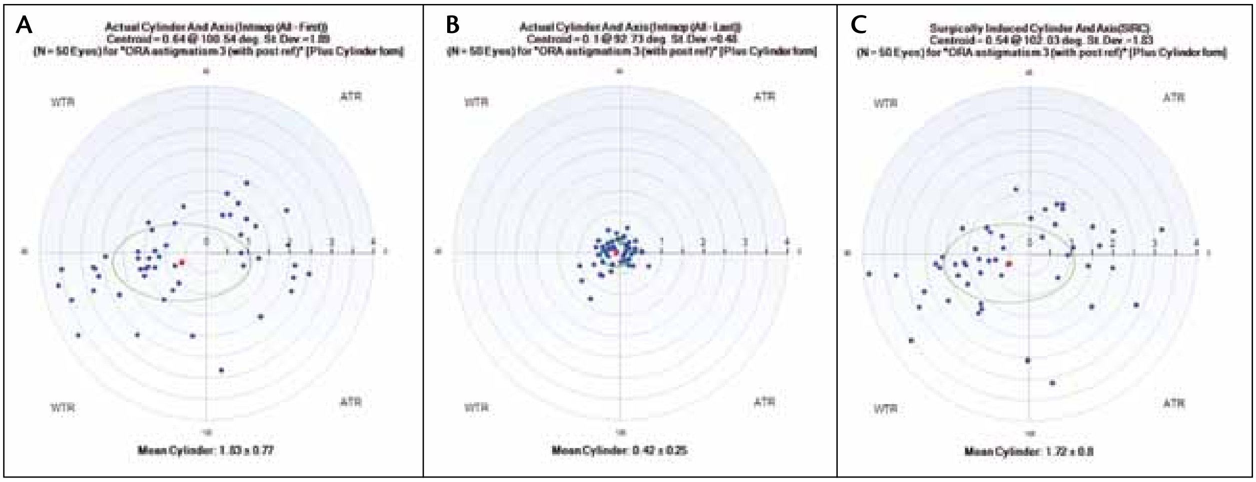

Figure 4. Intraoperative results for the first 50 toric IOLs implanted by the author using the ORA system. Displayed are (A) the aphakic refractive cylinder, (B) the final pseudophakic cylinder after IOL implantation and positioning, and (C) the surgically induced (treated) astigmatism.

As technology advances in the United States, I expect to hear of further uses for and additional benefits from intraoperative aberrometry. We will see symbiosis between this technology and the future merger of presbyopic and toric IOLs through single-platform lenses and/or piggyback IOL platforms. Multifocal toric IOLs require correct cylinder axis and power determination as well as correct placement. Intraoperative aberrometry will aid in choice and selection for these demanding lenses. Additionally, with the availability of piggyback toric or presbyopic IOLs, intraoperative aberrometry will be a crucial step in the process of placing these lenses, both for correct power and orientation.

I have had good results using piggyback IOLs in long or short astigmatic eyes that were outside the power range for the available toric IOLs. With these eyes, I use intraoperative aberrometry to first determine the power of the astigmatism, and then I choose the spherical portion of the lens power. If the spherical portion is outside the range of available powers, I still proceed and place the available toric lens on the aphakic refractive axis. I then perform a pseudophakic scan to determine the residual sphere (and to fine-tune the cylinder axis). Finally, based on the residual sphere, I choose a sphere lens to be placed in the sulcus to achieve the desired refractive result.

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Optimizing Outcomes With ORA

By Kerry Assil, MD

Intraoperative aberrometry would have little utilization if it were not for the desire to render patients spectacle-independent at the end of cataract surgery. We have entered an era in which providing freedom from spectacles has become one of the primary goals of cataract surgery, and therefore intraoperative aberrometry has become indispensable.

The ORA System has several uses in my practice. One function is to properly address astigmatism at the time of surgery. I prefer to correct astigmatism using LRIs rather than toric IOLs. Although both approaches are successful in treating astigmatism, I find that patients obtain even better UCVA (and better contrast acuity) when treated with LRIs. Based on astigmatism alone, intraoperative aberrometry weighs into more than 50% of my cataract cases, as the majority of my patients elect a premium pathway, anticipating spectacle-free vision upon departing from the surgical suite.

For astigmatism, intraoperative aberrometry assists with verifying the magnitude and axis of astigmatism and physically localizing that axis anatomically on the eye, thus substantially diminishing the guesswork. Real-time aberrometry further enables me to refine the astigmatic correction by repeating my measurements after performing the LRI. I can remeasure the amount of correction, and if either residual magnitude or a slight axis shift is noted, I can remedy that by deepening or lengthening a portion of the LRI. With the highest quality premium IOLs, such as the Tecnis Multifocal (Abbott Medical Optics Inc.), as long as astigmatism is reduced to 0.75 D or less, I find that patients are pretty much symptom-free with respect to postoperative astigmatism.

With respect to sphere, I find that spherical refinement becomes helpful in about 15% of previously unanticipated cases. I refine the IOL spherical power selection based on intraoperative measurements. In about half of those patients, the adjustment is approximately 0.50 D. Although 0.50 D may seem trivial, one must remember that, in a premium practice, it is important to have nearly every patient spectacle independent on postoperative day 1. Although there are two excimer lasers within my practice, I loathe using them on premium patients because the covenant of rendering them spectacle independent has been transgressed whenever we resort to an excimer laser procedure. For we clinicians, a subsequent procedure is viewed as an enhancement; however, by patients, it is interpreted as a primary treatment failure.

Additionally, there is a subset of patients (primarily those with previous corneal surgery) in whom real-time intraoperative spherical error measurement is indispensable. With refinement at the time of surgery, I have changed selected IOL power by up to 6.00 D, translating into 3.00 or 4.00 D in postoperative outcome difference, despite the availability of modern IOL power prediction formulas.

A third consideration of using the aberrometer for clinical practice is patient education and perception. The recognition that we will take additional images of their eyes at the time of surgery to better match the power of their selected lens translates into a greater sense of safety from the patients' perspective. To clinicians, a residual refractive error is simply a refractive error. Patients, however, interpret a refractive error as a complication, especially if they are seeking spectacle independence.

Combined, the aforementioned uses of the ORA System translate into greater adoption rates for premium IOLs. My practice has always been an outlier in terms of the percentage of patients seeking premium IOLs. As the world's first clinical center to use intraoperative aberrometry, it is not surprising that more than 85% of my patients seek a premium IOL pathway. That premium pathway can either mean a multifocal IOL or a monofocal IOL, coupled with intraoperative aberrometry and LRIs plus the guarantee of subsequent LASIK (if necessary).

Over the past several years, the WaveTec ORA System has evolved, and, with it, the precision of and reliability of LRIs have improved. The most recent advance, whereby the ORA projects a reticle onto the eye demonstrating the exact anatomic location of the axis and translating it onto the eye for me, has finally transformed LRIs from an art into a science.

There are several drawbacks to intraoperative aberrometry. One is that its use lengthens the duration of each case by about 5 minutes if both aphakic aberrometry for IOL power selection and pseudophakic aberrometry for astigmatism refinement are performed. Another drawback is the financial cost. As reimbursements continue to plummet, we must be prudent with our financial decisions. Therefore, I do not see intraoperative aberrometry having a significant role outside of premium IOL channels. Premium IOLs have a 7% penetration rate in the United States; however, in my practice, this rate exceeds 85%, almost a 13-fold difference. Improved patient satisfaction has helped me to achieve these milestones, as I do little external marketing. Therefore, from an economic perspective, the technology has been highly accretive to my practice. If, however, my practice were primarily focused on performing larger numbers of procedures and foregoing the premium IOL category, I would find intraoperative aberrometry to be a detraction.

Currently, the ORA System has its upper limits. Most significantly, the algorithms for eyes with extreme axial length deviations still require further refinement. Furthermore, for corneal transplant recipients with extremely large degrees of astigmatism, the system (although capable of measuring that astigmatism) does not display what it considers to be outlier measurements—cylinders in excess of 6.00 or 7.00 D, for example. In those cases, I resort to additional techniques to better estimate the astigmatism and reduce it at the time of surgery. In patients with extensive corneal scarring, the aberrometer may also reject a reading on those eyes.

There are also settings in which the intraoperative measurements may be questionable. If a patient has a known significant degree of astigmatism at a particular axis preoperatively, and aberrometry provides a different reading intraoperatively, there may be several concerns. First, the lens, having just been inserted into the eye, may not yet be completely unfolded, so the IOL could be contributing an artifactual complement of cylinder along its curled axis. Repeat measurements would show a progressively dynamic axis and magnitude of cylinder, for which the surgeon can wait 1 or 2 minutes to stabilize. Second, there may be IOL tilt. A tilted IOL should be easy to discern based on the Purkinje images of the cornea versus the IOL and by the observed aberrometry. Rotating the IOL a few degrees remedies this problem. A third potential cause of suspect measurements could be a mechanical issue such as hypotony. If a dispersive ophthalmic viscosurgical device was used and significant clumps of it remain in the eye, that can sometimes influence readings as well. Additionally, the patient's head may not be properly oriented, so that the globe or lid speculum could be pressing against the corneoscleral limbus in a certain region. This can be remedied by reorienting the patient's face under the microscope. Another factor to be cognizant of is wound hydration. When the wound is hydrated for closure, if the hydration is carried out so aggressively or if the corneal physiology is such that a significant portion of the cornea becomes edematous, then the edema can change the effective intraoperative corneal curvature and the resulting measurements of astigmatism. This is fairly easy to visualize at the time of surgery and is something for surgeons to be mindful of.

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Homing In On the Emmetropic Result of Surgery

By Stephen S. Lane, MD

Associated Eye Care was one of the original clinical sites for the ORange System, now the ORA System, so we have a lot of experience with intraoperative aberrometry. I use the ORA System routinely for patients who will be receiving any type of advanced technology IOL, which would include presbyopia-correcting IOLs or any toric IOLs. Intraoperative aberrometry can also be used for patients who have undergone previous corneal refractive surgery.

Using the ORA System, I can accurately determine the spherical power of the lens, which is done in an aphakic state. I take a measurement and then make the decision on the lens power based on the data I receive from the ORA reading. Additionally, I use intraoperative aberrometry for determination of the astigmatic correction, whether via implantation of a toric IOL or use of peripheral corneal relaxing incisions. I use the information I receive from the ORA System to determine the axis and amount of cylinder correction. For a toric IOL, for example, I take the aphakic measurement, select the spherical power based on the ORA, adjust the cylindrical power, and determine the axis of the steep meridian based on the readings.

Additionally, intraoperative aberreomtry can be used to determine the location and size of LRIs. With the adoption of laser cataract surgery, I have already made my LRIs before entering the operating room and performing any measurements with the ORA. I use the intraoperative measurements to determine whether to open the incisions at the time of surgery, and if so, can titrate the length to open. If there is a significant amount of cylinder, I open the incisions in the operating room. If a pair of incisions has been created, it may be beneficial to open one of the incisions, take a measurement with the ORA, and then determine whether to open the other.

An area in which I have found intraoperative aberrometry to be of limited benefit is in looking intraoperatively at the results following IOL implantation. For example, based on an aphakic reading, I may get a power of 21.00 D, and that is the lens I put in. When I measure again intraoperatively after IOL implantation to see the result, I would expect or want that result to be plano or close to plano, but, in fact, it is unpredictable, sometimes on the minus side and sometimes on the plus side. The reason for this lack of reliability is not due to inaccuracy of the aberrometry but rather occurs because we do not know the effective lens position. The lens may be a little anterior or posterior to where it will eventually sit, and as a result, the aberrometry reading is not an accurate representation of what the final power of the eye will be. Cylinder readings after implantation of a toric IOL, however, are highly accurate. There may be anterior or posterior movement of the lens that affects the effective lens position; however, the steep axis of the astigmatism is not going to change because of the anterior or poste-

Weigh in on this topic now!

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For which application do you believe the ORA System is most useful?

- ☐ **IOL power prediction**
- ☐ **Toric IOL implantation**
- ☐ **Performing cataract surgery in pots-LASIK patients**
- ☐ **Laser cataract surgery**
- ☐ **All of the above**
- ☐ **Do not know**

rior location of the lens. I find it useful to use the ORA after implantation of the toric IOL to ensure that I have the IOL aligned in the proper meridian.

For many surgeons, the goal of cataract surgery is to achieve emmetropia for their patients. However, we have a long history of surgeons who deliver good results, but their patients are required to wear glasses postoperatively to achieve functional visual acuity. Intraoperative aberrometry is one way for surgeons to home in on an emmetropic result of surgery. For the technology to be fully endorsed, we must first stop accepting glasses as the most desirable way of achieving good postoperative vision. ■

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The SG3000 for Toric Lens Implantation

This surgical guidance platform provides increased accuracy for toric IOL alignment.

BY NIENKE VISSER, MD; AND RUDY M.M.A. NUIJTS, MD, PhD

The Surgery Guidance 3000 (SG3000; SensoMotoric Instruments; Figure 1) is a novel eye-tracking device that may be used to implant toric IOLs without the use of manual ink-marker steps. The SG3000 system consists of two units: the reference unit, used to measure the patient preoperatively, and the surgery pilot, which is positioned in the operating room. The reference unit is a noncontact device that acquires a high-resolution digital image of the eye, in which the limbal vessels, scleral vessels, and iris characteristics are shown in detail (Figure 2). Simultaneously, this unit performs keratometry, and these results—including the steep and flat meridians of corneal astigmatism—and the position and diameter of the limbus and pupil are shown in an overlay in a digital image (Figure 2).

When the patient arrives in the operating room, the preoperative image from the reference unit is loaded into the surgery pilot, which consists of a PC, a microscope camera adaptor, and a microscope-integrated display. Next, the incision location and size, the capsulorrhexis location and size, and the implantation axis of the toric IOL are configured. The live image from the operating microscope is then matched with the preoperative digital image, based on blood vessel and iris characteristics. Intraoperatively, an overlay is visible in the operating microscope showing the intended incision location, capsulorrhexis, or IOL alignment axis (Figure 3). The SG3000 system uses eye-tracking technology based on limbal and scleral blood vessels and iris characteristics to correct for all rotational and translational movements of the eye during surgery.

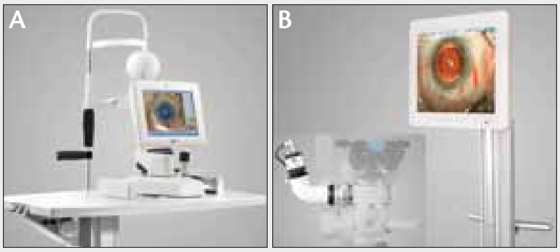

Figure 1. The SG3000 consists of a (A) reference unit and (B) surgery pilot. The surgery pilot consists of a PC, a microscope camera adaptor, and an optional microscope-integrated display.

We have been using the SG3000 system in our department for approximately 2 years. In our experience, it is an easy-to-use system that increases the accuracy of toric IOL alignment. We perform the preoperative measure-

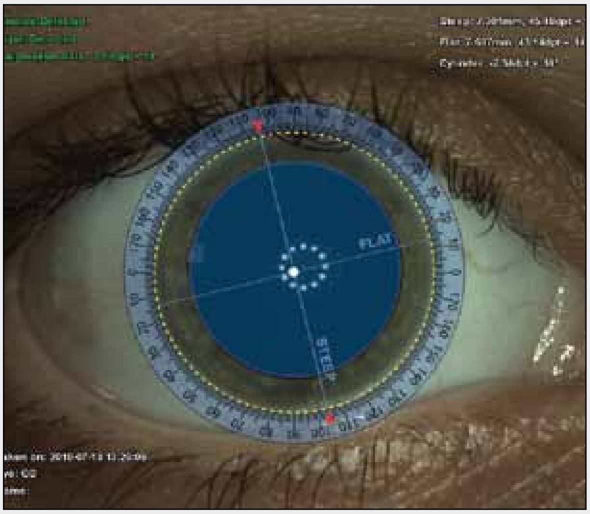

Figure 2. Image obtained with the reference unit, in which the limbal vessels, scleral vessels, and iris characteristics are visible. As the preoperative image is captured, keratometry is also performed, and the keratometry results and position and diameter of the limbus and pupil are shown in an overlay.

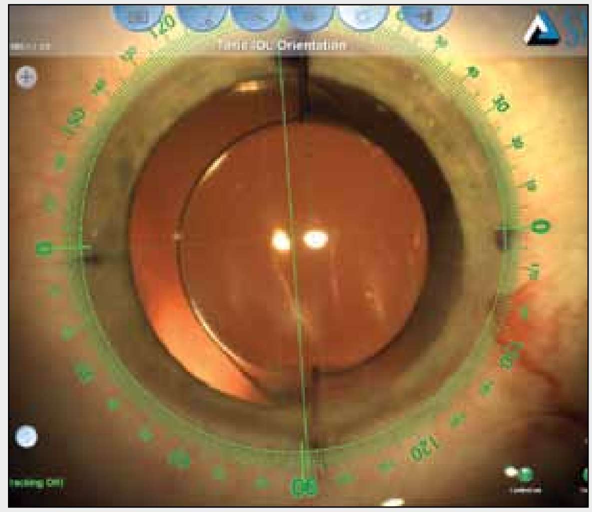

Figure 3. Overlay of the planned toric IOL alignment axis. This overlay is visible in the operating microscope.

> The SG3000 accurately aligns toric IOLs and can be used for incision location, capsulorrhexis creation, and IOL centration.

ment using the reference unit with the patient's eye in mydriasis because, in our experience, this provides the best match with the live image in the operating microscope. During surgery, we found that the system is stable and tolerant to zoom, light changes, and other surgery interactions. As shown in Figure 3, alignment of the toric IOL using the overlay in the operating microscope is fairly easy to do. This prevents problems that may occur with manual ink markings, such as wash-out or fading of ink marks, and increases the accuracy of toric IOL alignment.[1] Another advantage of the SG3000 is that the size of the overlay diagram matches well with the size of the IOL marks, whereas ink marks are usually much larger.

In addition to toric IOL alignment, we use the SG3000 system for other applications in lens implantation surgery. First, it provides an extra safety check, as it allows the surgeon to ensure that the correct eye of the correct patient is being operated on. Second, we use the SG3000 to plan the location of the main incision and paracenteses. Because the preoperative keratometry results are visible, it is possible to directly position the main incision on the steep axis of the cornea. Third, the SG3000 may be used to choose an exact capsulorrhexis diameter. Fourth, when implanting a multifocal IOL, the system helps to center the IOL according to the location of the undilated pupil.

Overall, the SG3000 system provides a simple and accurate method for toric IOL alignment. Additionally, this system may be used for other aspects of lens implantation surgery, including incision location, capsulorrhexis, and IOL centration. ■

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