Diagnostic Technologies for Enhanced Cataract Surgery Outcomes

Surgeons discuss their preferred tools for achieving superior results.

BY WARREN E. HILL, MD; CARLO LACKERBAUER, MD; THOMAS OLSEN, MD, PhD; AND SUNIL SHAH, MBBS, FRCOphth, FRCS(Ed), FBCLA

Greater Refractive Accuracy With the Lenstar LS900

By Warren E. Hill, MD

The Lenstar LS900 (Haag-Streit AG) represents the newest generation of optical biometers. I have found that this instrument, by allowing user validation of all aspects of the measurement process, increases the refractive accuracy of cataract surgical outcomes. No longer do we have to assume that a specific measurement is correct. Additionally, many of the individual measurements made by the Lenstar are more accurate than those made by other devices, with anterior chamber depth and lens thickness determined by optical biometry and a high density of corneal measurement points. Five scans on both eyes can be accomplished in 3 minutes or less.

KERATOMETRY

One of the strongest features of the Lenstar is its strategy of high measurement density for determining the central corneal power. Using two rings of 16 measurements each at 1.65 mm and 2.3 mm, the Lenstar carries out a total of 32 measurements spaced 22.5º apart. The greatest distance that any meridian can be located from a measurement point is approximately 11º. This renders the keratometry (K) readings of the Lenstar highly accurate for the determination of the steep and flat meridians and also the difference in power between them—a feature that makes this instrument especially useful for toric IOLs. The device's K measurements have been demonstrated to be equivalent to manual keratometry for use with a toric IOL.[1] Lenstar K measurements may also be used with the American Society of Cataract and Refractive Surgery (ASCRS) online post-keratorefractive surgery IOL power calculator.

Each button push allows the operator to view four images of the cornea with the reflected image of the measurement LEDs. Areas where the reflected image is not well formed, as with a dry eye, are an indication that information may not be correct in that area. Individual measurements can be deleted and repeated until it is certain that the quality of all measurements is acceptable.

The standard deviation for displayed K values should be a variation that is no greater than 3.5° in the steep meridian and no greater than 0.25 D for the power in each of the two principal meridians. For toric IOL calculations, we have found that the Lenstar is the only keratometry device needed in our practice.

AXIAL MEASUREMENTS

For axial measurements, the Lenstar segments the eye into three sections: cornea and aqueous, lens, and posterior segment. Central corneal thickness, anterior chamber depth (ACD), lens thickness, and overall axial length are all measured by optical biometry. The axial measurement display is presented in the familiar form of an immersion A-scan, with a spike at the location of each optical interface. Validation of each of the axial measurements simply involves verifying that the moveable electronic calipers are in the correct locations. Precise measurements of ACD and lens thickness are requirements of later-generation theoretical formulas such as the Holladay 2 and Olsen. For future generations of IOL power calculation methodologies, and also those that may employ advanced ray-tracing and engineering-based statistical models, exact measurements of the ACD and lens thickness will be critical.

HORIZONTAL CORNEAL DIAMETER

Each of the five measurements of the horizontal corneal diameter can be adjusted by the user to line up perfectly with the corneal limbus. This is especially important for patients with lightly colored irides, which sometimes make the interface between the sclera and the limbus difficult to discern. Once the user verifies that all five measurements are correct, the instrument generates a mean value, unless one or more of the measurements has been deselected. Again, newer-generation formulas incorporate horizontal corneal diameters into the calculation process, and this information is also used to estimate the size of back-up anterior chamber IOLs, making accuracy very important.

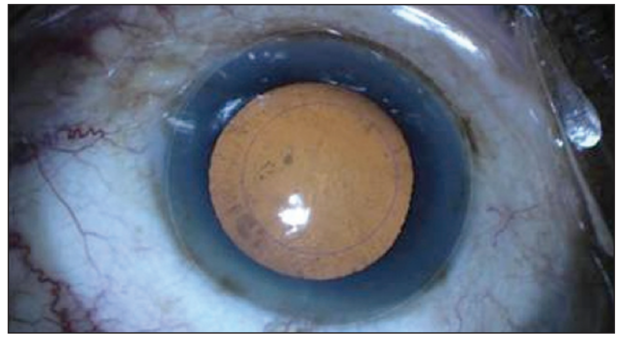
Warren E. Hill, MD, is in private practice at East Valley Ophthalmology in Mesa, Arizona. Dr. Hill may be reached at (480) 981-6130; hill@doctor-hill.com.

1. Hill WE,Osher R,Cooke D, et al. Simulation of toric IOL results comparing manual keratometry to dual-zone automated keratometry from an integrated biometer. *J Cataract Refract Surg*. 2011;37:2181-2187.

Modern Solutions for Refractive Cataract Surgery: Callisto eye

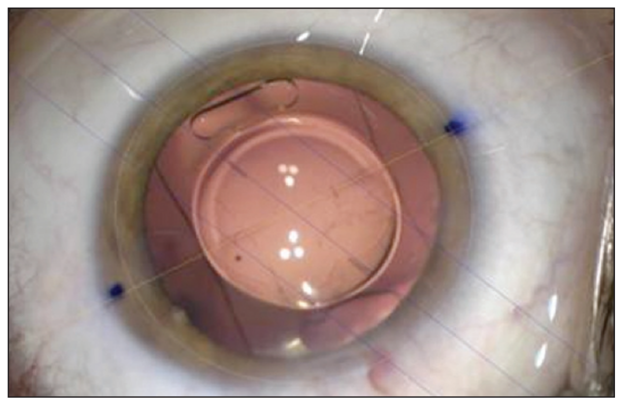
By Carlo Lackerbauer, MD

According to recent studies,[1,2] up to one-third of cataract patients with astigmatic refractive errors could benefit from the implantation of a toric IOL. The use of optical biometry, a microincisional surgical technique, and an IOL with rotationally stable geometry are mandatory in toric IOL surgery, and all are commonly used today. One of the main reasons that the use of toric IOLs in cataract surgery is limited, however, is the difficulty of accomplishing perfect IOL alignment using standard marking methods. This problem is well known and documented in the literature.[3-7]



(Courtesy of Carlo Lackerbauer, MD)

Figure 1. The Rhexis Assistant helps the surgeon achieve the



(Courtesy of Carlo Lackerbauer, MD)

Figure 2. The Z Align feature assists with toric IOL alignment.

Callisto eye (Carl Zeiss Meditec)—a novel intraoperative eye-tracking device designed to integrate with the OPMI Lumera 700 microscope (Carl Zeiss Meditec)—is a useful and safe assistance system to increase the accuracy of toric IOL positioning. All data including the toric axis of the lens to be implanted are configured in the Callisto eye system before surgery, optimizing the intraoperative workflow. When the patient arrives in the operating room, the reference axis is detected automatically based on two markers, at 0° and 180°, which were previously marked while the patient was in a seated position. With the help of the Integrated Data Injection System (IDIS), keratometry data including the steep axis (K-track), incision position, rhexis diameter (Figure 1), and toric IOL alignment (Z Align; Figure 2) are visible for the surgeon as an online overlay picture in the operating microscope.

We have been using the Callisto eye system in our department for more than 2 years. Based on our experience, it is an easy-to-learn and easy-to-use system that increases the accuracy of our daily cataract surgeries, especially when we are implanting toric IOLs. We have found that during surgery the system is stable and tolerant of magnification activities of the microscope, light changes, and surgical instrument interactions.

My colleagues and I conducted a comparative study including 62 eyes. The Callisto eye system was used in 45 eyes, and the standard marking method was used in 17 eyes. We observed improved toric IOL alignment with the use of the intraoperative eye-tracking device. The precision of the IOL alignment to the toric axis, measured 1 day postoperatively, showed the following results: Callisto eye, 2.88° ±2.76; standard marking method, 5.94° ±10.67 (P=.076; Mann-Whitney U test, P<.05).

The next step in the development of this system will be a data-based picture, generated from the IOLMaster (Carl Zeiss Meditec), that includes a high-resolution digital image in which the limbal vessels, scleral vessels, and iris characteristics are shown; this will be used for an ink-free reference intraoperatively.

Carlo Lackerbauer, MD, is the Clinical Director of the Eye-Competence-Munich and a member of the University

Eye Hospital Munich (Ludwig-Maximilians-University). Dr. Lackerbauer states that he has no financial interest in the products or companies mentioned. He may be reached at e-mail: carlo.lackerbauer@augen-kompetenz-muenchen.de.

1. Ferrer-Blasco T, Montés-Micó R, Peixoto-de-Matos SC, González-Méijome JM, Cerviño A. Prevalence of corneal astigmatism before cataract surgery. *J Cataract Refract Surg*. 2009;35:70-75.
2. Hoffmann PC, Hütz WW. Analysis of biometry and prevalence data for corneal astigmatism in 23,239 eyes. *J Cataract Refract Surg*. 2010; 36(9):1479-1485.
3. Tseng SS, Ma JJ. Calculating the optimal rotation of a misaligned toric intraocular lens. *J Cataract Refract Surg*. 2008;34(10):1767-1772.
4. Kohnen T, Klaproth OK. Correction of astigmatism during cataract surgery. *Klin Monbl Augenheilkd*. 2009;226(8):596-604.
5. Cha D, Kang SY, Kim SH, Song JS, Kim HM. New axis-marking method for a toric intraocular lens: mapping method. *J Refract Surg*. 2010;15:1-5.
6. Wolffsohn JS, Buckhurst PJ. Objective analysis of toric intraocular lens rotation and centration. *J Cataract Refract Surg*. 2010;36(5):778-782.
7. Carey PJ, Leccisotti A, McGilligan VE, Goodall EA, Moore CB. Assessment of toric intraocular lens alignment by a refractive power/corneal analyzer system and slit lamp observation. *J Cataract Refract Surg*. 2010;36(2):222-229.

Ray-Tracing Analysis and Other Improvements in IOL Power Calculation

By Thomas Olsen, MD, PhD

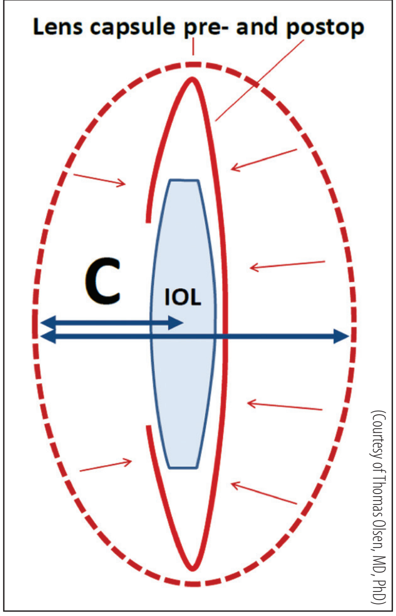
The frontier of IOL power calculation has changed considerably over the past 10 years. Before the era of optical biometry, ultrasound measurement of axial length was by far the largest source of error. Due to the introduction of laser biometry (IOLMaster, Carl Zeiss Meditec), the axial length can be determined with incredible accuracy, typically within 0.02 mm between repeated measurements. The major remaining sources of error are the estimated lens position (ELP) and the optics of the cornea.

NEW ACCURATE PRINCIPLE FOR ELP PREDICTION

My colleagues and I recently described a simple but very accurate method to predict individual IOL position based on preoperative measurements of the anterior chamber depth and lens thickness. The method introduces the C-constant (Figure 3), which is a new IOL-specific constant describing the location of the IOL within the capsular bag as a fraction of the lens thickness. The formula is:

$$IOLc = ACDpre + C \times LTpre$$

where IOLc represents the center of the IOL, ACDpre is the preoperative anterior chamber depth, LTpre is the preoperative thickness of the crystalline lens, and C is a constant related to the IOL type, determined as the mean value in a representative sample.



(Courtesy of Thomas Olsen, MD, PhD)

Figure 3. The C-constant is defined as a ratio of the preoperative thickness of the crystalline lens by which the IOL will locate itself after surgery.

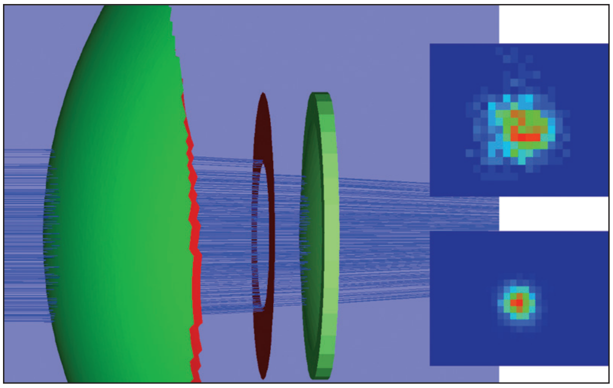
The advantage of this formula is that it is based entirely on the anterior segment anatomy and is independent of K reading and axial length (these measurements are still necessary to calculate the IOL power), and therefore it introduces no bias in short or long eyes, post-LASIK eyes, or other abnormal eyes. Its overall accuracy has been evaluated in more than 1,000 cases and found to be significantly greater than that of other formulas. For a video description of the C-constant, visit eyetube.net/?v=gumej.

eyetube.net
eyetube.net/?v=gumej

POST-LASIK CASES

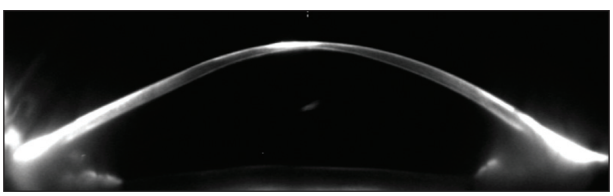
In postrefractive-surgery cases, the challenge in obtaining accurate IOL calculation arises from two sources: (1) difficulty in measuring the corneal optics and (2) errors in ELP calculation. The latter error stems from the fact that many conventional IOL power formulas (eg, SRK/T, Holladay, Hoffer Q) use only the K reading and the axial length for inputs and hence also base the ELP on those input variables. This will only work if there is a sound statistical relationship between the K readings and the effective ELP. An eye with an artificial flattening or steepening of the anterior corneal curvature will fall outside of normal relationships and therefore induce error. The C-constant offers a solution to this problem, as it will work in any type of eye, including post-LASIK eyes.

Difficulty measuring the corneal optics can be subdivided into (1) errors measuring the true cornea power and (2) difficulty reading the effective central radius. The latter error stems from the fact that all Placido-disc–based measurements are blind to the very central cornea, which may be flattest in an eye after myopic refractive surgery. Another problem is that the normal ratio between the front and back curvatures of the cornea is disrupted, making it impossible to deduce the true corneal power from the anterior curvature only. Measurements of both the front and back surfaces of the cornea are needed to get a better estimate of the effective corneal power.



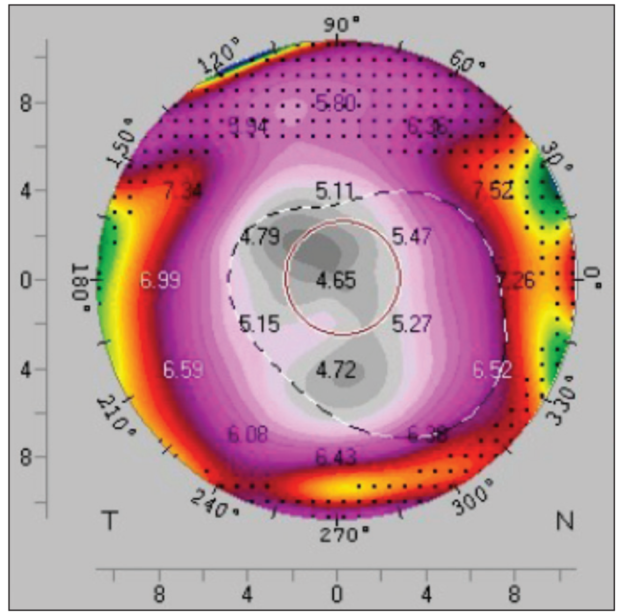
(Courtesy of Thomas Olsen, MD, PhD)

Figure 4. Ray-tracing experiment based on raw corneal height data measured by Pentacam and imported into Zemax optical engineering software. A pupil and an IOL have been added to the system, and the IOL power can be adjusted to obtain the sharpest point spread function at the retinal plane (inserts at right).



(Courtesy of Thomas Olsen, MD, PhD)

Figure 5. Pentacam Scheimpflug photo of a keratoconic eye, showing thinning and steepening of the central cornea.



(Courtesy of Thomas Olsen, MD, PhD)

Figure 6. Pentacam map of anterior curvature distribution showing central corneal curvature of about 4.6 mm (73.00 D) with considerable variation.

RAY TRACING

We now have access to several sophisticated instruments that yield high-definition resolution of the shape of the anterior and posterior surfaces of the cornea. The measurement points can be fitted to a spherocylinder, giving us curvatures in principal meridians; they can be fitted to an ellipsoid, giving us a conic coefficient that is useful to describe spherical aberration; or they can be used directly in a ray-tracing model, which produces a total picture of the refraction with no shape fitting at all.

We have begun a study importing Pentacam raw height data into ray-tracing software, such as the Zemax software (Radiant Zemax, LLC; Figure 4) developed for optical engineering. The advantage of this technique is that it is possible to compose and analyze the entire optical system and investigate the optimal performance of any element, such as how the IOL should be designed to fit the optical properties of the cornea. This technique shows great potential, as illustrated in the following case.

CASE REPORT

A 68-year-old man with stable keratoconus presented with a cataract in the right eye. His preoperative examination revealed visual acuity of less than 0.05 (20/400), refraction of about -20.00 D of sphere and -7.00 D of cylinder. Pentacam Scheimpflug photography showed a very steep cornea with considerable variation in central curvature (Figure 5).

Preliminary calculation predicted an IOL power of about -20.00 D with a large cylinder. We decided to perform high-definition analysis of the corneal optics and exported the Pentacam elevation data (Figure 6) into Zemax. The effective focal length was identified as the distance giving the minimum point spread at the image plane. We were therefore able to estimate the effective spherical and cylindrical powers of the cornea. These values were entered into the PhacoOptics software to determine the corresponding IOL power needed.

The surgery was performed as a two-stage procedure with in-the-bag implantation of a -12.00-D spherical IOL and sulcus placement of an add-on toric -9.00-D cylinder IOL. Four weeks later, the patient's UCVA in the operated eye was 0.5 (20/40).

CONCLUSION

In modern IOL power calculation, the focus has shifted from error in the measurement of axial length to better analysis of corneal optics, as we are challenged by an increasing number of patients who have had previous refractive surgery or who expect to achieve spectacle independence with premium IOLs. The future looks bright for lens-based refractive surgery.

Thomas Olsen, MD, PhD, is a Professor of Ophthalmology at the University Eye Clinic, Aarhus Hospital, in Denmark.

Tips for Optimizing Results

CRST Europe asked Editorial Advisory Board Members: What have you done in your practice to make patients say "wow"?

By Michael Amon, MD; A. John Kanellopoulos, MD; Thomas Kohnen, MD, PhD, FEBO; and Robert H. Osher, MD

MICHAEL AMON, MD

• I spend increased chair time, manage patient expectations appropriately, and perform a thorough preoperative work-up, especially when using premium IOLs;
• I perform meticulous, almost atraumatic surgery (resulting in a short rehabilitation period) under sufficient topical anesthesia (resulting in no pain during surgery);
• Candidates for multifocal IOLs receive an additional multifocal IOL during the same surgery (duet procedure) because of the reversibility of the procedure;
• I treat astigmatism greater than 1.00 D (with either limbal relaxing incision [LRI] or toric IOL); and
• Follow-up is performed in an organized fashion.

A. JOHN KANELLOPOULOS, MD

• A 70-year-old patient who received a toric IOL was "wowed" by the reduction in cylinder for probably the first time in his life!
• Patients' relatives or friends can observe the procedure and track the patients' whereabouts through glass-partitioned operating rooms.
• We webcast all cases on our website via live stream so that family and friends can watch. Believe it or not, this boosts patient confidence and reduces anxiety.
• We assign a team member to be the patient's exclusive companion throughout the whole experience in our center. This individual welcomes the patient at the doorstep; fast-tracks his or her registration; administers drops; instructs and answers questions; performs anesthesia prep; stays with the relative to explain the live procedure; attends the postop; and finally calls at night to check on the patient at home, which patients love.
• Femtosecond laser has helped us achieve a big "wow" factor for many patients.
• Most important, stellar outcomes are key.

THOMAS KOHNEN, MD, PHD, FEBO

The "wow" factor is achieved when
• Cataract surgery is performed under topical anesthesia;
• Toric IOLs are recommended for patients with appropriate levels of astigmatism;
• Bifocal and trifocal IOLs are implanted in patients requesting correction of presbyopia;
• Femtosecond laser is employed to create corneal incisions and perform lens fragmentation;
• Fast but precise surgery is carried out; and
• Perfect refractive outcomes are achieved.

ROBERT H. OSHER, MD

The "wow" factor depends on attaining emmetropia following cataract surgery. It is just that simple. Therefore, every surgeon needs to feel comfortable correcting not only the spherical component but also the cylindrical component of the pseudophakic refractive error. Having introduced astigmatic keratotomy combined with cataract surgery in the early 1980s, I have been elated with the more accurate results afforded by toric IOLs. Challenges still exist regarding more precise diagnostics, understanding of the role of posterior corneal astigmatism, intraoperative alignment, and the postoperative analysis of our outcomes. Yet it is still necessary that every cataract surgeon strive to become a refractive cataract surgeon. The truest definition of the "wow" factor is crystal-clear postoperative vision!

New-Technology IOLs Help Achieve Optimal Outcomes

By Allon Barsam, MD, MA, FRCOphth; Francesco Carones, MD; and H. Burkhard Dick, MD, PhD

ALLON BARSAM, MD, MA, FRCOPHTH

I use the Mplus MF30 and Mplus Toric (both by Oculentis GmbH) for patients who are motivated to have good uncorrected distance and near vision. For patients with corneal astigmatism who want excellent distance vision, I use the T-flex toric IOL (Rayner Intraocular Lenses, Ltd.), which has excellent rotational stability and a superb online toric IOL calculator for ease of use. This lens also works well for patients who have previously tolerated contact lens monovision. For high myopes who are young enough to remain phakic (younger than 40 years old) and who are outside the range of safe and predictable LASIK, I use the Visian ICL (STAAR Surgical). The safety profile of this phakic IOL in properly selected highly myopic patients makes it a far superior choice to a refractive lens exchange.

All of these lens options include aspheric optics optimized for reduction of positive spherical aberration to consistently achieve a high-definition postoperative visual outcome for patients. In the unlikely event that patients are left with small amounts of significant postoperative refractive error, I fine-tune them with Z-LASIK or advanced surface ablation.

FRANCESCO CARONES, MD

I am better able to help patients achieve the "wow" factor after cataract surgery since I started implanting the AcrySof IQ ReStor 2.5 (Alcon Laboratories, Inc.) in the patient's dominant eye and the AcrySof IQ ReStor 3.0 (Alcon Laboratories, Inc.) in the nondominant eye. This gives the patients the best of two worlds: spectacle independence and quality of vision, especially at nighttime.

H. BURKHARD DICK, MD, PHD

Despite the multitude of IOL solutions available to cataract patients today, limitations remain, particularly relating to suboptimal postoperative outcomes. The Light Adjustable Lens (LAL; Calhoun Vision, Inc.) takes an innovative approach to this problem by providing patients with outstanding and customizable postoperative results.

The LAL produces a final refractive outcome within 0.25 D of target in more than 98% of cases.[1] Its unique level of precision relates to the presence of light-sensitive macromers in the lens. These molecules change configuration on exposure to ultraviole light of a specific spatial intensity, allowing the lens' refractive power to be noninvasively altered after implantation. The lens power offered by the LAL is set only when a patient's residual error is known, and the light-based adjustments, which can correct up to 2.00 D of sphere and 2.00 D of cylinder, are guided by both refractive measurements and patient feedback. Multiple adjustments can be performed until the patient is happy.

The LAL is effective when implanted in myopic, hyperopic, and astigmatic eyes[2-4] and in difficult cases, such as eyes after refractive surgery and very short or long eyes. Excellent results have been achieved due to the LAL's ability to provide customized presbyopia solutions, such as adjustable monovision, customized near add, and asphericity control, positioned in the line of sight. A study of the LAL's customized near add function showed that it achieves good uncorrected distance and near visual acuity more frequently than an accommodating IOL.[5]

The LAL, used in conjunction with femtosecond laser-assisted cataract surgery, is a comprehensive solution to the increasing visual expectations of cataract surgery patients. This technology offers early postoperative correction and adjustment based on individual patient feedback, enriches our portfolio of premium lenses, and is able to deliver the "wow" factor even for challenging or demanding patients.

1. Dick HB. Change in paradigm refractive cataract surgery. Paper presented at: XXIX Congress of the European Society of Cataract & Refractive Surgeons; September 17-21, 2011; Vienna, Austria.
2. Hengerer FH, Dick HB, Conrad-Hengerer I. Clinical evaluation of an ultraviolet light adjustable intraocular lens implanted after cataract removal: eighteen months follow-up. *Ophthalmology*. 2011;118:2382-2388.
3. Hengerer FH, Hütz WW, Dick HB, Conrad-Hengerer I. Combined correction of axial hyperopia and astigmatism using the light adjustable intraocular lens. *Ophthalmology*. 2011;119:1236-1241
4. Hengerer FH, Hütz WW, Dick HB, Conrad-Hengerer I. Combined correction of sphere and astigmatism using the light adjustable intraocular lens in eyes with axial myopia. *J Cataract Refract Surg*. 2011;37:317-323.
5. Hengerer FH, Böcker J, Dick HB, Conrad-Hengerer I. Light adjustable intraocular lens. New options for customized correction of presbyopia. *Ophthalmologe*. 2012;109:676-682

Dr. Olsen states that he is a shareholder of IOL Innovations, manufacturer of the PhacoOptics program. He may be reached at tel: +45 89 493 228; fax: +45 86 121 653; e-mail: tkolsen@ dadlnet.dk.

The Aladdin for Precise Biometry

By Sunil Shah, MBBS, FRCOphth, FRCS(Ed), FBCLA

Cataract surgery has evolved into a refractive procedure from which patients demand accurate results. The correct selection of an appropriate IOL is crucial to achieve optimum refractive outcomes. Sources of error can arise from the inaccurate measurement of the biometric parameters of the eye, leading to the implantation of an incorrect IOL; therefore, precise biometry is extremely important to ensure successful outcomes of cataract and refractive surgery.

Since the advent of interformetry techniques, the market has been dominated by the IOLMaster (Carl Zeiss Meditec) and, more recently, the Lenstar (Haag-Streit). The most recent addition to the lineup of optical biometers is the Aladdin (Topcon Europe). For the refractive cataract surgeon who worries about keratometry readings from the earlier devices in regard to astigmatic correction, the Aladdin incorporates Placido-based topography.

The Aladdin was developed with three key points in mind: speed, accuracy, and ease of use. The device uses optical low-coherence interferometery and, because of its design, is thought to be able to measure a very high percentage of eyes regardless of the type of cataract. The topographer analyzes approximately 1,000 data points at a 3-mm diameter. This topography-based keratometry figure is provided for use with IOL calculation formulas.

We have assessed the accuracy and reproducibility of biometry performed with the Aladdin biometer in comparison with the current gold standard device, the IOLMaster 500. Measurements of axial length, ACD, and keratometry were undertaken with the Aladdin and IOLMaster 500 by two experienced practitioners. The results were evaluated and compared to assess the interobserver variability of the Aladdin.

In a study of 100 cataractous eyes comparing the two systems, the mean difference was 0.005 mm for axial length and 0.007 mm for anterior chamber depth. The average Ks were 0.02 D different. None of these parameters showed any statistically significant difference. The calculated intraocular power was also very similar, with a mean difference of only 0.40 D. Interestingly, in this group, 6% of eyes could not be read by the IOLMaster 500, but all eyes were read by the Aladdin (data on file with Topcon Europe).

There was no statistically significant difference in predicted IOL powers between the Aladdin and the IOLMaster. Interobserver agreement between the two practitioners was found to be good for each parameter measured by the Aladdin.

CONCLUSION

The Aladdin is an exciting addition to available biometry instruments. It is extremely fast and convenient to use, especially considering that one automatically gets a topography map within the series of measurements. This device is capable of rapidly becoming a gold standard for biometry among refractive cataract surgeons. ■

Sunil Shah, MBBS, FRCOphth, FRCS(Ed), FBCLA, is an Honorary Professor at the School of Biomedical Sciences, University of Ulster, Coleraine, Northern Ireland; Visiting Professor at the School of Life & Health Sciences, Aston University, Birmingham, United Kingdom; Director, Midland Eye Institute, Solihull, United Kingdom; and Consultant Ophthalmic Surgeon, Birmingham & Midland Eye Centre, Birmingham, United Kingdom. Professor Shah is a consultant to Topcon Europe. He may be reached at tel: +44 1217112020; fax: +44 1217114040; e-mail: sunilshah@doctors.net.uk.