

Posterior Segment OCT

A screening tool in premium IOL surgery.

BY MARK PACKER, MD, CPI

Ophthalmology has come far since the first postapproval Array multifocal IOL was implanted in the United States in 1997. In those days, candidacy for a multifocal IOL was defined by the patient's answers to two simple questions, as famously phrased by Howard Fine, MD:

1. Would it be of benefit to you if we could implant a lens that would reduce or eliminate your need for glasses?
2. Would it bother you if that lens were associated

with halos around lights at night?

A "yes" to the first question and a "no" to the second meant the surgeon should proceed. That was the extent of the specific evaluation for a multifocal IOL's implantation.

Today, preoperative evaluations include tear film analysis, corneal topography, wavefront analysis, anterior and/or posterior segment optical coherence tomography (OCT), and an in-depth interview or a formalized qualita-

SUCCESS WITH PRESBYOPIA-CORRECTING IOLS

The results with presbyopia-correcting IOLs can be extremely gratifying. In a retrospective analysis of refractive lens exchanges performed in my colleagues' and my practice between May 2007 and January 2010, a high percentage of patients achieved independence from glasses (Figure 1). Our data show that outcomes have kept pace as technology has improved. We were able to obtain these results, because candidates had been carefully screened to rule out preoperative pathology that might have diminished their chances of a successful outcome.

In addition, throughout the study period, we used a single standardized approach to biometry and IOL power calculations. We utilized the IOLMaster partial coherence interferometry device (Carl Zeiss Meditec, Inc., Dublin, CA) to measure axial length, anterior chamber depth, and corneal white to white. In addition, we entered simulated keratometry values from the EyeSys corneal topography system (Tracey Technologies, Houston, TX) into the Holladay IOL Consultant software program (Holladay Consulting, Inc., Bellaire, TX). We used the Holladay 2 formula to calculate IOL power. In August 2008, we began to perform intraoperative aberrometry to improve the correction of astigmatism.¹

Surgical technique also played a critical role in our outcomes. I performed phacoemulsification using a biaxial microincisional technique. In brief, I constructed two trapezoidal, temporal, clear corneal incisions of 1.4 mm, allowing the introduction of a 20-gauge, 30° beveled phaco tip and an irrigating chopper (Duet Bi-Manual System; MicroSurgical Technology, Redmond, WA). The location of

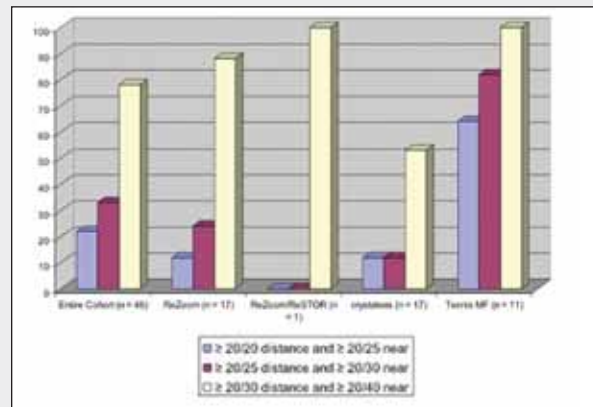


Figure 1. Combined uncorrected distance and near binocular acuities.

the two incisions varied depending on the anticipated location of any limbal relaxing incisions. In all cases, I designed the capsulorhexis to be round, centered, and smaller in diameter than the IOL's optic. The introduction of the Refractive Toolset virtual guidance program on the TrueVision 3D Visual System (TrueVision Systems, Inc., Santa Barbara, CA) improved the accuracy with which I constructed the capsulorhexis. Phacoemulsification proceeded with a vertical chopping technique. I inserted the IOL through a third temporal, trapezoidal, clear corneal incision. Its diameter was 2.2 to 2.8 mm, depending on the size required for implanting the IOL.

1. Packer M. Effect of intraoperative aberrometry on the rate of postoperative enhancement: retrospective study. *J Cataract Refract Surg*. 2010;36(5):747-755.

CORRECTING PREEXISTING CORNEAL CYLINDER

When corneal topography indicates a need for a limbal relaxing incision (LRI) to correct preexisting astigmatism, I measure corneal pachymetry (Cornea-Gage Plus; Sonogage, Inc., Cleveland, OH) at the 10-mm optical zone at both ends of the proposed arcuate incision and at points on either side of the axis. Before the patient is transferred to the OR, I mark the 12- and 6-o'clock positions with a surgical pen on the adjacent conjunctiva while the patient sits upright and fixates on a distant target. Alternatively, I use the TrueVision LRI Toolset (TrueVision Systems, Inc., Santa Barbara, CA) to image the eye preoperatively. It provides virtual three-dimensional guidance in the OR for construction of the LRIs.

After a standard protocol for topical anesthesia and preoperative antibiotic prophylaxis, the eye is prepped and draped for surgery.¹ I initially mark the planned arcs of the LRIs with a Ruminson astigmatic gauge and marker (Rhein Medical, Inc., Tampa, FL) to allow placement of the biaxial microincisions for the lens' extraction outside these areas. In the case of against-the-rule astigmatism, I construct the temporal arc before creating the incision for the IOL's insertion. Otherwise, I make both arcs after implanting the IOL.

I inflate the eye with an ophthalmic viscosurgical device

and mark the 10-mm zone with an optical zone marker. Next, I use ORange intraoperative wavefront aberrometer (WaveTec Vision, Aliso Viejo, CA) to measure the refractive astigmatism of the whole eye, and I adjust the planned LRI to take the new data into account. I fixate the eye with a large-diameter, short-handled Fine-Thornton ring (Rhein Medical, Inc.). The ocular surface is lubricated with the ophthalmic viscosurgical device, and I adjust a diamond blade (Stealth Triamond; Mastel Precision, Inc., Rapid City, SD) to 90% of the measured pachymetry. I am careful to hold the blade at 90° to the corneal surface and to completely and accurately incise the arc. Next, I probe and rinse the LRIs with balanced salt solution on a 30-gauge cannula to ensure the absence of skipped areas or bridging fibers between the walls of the incisions.

A follow-up intraoperative wavefront image is taken to ensure that astigmatic correction is adequate. I extend the arcs either symmetrically or asymmetrically if 1.00 D or more of astigmatism remains.

1. Packer M, Hoffman RS, Fine IH. Perfecting your protocol for infection prophylaxis. *Ophthalmology Management*. March 2008. <http://www.ophthmanagement.com/article.aspx?article=101484>. Accessed June 15, 2011.

tive or quantitative questionnaire regarding the patient's lifestyle choices, refractive goals, and degree of perfectionistic thinking. Macular OCT not only helps with preoperative counseling, but it also assists with the education of patients and their postoperative care.

PREOPERATIVE SCREENING

A simple misstep during the preoperative evaluation can negate the considerable effort ophthalmologists put into IOL power calculations, their surgical technique (see *Success With Presbyopia-Correcting IOLs*), and astigmatic correction (see *Correcting Preexisting Corneal Cylinder*). Aspheric multifocal IOLs are complex optical devices; they function well as long as the cornea, macula, optic nerve, and brain work well. A breakdown anywhere in the optical or neurological system can lead to dissatisfaction on the part of the patient and the surgeon.

For these reasons, imaging of the macula with spectral domain OCT represents an emerging standard in the care of cataract and refractive patients who are candidates for multifocal IOLs. A finding that may increase postoperative dysphotopsia (eg, an epiretinal membrane) or reduce postoperative contrast sensitivity (eg, retinal pigment atro-

phy) suggests a relative contraindication for the implantation of a multifocal IOL.¹ In these cases, patients may still do quite well with a toric or accommodating IOL, but they will likely have to accept some dependence on spectacles, at least for reading small print or doing fine work at near.

PATIENTS' EDUCATION

Another great advantage of posterior segment OCT (PS-OCT) is its ability to graphically and dramatically demonstrate pathological findings to patients. Thanks to our implementation of electronic medical records, my colleagues and I have a large screen in every examination room. This allows us to display full-color, high-resolution images of the macula to patients that demonstrate the impact of an epiretinal membrane, macular drusen, or cystoid macular edema (CME). Patients express appreciation and understanding when I point out the findings on the screen and explain how they affect vision (the same can be said of optic disc imaging in glaucoma). In the critical area of communication and counseling, show and tell with PS-OCT gives me a distinct advantage.

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Aberrometry

How these devices work.

BY ALAN R. FAULKNER, MD

Aberrometry is the measurement of the imperfections in an optical system. This technique has been used for years, particularly in astronomy, to develop accurate optical systems. Aberrometry was introduced to the vision sciences in the mid-1990s, and the first commercially available clinical aberrometer was the COAS (Complete Ophthalmic Analysis System) from AMO WaveFront Sciences, LLC (Albuquerque, NM), released in 2000. The original aberrometers were based on the Shack-Hartmann principle, a technique developed by Johannes Hartmann in 1900 and modified by Shack and Platt in the late 1960s. Numerous other methodologies and applications have since arisen.

THERAPEUTIC ABERROMETERS

The widespread introduction of aberrometers into clinical ophthalmology occurred primarily in association with the development and approval of wavefront-guided laser treatments. Theo Seiler, MD, PhD, performed the first such procedure in the world using the WaveLight platform (WaveLight Laser Technologie AG, Erlangen, Germany) in 1999.

In the United States, the LADARWave aberrometer (built by Carl Zeiss Meditec, Inc., Dublin, CA) was approved for use in 2002 with the LADARVision excimer laser (both products from Alcon Laboratories, Inc., Fort Worth, TX). The WaveScan Wavefront System was approved in 2003 for use with the Visx Star S4 excimer laser (both products from Abbott Medical Optics Inc., Santa Ana, CA). These aberrometers are based on Shack-Hartmann principles and use Zernike analysis to express the results in both mathematical and graphic terms. The WaveScan currently uses Fourier algorithms to analyze data and improve precision. The LADARWave, although no longer commercially available, is still used by many clinicians for diagnostic evaluations.

The Allegro Analyzer, part of the WaveLight Allegretto line (Alcon Laboratories, Inc.), uses the Tscherning principle to obtain wavefront data and expresses the results in Zernike polynomials. Shack-Hartmann aberrometers send a single light beam into the eye and then analyze the outgoing light bundle. In contrast, Tscherning aberrometers project a spot pattern of 168 points into the

“A number of devices have been developed using various strategies to increase the sensitivity, validity, and range of wavefront measurements.”

eye and analyze the image of the spot pattern on the retina. According to Alcon Laboratories, Inc., the advantage of the Tscherning method for wavefront-guided laser treatments is that it avoids inaccurate results from media opacities, which can produce false positives with a Shack-Hartmann device. The vast majority of aberrometers in use with laser systems employ the Shack-Hartmann principle.

DIAGNOSTIC DEVICES

The proliferation of devices associated with wavefront-guided laser procedures allowed ophthalmologists to examine numerous eyes in association with various refractive treatments, IOLs, and naturally occurring pathology. As a result, surgeons came to appreciate the diagnostic value of aberrometry as well as its limitations. A number of devices have been developed using various strategies to increase the sensitivity, validity, and range of wavefront measurements.

The Nidek-OPD Scan II (Nidek, Inc., Fremont, CA) utilizes the principle of skiascopic phase difference to measure refractive error. The unit scans the retina with an infrared slit beam, and the reflected light is captured by an array of rotating photo detectors over a 360° area. In essence, the device produces a highly detailed retinoscopic map of the refractive state of the eye from numerous points on the cornea. The Nidek-OPD Scan II provides information on corneal topography, wavefront measurements, autorefractometry, keratometry, and pupillometry. By subtracting the corneal refractive power from the total optical path difference or wavefront error, the unit is able to generate an internal optical path difference reflecting the optical quality and refractive state of the crystalline lens and internal ocular media. The tech-



Figure 1. ORange intraoperative wavefront aberrometer.

nique functions over a wide range of refractive errors and is capable of measuring highly aberrated eyes.

According to literature from AMO WaveFront Sciences, LLC, the current version of the COAS is the world's highest-resolution wavefront aberrometer. The same literature states that, based on patented Shack-Hartmann wavefront-sensing technology, COAS provides unparalleled accuracy, range, and resolution for wavefront-based ophthalmic metrology and gives the physician an ultradetailed map of the eye. The COAS-VR uses both dynamic and static wavefront measurements, making it capable of measuring accommodation. Real-time measurements allow users to analyze aberrations in

many forms, including displays of cylinder, higher-order aberrations, Zernike polynomials, pupillary size, high-resolution wavefront maps, power maps, gradient maps, modulation transfer function, point spread function, and visual acuity simulation.

The iTrace (Tracey Technologies, Houston, TX) is unique in eye care diagnostics: it measures quality of vision and visual function using a fundamental thin-beam principle of optical ray tracing. The iTrace sequentially projects 256 near-infrared laser beams into the eye to measure forward aberrations; it processes data point by point. This system provides autorefractometry, corneal topography, ray-tracing aberrometry, pupillometry, and autokeratometry. As with the Nidek-OPD II, the iTrace can distinguish internal aberrations from surface or corneal aberrations.

The Maxwell Optical Wavefront Aberrometer (Ziemer Ophthalmic Systems AG, Port, Switzerland) measures a wide range of functions. It is designed to effectively assess all of the wavefront aberrations present in a subject's eye. According to the company, this device offers the widest wavefront diagnostic range and functions on more than 99% of subjects.

INTRAOPERATIVE ABERROMETRY

The newest and possibly most significant use of aberrometry is intraoperatively. ORange (WaveTec Vision, Aliso Viejo, CA) is the first intraoperative wavefront aberrometer registered with the FDA for cataract surgery.

Method	Absolute		ORange v2.5 (N = 141)	ORange v2.6 Optimized** > 26.00 mm (N = 106)
	Mean ± SD	Range		
Pre-LASIK / PRK K + ΔMR				
Clinical History	1.10 ± 0.96	0.01 to 4.34		
Feiz / Mannis	1.31 ± 1.11	0.00 to 4.67		
Corneal bypass	1.11 ± 0.95	0.00 to 4.09		
ΔMR†				
Adjusted EffRP	0.64 ± 0.59	0.00 to 1.97		
Adjusted Atlas0-3	0.64 ± 0.51	0.03 to 2.26		
Masket	0.71 ± 0.59	0.02 to 2.77		
Modified Masket	0.62 ± 0.49	0.02 to 2.02		
No prior data†				
Wang / Koch / Maloney	0.66 ± 0.48	0.02 to 2.29		
Shammas	0.69 ± 0.49	0.01 to 2.30		
Haigis-L	0.65 ± 0.51	0.01 to 2.70		
Average (mean) IOL power‡	0.57 ± 0.51	0.01 to 1.99		
			ORange v2.5 ≤ 27.00 mm (N = 93)	ORange v2.6 Optimized** ≤ 26.00 mm (N = 206)
Mean Absolute Error (MAE)			0.63	0.53
Standard Deviation			±0.52	±0.44
≤ % 0.50			50%	58%
≤ % 1.00			82%	85%
Mean Absolute Error (MAE)			0.60	0.54
Standard Deviation			±0.49	±0.46
≤ % 0.50 D			49%	61%
≤ % 1.00 D			78%	87%

Figure 2. IOL power calculations after refractive surgery using ORange Custom Cataract System for myopic procedures.

Consisting of an optical head attached below the operating microscope and the ORange processor, the device uses a technology known as Talbot-Moiré interferometry to analyze the wavefront and produce the refractive value of the eye (Figure 1).

The first generation of ORange was only capable of making pseudophakic measurements, but the second generation takes both pseudophakic and aphakic measurements. Using the aphakic measurement as the primary data point, the device provides guidance on IOL power selection—of particular interest in eyes that have undergone refractive surgery. Additionally, ORange assists with the orientation of toric IOLs and the placement of limbal relaxing incisions in phakic, aphakic, and pseudophakic eyes.

As an early adopter of this technology, I have seen steady progress in the reliability of the primary data and the generation of IOL power calculations, especially in the difficult scenario of a patient with a history of refractive surgery. The results of ORange in postrefractive surgery patients compare favorably to those achieved using the methods in the ASCRS postkeratorefractive IOL calculator (Figure 2). My partners' and my results have exceeded the global data, with a mean absolute value of the prediction error of $0.42 \text{ D} \pm 0.33$ and a range of 0.005 to 1.185 D. Anecdotally, the device has prevented several of our patients from receiving IOLs of the wrong power, and it has provided accurate confirmation of the power in many other cases.

Other intraoperative systems are in development but not yet available commercially. The Holos (Clarity Medical Systems, Inc., Pleasanton, CA) will reportedly supply real-time, continuous measurements of the eye's refractive state.

CONCLUSION

Thanks to ongoing enhancements of hardware design and software development, the current generation of aberrometers has numerous investigational, diagnostic, and therapeutic applications. This technology contributes valuable information about the optical system of the eye that enhances physicians' ability to deliver quality care to their patients. ■

Alan R. Faulkner, MD, is the founder of and is in private practice with Aloha Laser Vision in Honolulu, Hawaii. He is a paid member of the Refractive Clinical Advisory Board of Alcon Laboratories, Inc., but stated that he holds no financial interest in the products or other companies mentioned herein. Dr. Faulkner may be reached at (808) 792-3937; dralan@alohalaser.com.

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POSTOPERATIVE COUNSELING

A fear of encountering dissatisfied patients postoperatively continues to prevent many surgeons from offering presbyopia-correcting IOLs. When their UCVA is not as expected and patients express dissatisfaction, my goal becomes accurate diagnosis. Many factors may explain the situation, including residual refractive error, a poor-quality tear film, irregular astigmatism, tilting or decentration of the IOL, posterior capsular opacification, vitreous floaters, and CME. Imaging studies (including corneal topography, anterior segment OCT, Scheimpflug photography, and PS-OCT) can help differentiate the various pathophysiological particulars.

Trace, subclinical CME can reduce patients' contrast sensitivity during the early postoperative period, and it warrants a more intense anti-inflammatory regimen. Particularly in today's environment of generic topical medications and absent pharmaceutical samples, surgeons must be alert to the efficacy and safety of the various available medications. PS-OCT has become the standard for diagnosing CME. I greatly prefer this non-invasive imaging option to fluorescein angiography, which I reserve for doubtful cases.

CONCLUSION

In our practice, my colleagues and I perform PS-OCT only when indicated. Patients are billed if there is a corresponding medical diagnosis for which the test is indicated (eg, epiretinal membrane).

PS-OCT has made a dramatic entry into anterior segment surgery. At the 2010 annual meeting of the ASCRS, 60% of attendees at a joint symposium sponsored by the Retina and Cataract Clinical Committees stated that they were currently using OCT for preoperative imaging of the macula prior to cataract surgery. PS-OCT represents an emerging standard of care and an invaluable diagnostic modality. ■

Mark Packer, MD, CPI, is a clinical associate professor at the Casey Eye Institute, Department of Ophthalmology, Oregon Health and Science University, and he is in private practice with Drs. Fine, Hoffman & Packer, LLC. He is a consultant to Abbott Medical Optics Inc. and Bausch + Lomb. He is a consultant to and holds equity in TrueVision Systems, Inc., and WaveTec Vision. Dr. Packer may be reached at (541) 687-2110; mpacker@finemd.com.



1. Sunness JS, Rubin GS, Applegate CA, et al. Visual function abnormalities and prognosis in eyes with age-related geographic atrophy of the macula and good visual acuity. *Ophthalmology*. 1997;104(10):1677-1691.