Wavefront Aberrometry in Cataract Surgery and Laser Vision Correction

BY ALLON BARSAM, MD, MA, FRCOphth, AND DAN B. TRAN, MD

The Munnerlyn ablation profiles first used in laser vision correction did not respect the normal prolate shape of the cornea. As a result, these ablation profiles induced aberrations that reduced patients' quality of vision. In recent years, enhanced understanding and technological adaptation to address spherocylindrical refractive error and higher-order aberrations (HOAs) have resulted in vast improvements in patients' quality of vision after laser vision correction. Today, the goal of refractive surgeons is to enable their patients to see better than 20/20 and to improve their quality of vision beyond what they might expect with glasses or contact lenses.

Cataract surgeons have developed and refined methods for calculating the IOL's power to achieve accurate and satisfactory postoperative refractive results. The same technology that helps provide optimal visual acuity with laser vision correction is now being used for cataract patients. Modern aspheric IOLs address the tendency of the cornea to induce less negative spherical aberration with advancing age, and some surgeons advocate customizing the choice of IOL depending on a patient's individual optical aberrations.[1] Perhaps the culmination of this attitude has been the development of intraoperative wavefront aberrometry, where a wavefront refraction measurement can be taken of the eye in the aphakic state at the time of surgery to guide the choice of IOL.

The term wavefront-guided approach *refers to an ablation profile that considers preoperative HOAs. The final goal is to avoid inducing aberrations and to eliminate some that exist. The laser ablation profile is computed preoperatively according to the results of aberrometry and is transferred to the excimer laser system for use during surgery.*

Despite the many advantages that wavefront technology offers refractive surgeons, customized ablation surgery based on an ocular wavefront has been subject to controversy over the effectiveness of the procedures. Shortcomings of ocular wavefront technology include a relatively limited number of points of analysis over the pupil's area, and some models falsely assume local corneal flatness of the analyzed area. In addition, generic variables such as accommodation, tear film distribution, and the pupil's motility can induce changes in HOAs that will influence the accuracy and efficacy of the customized ablation.

This edition of "Peer Review" highlights important findings of several recent studies evaluating wavefront aberrometry for both laser vision correction and cataract surgery. Having been treated last year by Eric Donnenfeld, MD, I (AB) have personally benefited from the fantastic results of customized LASIK. It is, therefore, a particular pleasure to put together this column for you. We hope you enjoy this installment of "Peer Review," and we encourage you to seek out and review the articles in their entirety at your convenience.

WAVEFRONT-CUSTOMIZED SURGERY

Oliveira et al reviewed the current knowledge regarding the optical properties of the cornea, and they emphasize the findings and conclusions obtained through corneal wavefront analysis. The authors highlighted current techniques for corneal topography and their application in wavefront analysis, and they described the use of Zernike polynomials in the decomposition of aberrations. The authors explained that a myopic excimer ablation induced positive spherical aberration by shifting the corneal asphericity to more positive values, whereas a hyperopic ablation induced negative spherical aberration on the cornea. Furthermore, hyperopic LASIK procedures have been shown to induce more spherical and coma-like aberrations than myopic LASIK. The authors described the potential benefits of selecting customized IOLs to compensate for the interindividual variability of corneal spherical aberration. They concluded that the computation of corneal spherical aberration before surgery is helpful for choosing the asphericity of the IOL to reduce postoperative ocular spherical aberration.[2]

Aslanides et al evaluated the long-term outcomes of aspheric corneal wavefront ablation profiles for excimer laser retreatment. The investigators performed a LASIK retreatment using the corneal wavefront ablation profile on 18 eyes that had previously undergone LASIK or PRK. The researchers used Custom Ablation Manager software and the Esiris excimer laser (both from Schwind eye-tech-solutions; not available in the United States) to perform the ablations. The mean manifest refraction spherical equivalent (MRSE) was -0.38 ±1.85 D before retreatment, -0.09 ±0.22 D 6 months postoperatively, and -0.10 ±0.38 D 4 years postoperatively. The reduction in MRSE was statistically significant at both postoperative time points ($P < .005$). Postoperative aberrations were statistically lower (spherical aberration, $P < .05$; coma, $P < .005$; root-mean-square [RMS] HOA, $P < .0001$) 4 years postoperatively. Distribution of the postoperative distance UCVA ($P < .0001$) and distance BCVA ($P < .01$) was statistically better than the preoperative values. Aslanides et al concluded that aspheric corneal wavefront customization with the Esiris yields visual, optical, and refractive results comparable to those achieved with other wavefront-guided customized techniques for the correction of myopia and myopic astigmatism. The corneal-wavefront-customized approach showed its strength when abnormal optical systems were expected. The investigators also stated that systematic wavefront-customized corneal ablation appears to be safe and efficacious for retreatment cases.[3]

Khalifa et al evaluated the improvement in near vision in 26 presbyopic patients (n = 52 eyes) with low to moderate myopia who underwent the selective treatment of HOAs using the ORK-CAM software aberrometer (Schwind eye-tech solutions) and the Esiris excimer laser. The patients were divided into two groups. In group A (30 eyes), all HOAs were treated. In group B (22 eyes), vertical coma was left untreated. All included eyes had a total coma of 0.2 µm, and the investigators performed wavefront-guided LASIK with the Esiris on all eyes. The mean preoperative MRSE was -2.37 and -2.87 D, and the mean preoperative total HOAs were 0.35 and 0.38 µm in groups A and B, respectively. There was no significant difference between groups regarding age, sex, preoperative MRSE, and preoperative total HOAs. After 3 months, there was no significant difference between groups in terms of UCVA, BCVA, MRSE, and contrast sensitivity. An analysis of postoperative HOAs showed a significant difference in vertical coma between the two groups ($P < .001$), and distance BCVA was significantly better in group B ($P < .01$).[4]

Schumacher et al conducted a multicenter study to assess the efficacy, safety, and predictability of an individualized LASIK ablation profile based on an optical ray-tracing algorithm to treat moderate to high myopic astigmatism. The algorithm generates data from every optically relevant structure in the eye and calculates an individual eye model from which the customized ablation profile is derived. The study included 71 patients (127 eyes) with a manifest refraction sphere ranging from 0.50 to -10.25 D and/or astigmatism ranging from 0.00 to -4.50 D. By 3 months postoperatively, 15 eyes had been lost to follow-up, and one eye was excluded from analysis because of early retreatment. Of the remaining 111 eyes, 93 (83.8%) had a distance UCVA of 20/20 or better. The mean MRSE in all eyes was 0.03 ±0.30 D. In 97 eyes (87.4%), the MRSE was within ±0.50 D, and in 107 eyes (96.4%), the MRSE was within ±1.00 D. No eye lost 2 or more lines of distance BCVA. The authors concluded that the new optical ray-tracing algorithm for individualized LASIK ablation profiles was efficacious, safe, and predictable.[5]

WAVEFRONT OPTIMIZED VERSUS WAVEFRONT CUSTOMIZED

In a randomized, prospective, single-masked, fellow eye study, Moshirfar et al compared outcomes in terms of visual acuity, refractive error, HOAs, contrast sensitivity, and dry eye in patients undergoing LASIK using the wavefront-guided Visx CustomVue (Abbott Medical Optics Inc.) and the wavefront-optimized WaveLight Allegretto (Alcon Laboratories, Inc.) platforms. The investigators performed LASIK on 44 eyes (22 patients); for each patient, one eye was randomized to receive a wavefront-optimized treatment, and the fellow eye received a wavefront-guided treatment. Postoperative outcome measures at 3 months included distance UCVA, distance BCVA, refractive error, an RMS value of total and grouped HOAs, contrast sensitivity, and Schirmer testing. According to the investigators, the only statistically significant change discovered was a 4% increase in total HOA RMS ($P = .012$) in the wavefront-optimized group. There were no statistically significant differences in distance UCVA, distance BCVA, contrast sensitivity, or Schirmer testing 3 months postoperatively. Moshirfar et al concluded that both platforms are effective and predictable in LASIK surgery.[6]

In a prospective, comparative study, Miraftab et al compared wavefront-guided and wavefront-optimized LASIK in patients with myopic astigmatism of up to -7.00 D sphere and 3.00 D cylinder. Forty-one patients had wavefront-guided LASIK on one eye and wavefront-optimized LASIK on their fellow eye. The investigators used the Allegretto Concerto excimer laser (Alcon Laboratories, Inc.; not available in the United States) for photoablation. Pupil centroid shift and cyclotorsion were not compensated for in the wavefront-guided treatments. The Allegretto Wave analyzer (Alcon Laboratories, Inc.) was used to measure ocular wavefront aberrations, and the CSV-1000 instrument (VectorVision) was used to measure contrast sensitivity before and 1 and 3 months after LASIK. HOAs increased from 0.28 ±0.08 µm (range, 0.13-0.48 µm) and 0.26 ±0.08 µm (range, 0.13-0.55 µm) to 0.45 ±0.17 µm (range, 0.18-0.71 µm) and 0.45 ±0.16 µm (range, 0.21-0.84 µm) in the wavefront-guided and wavefront-optimized groups, respectively. Except for C6 trefoil ($P = .006$), all Zernike polynomials increased in both groups postoperatively with no statistical difference between the groups. Contrast sensitivity did not decrease in either group, and the investigators did not note statistically significant differences overall between the groups.[7]

INTRAOPERATIVE ABERROMETRY IN CATARACT SURGERY

Packer conducted a retrospective case-controlled chart review to determine whether the use of intraoperative wavefront aberrometry reduced the frequency of postoperative laser enhancements compared with the rate in cases in which aberrometry was not used. The study included patients who chose to receive correction of preexisting corneal astigmatism with limbal relaxing incisions (LRIs) at the time of cataract surgery. Packer used the ORange System (WaveTec Vision) intraoperatively to measure total ocular refractive cylinder after the implantation of an IOL and to guide the LRI enhancement in 30 eyes. A group in which the aberrometer was not used served as the control (n = 37). The excimer laser enhancement rate was 3.3% in the aberrometry group and 16.2% in the control group. The mean postoperative cylinder was 0.37 D in the aberrometry group and 0.48 D in the control group. According to Packer, residual cylindrical refractive error, not sphere, determined the patients' decision to have an enhancement. The use of intraoperative wavefront aberrometry to measure and enhance the effect of LRIs produced a trend that led to a 5.7-fold reduction in the odds ratio of subsequent excimer laser enhancement. This was not statistically significant.[8]

Stringham et al explored some of the variable refractive changes that occur during routine cataract surgery that could affect the accuracy and effectiveness of intraoperative aberrometry as it relates to the postoperative refractive state. In phase 1 of this study, the investigators assessed the cylinder induced by two eyelid speculums (open wire and closed wire) with 99 corneal topographic images from five participants without a cataract. In phase 2, the investigators assessed the refractive change in cylinder, its axis, and the spherical equivalent in 10 patients within 1 hour of cataract surgery compared with 1 week after the procedure. These measurements were taken using wavefront aberrometry, manual refraction, and corneal topography. The investigators found that the presence of a speculum induced erratic changes in cylinder and a statistically significant difference in axis when they compared the open-wire and the closed-wire models (both $P < .0001$). Moreover, they reported a significant change in the spherical equivalent within 1 hour of cataract surgery compared with 1 week after the procedure ($P = .039$). The investigators concluded that decisions based on intraoperative aberrometry may be inaccurate. One major limitation of this study, however, is that its premise was based on the pseudophakic confirmation measurements, whereas most surgeons using the ORA System (WaveTec Vision) base their choice of IOL on the aphakic measurement.[9] ■

This edition of "Peer Review" is dedicated to Eric Donnenfeld, MD.

Section Editor Allon Barsam, MD, MA, FRCOphth, is an appointed consultant ophthalmic surgeon at Luton and Dunstable University Hospital, Bedfordshire, United Kingdom. He acknowledged no financial interest in the products or companies mentioned herein. Dr. Barsam may be reached at abarsam@hotmail.com.

Section Editor Mitchell C. Shultz, MD, is in private practice and is an assistant clinical professor at the Jules Stein Eye Institute, University of California, Los Angeles.

Dan B. Tran, MD, is the medical director of Coastal Vision Medical Group, with offices in Long Beach and Orange, California, and the medical director for NVISION Cataract Center in Newport Beach, California. He is a consultant to Alcon Laboratories, Inc., Bausch+Lomb, ReVision Optics, Inc., and WaveTec Vision. Dr. Tran may be reached at danbtran@gmail.com.

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