Developing Wavefront Technology

Several issues are inhibiting the growth and acceptance of the technology, but upgrades in equipment may be on the horizon.

BY SCOTT M. MACRAE, MD

Wavefront technology makes up 48% of the current US refractive surgery market. By and large, however, old wavefront sensors, problems related to wound healing, needed improvements in terms of eye trackers, the creation of LASIK flaps, and biomechanics are inhibiting the outcomes and growth of wavefront technology, because the results have not been dramatically better than conventional treatment, as we originally hoped. Other obstacles include the platforms' ergonomics, the time necessary to perform a procedure, and the cost of excimer laser systems. Help may be on the way.

COMBINED TECHNOLOGIES

More sophisticated combinations of corneal and wavefront sensors are entering the refractive surgery market. As we surgeons envisioned, topographers are being merged with entire-eye wavefront sensing. The Wavefront Sciences wavefront sensor (Advanced Medical Optics, Inc., Santa Ana, CA) is being coupled with a scanning spot topographer. Bausch & Lomb (Rochester, NY) is combining its next-generation scanning slit topographer, which will replace the Orbscan topographer with a new higher-resolution wavefront sensor. Schwind (Kleinostheim, Germany) is working to merge its wavefront sensor and topographer. Alcon Laboratories, Inc. (Fort Worth, TX), is also working to integrate its wavefront sensor and corneal topographer (the latter was originally manufactured by Wavelight, which Alcon recently acquired). Similarly, Carl Zeiss Meditec, Inc. (Dublin, CA), mixed its wavefront sensor and topographer.

Blending corneal topography and wavefront sensing enables us to account better for aberrations in the cornea, lens, and entire eye. Moreover, the grouped technology will assimilate data on the cornea's shape with wavefront information on the entire eye.

ONGOING RESEARCH

In our laboratory in Rochester, New York, my colleagues Geunyoung Yoon, PhD, Lana Nagy, BS, and I are testing high-resolution wavefront sensors on eyes implanted with either the ReZoom lens (Advanced Medical Optics, Inc.) or the AcrySof Restor IOL (Alcon Laboratories, Inc.). We used a Shack-Hartman wavefront sensor designed by Dr. Yoon that measures 1,489 lenslets on a 6-mm pupil—almost two to eight times the resolution of other systems currently on the market. We performed wavefront measurements on the implants on an optical bench and then confirmed the optics using a laser collimated beam to compare the point spread function of the wavefront with the collimated beam. We took Orbscan corneal wavefront data generated by Thomas Kohnen, MD, and Jens Buhren, MD, on 21 normal pseudophakic eyes and added them to the aberration pattern of the multifocal implants to simulate the multifocal optics clinically. Next, we convolved the images based on the combined wavefronts to assess visual quality. We used the visual Strehl ratio based on the optical transfer function, which is a good metric to predict visual quality based on wavefront measurements and defined a reasonable image quality of 20/40 as our threshold. The dominant aberrations in the corneas were second-order corneal astigmatism, third-order trefoil and coma, and

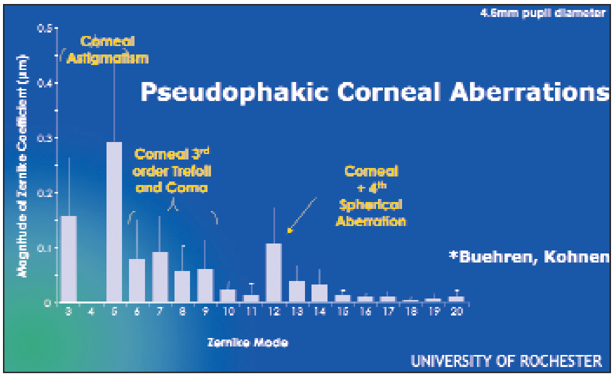

Figure 1. The magnitude of patients' corneal aberrations for a 4.6-mm pupil.

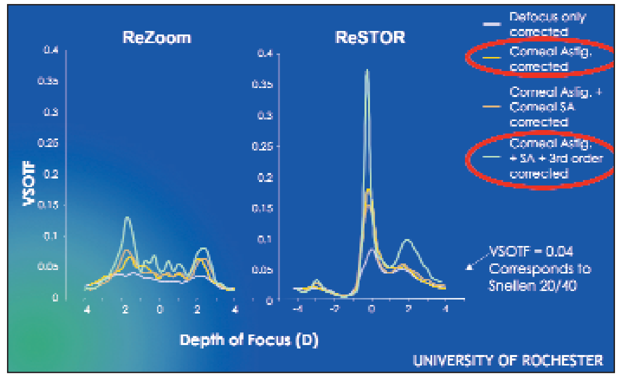

Figure 2. After combining the corneal and lenticular aberrations and assuming defocus correction, the optical quality decreased significantly for both of the multifocal IOLs.

fourth-order spherical aberrations, all of which are fairly normal findings in older pseudophakics in terms of amplitude (Figure 1).

These corneal aberrations significantly decreased optical quality with both multifocal IOLs, however, even after we corrected for defocus. When we superimposed the multifocal wavefront map on average normal pseudophakic corneal wavefront maps and only corrected sphere, we found that each implant could provide a visual acuity no higher than the 20/40 range with both the ReZoom and AcrySof Restor IOLs. For the ReZoom lens, its interacting image quality fell below the listed criterion. For the AcrySof Restor IOL, although the image quality also decreased, the near and far foci remained above the designated cutoff indicating 20/40 or worse visual quality of a visual Strehl ratio based on the optical transfer function. When we corrected lower-order aberrations including corneal astigmatism, the image quality increased for both lenses. The depth of focus for both lenses remained relatively stable. Correcting for lower-order corneal aberrations and spherical aberration produced little improvement in retinal image quality or depth of focus. Correcting lower-order aberrations, spherical aberrations, and third-order aberrations increased depth of focus and retinal image quality (Figure 2).

This is just one example of how using higher-resolution, whole-eye wavefront sensing with corneal topographic wavefront measurement can enable us to more fully understand how different aberrations from the lens, IOL, and cornea interact. This information will help us determine whether aberrations reside in the cornea, the IOL, or the crystalline lens and allow us to decide whether we want to correct them.

Based upon our research, I believe that future wavefront technology must perform more frequent sampling using whole-eye wavefront measurements. By gathering more real-time data and sampling more frequently over time, we surgeons will be able to achieve a better picture of average wavefront measurements.

In the future, clinicians may perform something like a wavefront version of an EKG strip over 30 seconds to achieve a better selection of wavefront measurements with time and use an average measurement based on this. Wavefront measurements could be combined with adaptive optics mirrors, which would allow for the simulation of images for patients to visualize an intended correction. I believe that we will eventually use wavefront sensing during cataract surgery and corneal ablations to confirm that the correct IOL power has been implanted or corneal treatment has been performed.

Wound healing can also play an important role in improving laser refractive results. In studies performed by Krystel Huxlin, PhD, in a cat model in our laboratory, she found that, if inflammation was minimized, higher-order aberrations decreased. Thus, controlling wound healing and inflammation may also result in greater accuracy and predictability.

IN SUMMARY

I anticipate improvements in the diagnostic capabilities of wavefront sensors, real-time rotational eye trackers, more accurate flap-making technology, our control of biomechanics, and the modulation of wound healing. All of these subtle refinements will take us closer to our aim of providing crystal clear vision under all conditions, whether it be in the clinic or driving on a rainy night on a country road. ■

Scott M. MacRae, MD, is Professor of Ophthalmology and Professor of Visual Science at the University of Rochester in New York. He is a consultant to Bausch & Lomb. Dr. MacRae may be reached at (585) 273-2020; scott_macrae@urmc.rochester.edu.