Wavefront Aberrometry: the Past and the Future

High-resolution wavefront aberrometry imaging was initially developed for weapons applications.

BY STEPHEN C. COLEMAN, MD

Within the realm of refractive vision correction, expanding the range of indications in terms of treatable patients comes down to the ability to obtain detailed diagnostic information on both the topography and internal eye structure. Driven by the projected increase in the geriatric population in the United States[1] and the lucrative growing and emerging markets of Asia, Europe, and South America, substantial progress and novel improvements in the capabilities of ophthalmological devices are prevalent.

One of the most exciting developments is in wavefront aberrometry. Patients who, in the past, had been considered unsuitable candidates for refractive surgery, such as those with highly aberrated or scarred corneas or previous incisional surgery, can now look forward to diagnostic advances. Current diagnostic equipment is capable of providing surgeons with the data required to develop surgical plans yielding great outcomes.

HISTORY

High-resolution wavefront aberrometry imaging, was initially developed for weapons applications as part of the Star Wars initiative during the Reagan administration. Dan Neal, PhD, was one of the key scientists in adapting this technology to ophthalmology applications.

The aberrometer evolved for practical application in the medical industry for customized medical procedures and was eventually introduced in the year 2000 at the first International Wavefront Congress held in Santa Fe, New Mexico, marking the beginning of today's ongoing collaboration between optical scientists and ophthalmologists worldwide. I had the opportunity to compare the instrument side by side against others and observe the level of sophistication and power enabling the device to produce substantially more data points than its counterparts. This technology has finally made it to the market as the iDesignDX (Abbott Medical Optics). This aberrometer can map larger refractive ranges with full-gradient topography, capturing images of the eye with a level of detail heretofore unavailable.

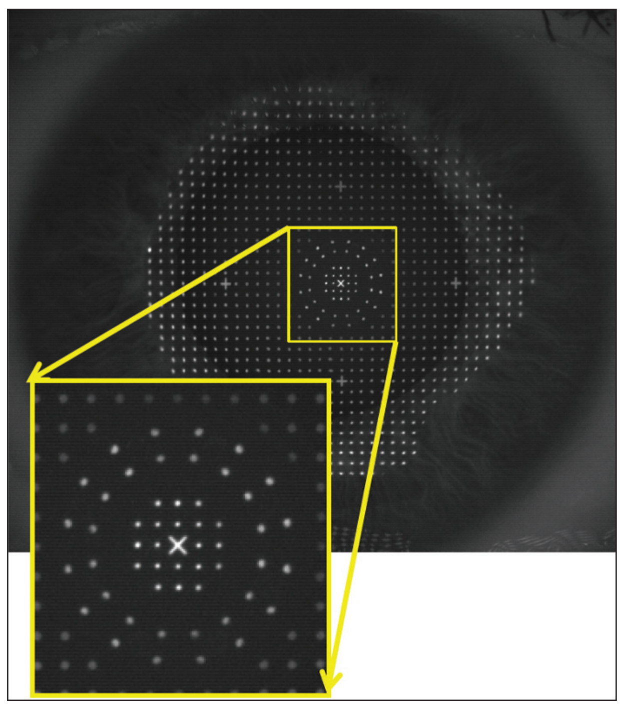

Figure. A full-gradient corneal topographer provides central corneal coverage. Central spots illuminate the corneal vertex area. The location of these spots does not depend on the distance to the eye or its position within the field of view.

The same advanced wavefront-sensing technology that maps ocular aberrations for ophthalmologists is used by the National Aeronautics and Space Administration to measure and precisely shape the mirrors in the James Webb Space Telescope. This technology will allow the transmission of high-resolution images from deep space back to Earth after this telescope launches in 2018.

FUNCTIONALITY

The iDesignDX utilizes a Fourier reconstruction algorithm and Hartmann-Shack technology and has an enhanced interface with multiple measures, including wavefront-derived refraction, wavefront aberrometry, pupillometry, full-gradient corneal topography, and keratometry. Image capture is easier and faster than in earlier generations, and the unit has the ability to measure corneal curvature and automatically incorporate keratometry into the treatment design eventually eliminating the need to manually input data into the treatment device. Although the iDesignDX has not replaced our diagnostic systems as of yet, I have used all of these functions during clinical trials with excellent results, and the device is currently available in Europe.

Full-gradient topography revolutionizes the way we surgeons see the eye's surface. Structured, well-accepted imaging and the Fourier reconstruction algorithms make Placido disk topographers the current industry standard; however, these devices are limited by their inability to directly capture skew rays and their sensitivity to the radial component of the gradient. This causes Placido disk topographers to exhibit inaccuracy occasionally. Full-gradient topography fills these gaps, potentially increasing accuracy by providing central corneal coverage, capturing both x and y slopes for each spot, reconstructing the corneal elevation much like Hartmann-Shack sensor methods, and it is not inherently sensitive to misaligned eyes. Most notably, central spots illuminate the corneal vertex area, a crucial point left empty by Placido imaging (Figure).

The high-definition Hartmann-Shack wavefront sensor provides five times higher spatial resolution (177 µm), a high dynamic range, and an eight times higher local slope range than the system that precedes it (1,257 lenslets on a 7-mm pupil).[2]

THE DATA

A European study demonstrated that the iDesign technology (available only in Europe) produced superior results than its predecessor, the WaveScan Wavefront System (also from Abbott Medical Optics). I have achieved promising results and expect the US data to report equally good and predictable results.

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The European study included 243 eyes of 126 patients who underwent primary wavefront-guided LASIK. The iDesign was utilized to capture wavefront data. In 82% of patients, flaps were created with the iFS femtosecond laser (Abbott Medical Optics), and 18% had mechanical microkeratome-created flaps. Ablation was performed with the Visx Star S4 IR excimer laser (Abbott Medical Optics).

One month after surgery, uncorrected distance visual acuity of 20/16 or better was attained in 79% of eyes, 20/20 or better in 93.4%, and 20/25 or better in 96.7%. No eyes lost 2 or more lines of corrected distance visual acuity. Fourteen percent of eyes gained 2 or more lines.

Manifest refraction decreased significantly ($P < .01$). Mean manifest spherical equivalent decreased from -3.28 D preoperatively to -0.03 D. Manifest spherical equivalent was within 0.50 D of emmetropia in 93% of eyes and within 1.00 D in 99.6%. Mean manifest astigmatism decreased from -0.72 D to -0.14 D.[1]

CONCLUSION

We surgeons routinely achieve excellent refractive outcomes. Diagnostic devices continue to evolve, offering us the ability to analyze and potentially treat complicated cases and affording us even better results with increased predictability for patients who have low to moderate myopia. Advanced imaging systems that capture data to calculate a patient's ideal excimer ablation promise to open the door to people previously unsuited to refractive surgery with excellent, consistent outcomes. ■

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1. Neal DR, Baer CD, Copland J, et al. Combined wavefront aberrometer and new advanced corneal topographer. Paper presented at: The American Society of Cataract and Refractive Surgery Annual Meeting; April 4-9, 2008; Chicago, IL
2. Schallhorn S, Brown M, Venter J, et al. Early clinical outcomes of wavefront-guided myopic LASIK treatments using a new-generation hartmann-shack aberrometer. *J Refract Surg*. 2014;30(1):14-21.