Introduction

The September/October 2002 issue of the *Journal of Refractive Surgery* contained the Proceedings of the Third International Congress of Wavefront Sensing and Aberration-free Refractive Correction. The published proceedings, which were selected and editorially reviewed, included some 20 articles, many pointing out the positive potential role of aberrometry in refractive surgery. These, along with dozens of articles in other journals and presentations at meetings, can leave the ophthalmic practitioner with the impression that wavefront analysis will lead us to the holy grail of super vision for our patients, most seeing 20/10 without correction. Such a simplistic cartoonish view is, of course, unrealistic and inaccurate. Although it is undeniable that wavefront technology is significantly improving the outcomes of excimer laser corneal surgery and the designs of intraocular lenses and contact lenses, the details of how to apply aberrometry in clinical practice—especially for the correction of higher order optical aberrations—are still being worked out. A reasonable aphorism to cling to is “20/10 by 2010.”

To balance any excessively positive and rosy view of aberrometry as our refractive salvation, this special section contains articles that challenge and question different aspects of the clinical application of aberrometry in refractive surgery. The articles are not intended to be negative or to undermine the contributions of wavefront analysis in refractive surgery, but rather to pose challenges to the clinical and research vision communities.

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Wavefront Technology: A New Advance That Fails to Answer Old Questions on Corneal vs. Refractive Astigmatism Correction

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Wavefront technology brings our understanding of the eye's refractive characteristics to a new level. It has changed our concepts for examining refraction in the same way that computerized corneal topography changed corneal surface measurement, which previously had been limited to the yardstick of keratometry. We now possess two, highly sensitive tools for the objective measurement of the eye—corneal topography and wavefront assessment. Our challenge is to reconcile them toward the ultimate goal: the best possible vision for our patients.

BENEFITS OF WAVEFRONT TECHNOLOGY

The debate on how best to use the abundance of data afforded by these two new technologies is far from settled. In terms of refractive surgical procedures such as laser in situ keratomileusis (LASIK), the diagnostic utility of wavefront analysis in detailing sphero-cylindrical and higher order optical aberrations is unquestioned. However, wavefront technology is unlikely to prove a refractive surgical panacea, just as corneal topography fell short of its expected performance.

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The various modes available for measurement of wavefront error employ different methods to examine the same fundamental optical characteristic of the eye. The techniques provide a spatially oriented refractive map of the pathway of light through the eye. This provides a more detailed optical examination than that provided by manifest refraction. In a similar manner, videokeratography displays a more detailed depiction of corneal shape than the average curvature view provided by keratometry.

Wavefront-assisted LASIK does not consider the amount of resultant corneal astigmatism. In this it is similar to LASIK based on manifest refraction or any other type of refractive measurement. The refractive guidance provided by wavefront technology to reduce spherical aberrations by achieving the most effective prolate aspheric profile may be significant and the benefits clear[1]; however, for astigmatism, the treatment issues are more complex.

THE EYE VS. HUBBLE

The suggestion that wavefront analysis is a comprehensive treatment solution—a view championed by well-qualified optical scientists with good intentions—is based on the principle that all optical aberrations in the optical system of the eye, from the anterior surface of the cornea back to the retina, can be corrected on the surface of the cornea. The correction of aberrations that exist in the eye has been likened to an optical instrument that, like the Hubble space telescope, can be modified with optical patches to achieve a clear focus for infinity (lower order) and the correction of higher order aberrations.[2] Assigning to the living eye-brain system a concept that might hold true for an optical instrument—with corneal surgical principles playing a secondary role to optical priorities—is contrary to surgical intuition and understanding developed from past experience.

The process of laser vision correction should be regarded as a surgical science as much as an optical science. One must balance corneal astigmatism priorities with total ocular refractive values to achieve the optimal visual outcome—the eye functioning at its maximum potential. Surgical vectors are used to design the customized treatment of natural asymmetry of corneal astigmatism. This creates an individualized treatment plan that addresses each patient's unique preoperative corneal and refractive parameters. The omission of vector planning[3,4] from the discussion of customized treatments shows that the importance of vectors is not well understood.[5]

REFRACTION ALONE IS INSUFFICIENT

When it comes to achieving "supernormal" vision—that is, an improvement in best spectacle-corrected visual acuity—any approach that relies solely on refractive parameters such as wavefront analysis has a number of inherent flaws. First, refractive and corneal astigmatism values are rarely equivalent.[3] Simple arithmetic analysis shows that applying astigmatism treatment exclusively on the refractive cylinder axis can leave an excessive amount of corneal astigmatism.[6] This should not be surprising, as the failure to align the maximum ablation closer to the flattest corneal meridian results in off-axis loss of effect in reducing this corneal astigmatism. Lower order astigmatic aberrations and coma would not be minimized as a consequence.

A second issue is that the correction of all ocular aberrations at the corneal surface pays no regard to the effects of corneal irregularities that will be produced by this uneven mode of treatment. Refractive surgeons have long known that corneal regularity (orthogonal and symmetrical astigmatism) is the foundation of a superior visual outcome. Corneal irregularity can only increase if all corrections for internal optical errors are surgically sculpted onto the corneal surface without considering any preexisting corneal topographical irregularities.

Technical challenges also impair our ability to accurately align the ablative patterns to make the focal changes to correct underlying optical aberrations. It is difficult to permanently change regional corneal shape in this uneven manner, especially when the treatment can be neutralized by epithelial healing. Any change in the crystalline lens will also complicate the long-term usefulness of wavefront-driven changes.

Finally, wavefront refraction analysis does not deal with the non-optical component of refractive astigmatism, that is, cerebral integration of visual images. This phenomenon influences the astigmatic values contained in a manifest refraction, which in turn affects the treatment delivered by LASIK. The inclusion in the treatment of patients' conscious perception of their astigmatism is likely to benefit patient satisfaction.

FINDING A BALANCE

Amid the enthusiasm of thought-leaders and industry regarding this new technology, it is easy to overlook that the correction of optical errors of the eye is a surgical process and not a purely optical process.

It was not that many years ago that linking computerized topography to laser treatment was lauded by many as the most desirable means to gain the best visual outcome. This is now infrequently advocated except for the occasional incidence of certain types of natural or postoperative corneal irregularity. In some quarters, corneal topographical analysis has been relegated to one of secondary importance, when in fact it is just as essential now in monitoring the effects of refractive treatment as it was in the past.

Understanding the vector planning process is an intellectual challenge—one that must be surmounted before the benefits derived from its implementation become apparent. However, refractive surgeons omit this discipline to their peril. The changeover can be likened to the locomotor challenge we went through a decade or so ago to convert to small-incision cataract surgery incorporating phacoemulsification.

One of the benefits of the greater understanding of vectors and corneal astigmatism is the recognition that the pathway to "supernormal vision" requires a greater customized reduction of corneal astigmatism than is currently attempted. Also, whatever corneal astigmatism remains is better left in a regular state. These fundamental principles of vector planning are overlooked in an entirely wavefront-driven treatment plan. However, they are necessary to achieve ultimate corneal shape for maximum visual outcome.

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