# Wavefront Plus Topography for Superior LASIK Outcomes

With this combination of diagnostic data, patients had a greater reduction in corneal astigmatism and better visual outcomes in low-light situations.

BY NOEL ALPINS, FRANZCO, FRCOPHTH

Public scrutiny of LASIK reached a new level in April 2008 at the US FDA Ophthalmic Devices Advisory Panel hearing on post-LASIK quality-of-life issues. The discussion was a response to more than 140 letters of complaint addressed to the FDA regarding LASIK complications.[1]

Without doubt, a variety of causes contribute to patients' dissatisfaction with LASIK. I am of the firm opinion however that a high proportion of these patients are genuinely dissatisfied with their refractive outcomes, including those with an excess amount of remaining corneal astigmatism. Many of these problematic cases can be predicted prior to refractive surgery by determining the patient's ocular residual astigmatism (ORA). This occurs when a larger-than-usual discrepancy between the corneal and refractive astigmatism measurements is evident. This relatively common predicament is avoidable if the surgeon employs vector planning and uses a combination of topography and wavefront refractive data for treatment. Vector planning reduces a greater amount of corneal astigmatism versus treatments using refractive parameters only.[2]

The ORA is determined by calculating the vectorial difference between refractive cylinder, as measured by wavefront or manifest refraction, and corneal astigmatism, as measured by topography or keratometry measurements for corneal astigmatism.[3,4] The ORA vector is transferred to the origin (x=0, y=0) and halved to simulate how it would exist within the eye (Figure 1). This difference, measured in diopters and degrees and calculated using basic trigonometric principles, has a proportional relationship with astigmatism. As the astigmatic difference between refractive and corneal astigmatism increases, the magnitude of the ORA also increases. Therefore, the amount of residual postoperative astigmatism is also greater. This would all be left on the cornea using conventional refractive techniques.

It is my belief that if ORA assessment was a routine part of the preoperative examination, then the unfortunate occurrence of residual refractive error after LASIK—as well as the FDA panel hearing and its subsequent prospective evaluation of LASIK satisfaction—would have been avoidable where adverse refractive outcomes occurred. The prospective quality-of-life study is scheduled to begin in 2009 and will be jointly conducted by the US FDA, the National Eye Institute, the ASCRS, and the AAO. Participating surgeons will study the change in patients' quality of life after LASIK and the factors associated with postoperative satisfaction or dissatisfaction.

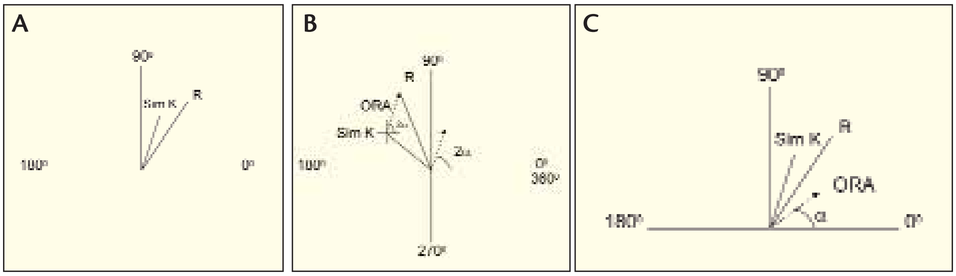


**Figure 1. Calculating ORA. Polar diagram of refractive wavefront cylinder at the positive axis and simulated keratometry from the topography (A). The double-angle vector diagram showing a doubling of the angles without a change in the astigmatic magnitudes (B). Polar diagram displaying the ORA as it would appear on the eye (C). (R = refractive wavefront astigmatism [corneal plane]; Sim K = simulated keratometry from topography.)**

## WHAT IS VECTOR PLANNING?

Although wavefront-customized treatments offer many benefits to our patients, wavefront refraction alone does not entirely treat astigmatism. In fact, it may create an excessive amount of residual corneal astigmatism and increase the irregularity of the cornea when used alone.[3,5-8] Alternatively, topography-guided treatments, which are typically used to treat irregular corneas after previous corneal surgery, may induce higher-order aberrations.[9]

I have published two studies in the past 2 years[3,4] discussing the combination of topography and refractive data for a vectorial approach to PRK and LASIK. I believe that using vector planning is the final piece missing from the refractive surgery puzzle. It demonstrates a fundamental and unique ability to combine topographic with refractive astigmatic parameters in an effective, optimized manner. The main goal of vector planning is to aim closer to corneal sphericity, particularly in patients who have an expected unfavorable astigmatism orientation, including cases of oblique and against-the-rule astigmatism.

Herein, I will describe my latest results with treatments that combine topography and wavefront refractive parameters. My colleagues and I recently reported that patients achieve superior visual results under mesopic conditions (ie, low-ight situations) and have a greater reduction in horizontal coma and corneal astigmatism when wavefront is combined with topographic values.[10]

To our knowledge, this is the first study to combine topographic astigmatism and wavefront aberrometry cylinder into one treatment paradigm. Between October 2005 and March 2006, we evaluated wavefront-guided LASIK outcomes in 21 eyes with myopic astigmatism—10 with wavefront and topography combined and 11 with wavefront alone in the surgical plan. The treatment profile for the combined group was modified according to my planning module, the Alpins Statistical System for Ophthalmic Refractive surgery Techniques (ASSORT). This module combines topographic data with the measured wavefront aberrometry and adjusts the Visx CustomVue treatment profile (Advanced Medical Optics, Inc., Santa Ana, CA). The measurements of higher-order aberrations were not modified.

We chose to vary the wavefront aberrometry treatment of patients in the combined group as follows: Instead of leaving 100% of the ORA corrected on the cornea, we left only 60%. Additionally, we left 40% of ORA in the wavefront refraction (Figure 2). We chose this 40/60 emphasis on the ORA because it significantly reduces the corneal astigmatism without compromising the refractive astigmatism outcome.[2] If the surgeon wanted, however, he could choose to incorporate any percentage of topographic parameters, determining them based on each individual patient, to optimize the treatment and minimize the remaining corneal and refractive astigmatism. We chose the treatment for the wavefront- alone group based on standard aberrometry measurements from the WaveScan system, leaving 100% of the ORA on the cornea.

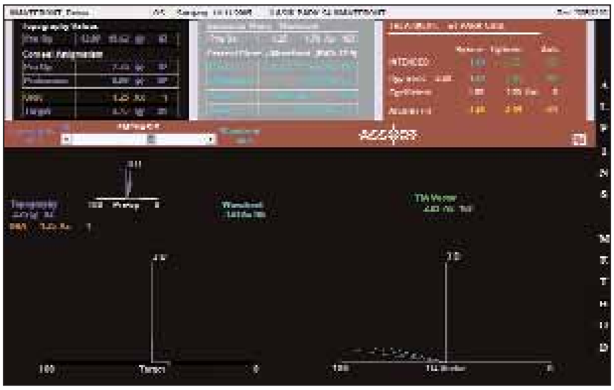

**Figure 2. The ASSORT planning screen displaying an emphasis of 40% topography and 60% wavefront refraction achieving a greater reduction in postoperative corneal astigmatism.**

## SURGICAL TREATMENT, OUTCOMES

Patients remained in a dark room for approximately 15 minutes prior to assessment. We took minimum of three aberrometry acquisitions with the WaveScan WaveFront system (Advanced Medical Optics, Inc.) for each patient. At the time of surgery, my colleagues and I created a corneal flap with a nasal hinge using a 140-µm–head microkeratome (Amadeus; Ziemer Group AG, Port, Switzerland). We left a residual stromal bed of at least 270 µm in each eye and used the Visx Star S4 excimer laser with CustomVue software (Advanced Medical Optics, Inc.) to perform the ablation. We used iris registration and tracking in both groups.

After laser vision correction was complete, we covered all eyes with plastic shields overnight. Patients were also asked to wear the shields during sleep for the following two nights. Follow-up visits were scheduled for day 1 and at 1, 3, and 6 months postoperatively.

Prior to surgery, mean ORA of the combined topography-wavefront group was 1.06 ±0.23 D and 1.00 ±0.16 D in the wavefront-alone group. At 6 months, these figures were 0.82 ±0.42 D and 0.73 ±0.25 D, respectively. Mean preoperative corneal astigmatism (by topography) was 1.50 D in the combined group and 1.07 D in the wavefront-alone group; however, at 6 months, the mean reduction was 44% in the combined group and 39% in the wavefront-alone group. Comparatively, mean preoperative astigmatism (by wavefront refraction) was -1.69 D of cylinder and -1.71 D of cylinder in the combined and wavefront-alone groups, respectively, and the mean reduction was 55% versus 69% at 6 months. When both wavefront and topography

**TAKE-HOME MESSAGE**

- Excess corneal astigmatism can be reduced with the use of vector planning using a combination of topography and wavefront data.
- The magnitude of ORA and residual postoperative astigmatism increases as the difference between refractive and corneal astigmatism increases.
- Vector planning combines topographic with refractive astigmatism parameters to minimize irregularity of postoperative corneal shape.
- Combined vector planning and wavefront treatments produce a greater chance for improvement in BCVA.

parameters we used, the mean total astigmatic reduction at 6 months was similar in both groups (-1.62 D in the combined group versus -1.58 D in the wavefront-alone group); however, the combined group had a greater mean reduction in total astigmatism when we used manifest and keratometry measurements. Additionally, the horizontal coma decreased by 0.04 µm in the combined group compared with a gain of 0.02 µm in the wavefront-alone group.

We observed that the combined wavefront and vector planning treatments were more likely to improve BCVA. Although both groups had the same mean preoperative BCVA and similar low- and high-contrast visual acuities under mesopic conditions, the gain in low-contrast visual acuity under mesopic conditions at 6 months was 0.05 more for the combined group (0.11 vs 0.06). When we looked at high-contrast visual acuity under mesopic conditions, the combined group experienced a 0.05 gain, whereas the wavefront-alone group gained only 0.02. Gains were identical under photopic conditions. When lines of BCVA were studied, there was a greater potential for improvement in BCVA for the combined group.

## TREATMENT LIMITATIONS

My colleagues and I have been pleased with the treatment outcomes when combining topography with refractive wavefront parameters; however, there are several limitations to the current technology that could be improved. These include a variation in measurements obtained from topographic and wavefront devices, usually resulting in difficulty obtaining the most consistent numbers from each technology. Additionally, wavefront technology displays one overall refraction—this could be extended to multiple refractions relating to the topographic map.

Further advances in technology may increase the efficacy of treatment by allowing higher-order aberrations to reflect any modification present during vector planning. Additionally, the method of vector planning could be repeated over the entire ablation profile by having a shape profile of the cornea that maps directly with the shape profile of the wavefront. Such advances can occur only if laser manufacturers modify their treatment profiles to enable rotation of the treatment axis.

## CONCLUSION

In 2006, the American National Standards Institute adopted my astigmatic vector analysis technique for refractive outcomes[11] as a standard to evaluate the safety and effectiveness of laser systems that reshape the cornea when treating astigmatism. I have confidence that it is only a matter of time before this vector planning technique[3] will also be adopted as a standard of care.

With this strategy for treatment planning, the downturn in the number of patients currently looking into or undergoing LASIK in Europe as well as the United States may be reversed. Although a small nucleus of patients might remain ambivalent or unsympathetic to the procedure—which could continue to prevent absolute acceptance of laser vision correction—it is my belief that addressing astigmatic treatment, and hence visual outcomes, will again increase the interest in LASIK surgery. The inclusion of vector planning integrates topographic and wavefront data into a systematic treatment paradigm that is a significant advance to achieving the ideal treatment profile. ■

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