A concept in astigmatic treatment that many refractive surgeons find hard to digest is the nonzero target. When laser treatment is guided wholly by refractive (manifest refraction or wavefront refraction) or by corneal (topography-guided) parameters, surgeons believe they are targeting zero, but they are neglecting the other mode of treatment (corneal or refractive). It is almost as if a mirror were blocking their view of the effect of treatment on the other parameter of measurement.

The target-induced astigmatism vector is the link that connects the two treatment paradigms by considering and analyzing the astigmatic effect of both modes. This effect is rarely zero. Consider an example in which the astigmatic treatment was planned on the basis of the manifest refraction, and the refractive cylinder was +2.00 D x 20º (corneal plane). Corneal astigmatism, however, was 1.50 D @ 10º. This discrepancy (calculated vectorially to account for differences in magnitude and orientation) in preoperative corneal-refractive parameters is common, and it is known as ocular residual astigmatism (ORA).

Given this difference, it would not be possible to achieve zero astigmatism on the cornea because the planned treatment is +2.00 D x 20º (based on manifest refraction parameters). In theory, ablating +2.00 D x 20º onto a cornea with cylinder measured at 1.50 D @ 10º would leave 0.78 D x 40º ORA. This is what is termed the nonzero target. It would be only by chance—perhaps healing factors—that zero astigmatism would be achieved on the cornea in this case. The higher the nonzero amount (as quantified by the ORA), the worse the prospect of an outcome that will please the patient.

This unfortunate situation can be avoided in several ways. One of these is to identify the problem, if it exists, prior to performing surgery by quantifying the patient’s ORA at the time of counseling. It is a straightforward calculation with resources made available for free on websites such as www.assort.com.

Questions for the panel:

No. 1: Do you see a need to change the treatment plan for excimer laser surgery if preoperative differences exist between refractive cylinder and corneal astigmatism?

No. 2: Do you analyze refractive surgery astigmatism outcomes by corneal or refractive parameters, or do you consider both relevant?
refractive astigmatism is the sum total of all of the refractive vectors that contribute to astigmatism as seen by the patient.

A mathematical approach is clearly required to determine what effect removing corneal irregularity in topography-guided ablation may have on overall refractive error. I have had the opportunity to work with the Phorcides Analytical Software designed by Mark Lobanoff, MD. It is designed to make these calculations more reproducible and less prone to subjective variation by analyzing the individual topographic elevation data and using vector analysis of the various sources of astigmatism to minimize ORA.

Phorcides was developed to perform the complex analysis of all sources of astigmatism within the eye. The program uses geographic imaging software to assess raised areas of corneal tissue, which create smaller slopes superimposed on the larger slope of the anterior corneal curvature. In geology, this formation is known as a talus, and this nomenclature has been adapted to corneal topography as well. Using lens theory and optical physics, the refractive cylinder contribution of the talus can be calculated.

The software program analyzes anterior and posterior curvature data from a Scheimpflug device, and it uses vector analysis to compare all the known vectors that contribute to refractive cylinder (corneal irregularity vector, anterior corneal astigmatism vector, posterior corneal astigmatism vector). The program compares this result to the manifest refraction of the patient, allowing calculation of any internal astigmatism vectors that reside between the posterior corneal curvature and the retina. The program assumes that topographic treatment will remove the corneal irregularity vectors. It then calculates how much anterior corneal astigmatism should be left after correction of the topography to counterbalance the posterior corneal and internal astigmatism vectors. Finally, Phorcides combines all the known and calculated vectors that contribute to astigmatism and recommends a treatment (Figure 1).

Early clinical results with Phorcides have been promising, exceeding those obtained when treating simply off the manifest refraction or the measured anterior astigmatism (TMR). More impressive, early Phorcides results are exceeding those found in the FDA study of Contoura Vision (Alcon). In the FDA study, patients were included only if their manifest and measured astigmatism were similar (within 10º or with magnitude differences < 0.75 D). In the current Phorcides studies, the results of which are expected to be published later this year, all eyes are included, even those with vast differences between manifest and measured astigmatism, according to Dr. Lobanoff.

Efforts of this sort will enable surgeons to predict the effect of topography-derived astigmatic ablation and, in turn, its effect on overall refractive condition. This may help to answer the question of what to do when surgeons face a patient with a discrepancy between manifest and corneal astigmatism in order to improve outcomes.

Regarding Dr. Alpins’ second question, the best measure of refractive surgery outcomes may be through analysis of refractive parameters as opposed to solely corneal parameters. It is well known that treatment of corneal astigmatism and especially higher-order aberrations affects lower-order aberrations such as sphere and cylinder. Although technology for assessing corneal aberrations is steadily improving, the most practical measure of success after refractive surgery will come from subjective manifest refraction, which will be an indicator of the global refraction, not just the corneal component.

For any refractive surgeon, astigmatism is a persistent challenge. For this article, I will limit my discussion to the
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The treatment of regular astigmatism. If a patient’s corneal and refractive astigmatism match perfectly, the challenge is simple, but this is rarely the case with the patients I see daily. I look at the astigmatism of each patient and concentrate on refractive, anterior corneal, posterior corneal, and, of course, lenticular astigmatism.

My colleagues and I use several diagnostic devices in our clinic, including the OPD-Scan III (Nidek), Pentacam (Oculus Optikgeräte), WaveLight Topolyzer Vario Diagnostic Device (Alcon), and Advanced CustomVue (Johnson & Johnson Vision). Each of these technologies can either confirm or contradict the manifest and/or cycloplegic refraction obtained in the clinic.7-9

Now we can overanalyze the patient by reading too much into the diagnostics, especially when they conflict and do not make sense, and we have achieved excellent outcomes by treating the manifest refraction with wavefront-optimized protocols.7,8 If something does not make sense in terms of preoperative evaluation, we perform a wavefront-optimized treatment.

The goal, however, is to improve UCVA beyond what the patient saw with glasses or contact lenses. My colleagues and I are looking at ways to achieve outcomes better than 20/20 by using Phorcides software with the Vario topographer and the Pentacam tomographer in conjunction with the WaveLight excimer laser (Alcon). The software compares the manifest refraction, computed topography, and tomography using mathematics and vector analysis to calculate treatments (Figure 2). The Phorcides software is unique in that it finds the astigmatism vector created by topographic irregularities and compares it to both the cognitive refractive cylinder (CorT Total) found in the manifest and the actual measured corneal topographic astigmatism and posterior topographic astigmatism. Topographic irregularities can throw off the accuracy of Placido disc and Scheimpflug topographers based on their proximity to the corneal astigmatism. Greater precision and accounting for all sources of astigmatism, including that from topographic irregularities, leads to the most precise detection of ORA. The goal with the Phorcides software is to remove topographic irregularities while producing the perfect anterior corneal astigmatism to counterbalance ORA from posterior corneal and lenticular astigmatism that remains after LASIK. So far, we have been impressed with the outcomes.

We use a variety of parameters to measure our outcomes. Corneal and refractive outcomes are important, but, simply put, if the patient is happy and our enhancement rate is negligible, we do not complain too much. Currently, our enhancement rate with topography-guided treatments using the WaveLight excimer laser in a prospective trial is 0.2% (N = 1,712 eyes). That is for treatments of up to -9.00 D of myopia and up to 3.25 D of astigmatism by manifest refraction using wavefront-optimized software and topography-guided software. Outcomes using these treatment profiles are excellent.6 That said, analyzing corneal, refractive, and aberrometry outcomes is important. They all influence what the patient sees, which is the bottom line. Happy patient equals happy life.

A prospective contralateral eye study that we are conducting (N = 82 eyes of 42 patients) comparing results with the WaveLight Allegretto T-CAT treatment (Alcon) from the FDA study to those using Phorcides software are showing great outcomes as early as 1 day postoperatively (Figure 3). In this series, we have treated up to -7.63 D spherical equivalent with up to 3.25 D of manifest refractive cylinder. The average

Figure 2. Phorcides software compares the manifest refraction, computed topography from the Vario, and tomography from the Pentacam to recommend a treatment (top). The underlying vector analysis of the corneal astigmatism, induced refractive change, internal astigmatism, and final treatment vector (bottom).

Figure 3. Postoperative day 1 outcomes in a contralateral eye study.
spherical equivalent was -3.72 ± 1.58 D, and the average amount of astigmatism was 0.96 ± 0.90 D. On postoperative day 1, UCVA was 1.42 ± 0.28 (1.33 = 20/15) OU on average.

Having patients see well qualitatively and quantitatively on the first postoperative day is essential. In my experience, patients expect excellent vision the day after surgery. How do surgeons keep raising the bar? They must continue to track postoperative outcomes any way they can. As Drs. Alpins and Majmudar point out, however, mean ORA is not to be overlooked, and, as we begin to understand dynamic accommodative astigmatism, we will continue to improve already excellent results.