Corneal versus refractive astigmatism: integrated analysis

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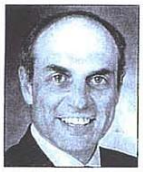
Special to Ocular Surgery News

Editor's note: This article, by Noel A. Alpins, FRACO, FRCOphth, FACS, is the third in a series of articles that Ocular Surgery News *plans to publish in its Refractive Surgery Section.*

The genesis of my approach to astigmatism treatment stems from a contradiction that existed in the way I was taught to approach astigmatism surgery. Spencer Thornton and other early investigators who helped refine our use of astigmatic keratotomy recommended placement of astigmatic keratotomy (AK) incisions on the steepest corneal meridian. Later, the laser manufacturers and their medical investigators recommended placement of the astigmatic correction on the axis of refractive astigmatism, which in many patients differs significantly from corneal astigmatism. Some AK surgeons also advocate this approach. Should treatment be based on corneal or refractive astigmatism? I wondered. Answering that question led me to a system that considered corneal and refractive measurements separately – and described a link between them – utilizing vector planning.


Noel A. Alpins

With AK, the pendulum swung in favor of corneal astigmatism. With laser procedures, the pendulum swung to refractive astigmatism. Manufacturers now appear ready to link corneal topography to scanning excimer lasers, which contradicts prior wisdom and ignores valuable information provided by refractive astigmatism values. With my approach, the pendulum does not need to swing all the way back to a reliance solely on corneal shape as a determinant of treatment. My method provides a way to merge diagnostic (topography), therapeutic (laser) and analytic (vector analysis) functions into an integrated refractive surgical approach.

Basic concepts

The mathematics of my method are described in previous papers (see references at end of article); therefore, I will not go into detail here. Some basic concepts, however, must be understood.

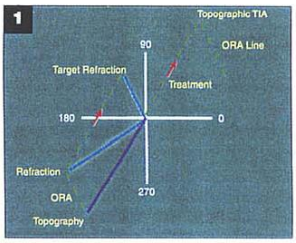
Figures 1, 2 and 3 demonstrate how my approach can be used in treating a patient who has a discrepancy between topographic astigmatism (T) and refractive astigmatism (R). If the surgeon treats with 100% emphasis on eliminating the refractive astigmatism, obviously some corneal astigmatism will remain. I have described the separation (vector) between T and R as ocular residual astigmatism (ORA) – the least astigmatism remaining that can be achieved in any individual eye. This quantity has, in the past, been termed "residual astigmatism." But using this term might cause confusion with the same term often used to describe the amount of astigmatism remaining after surgery. Of course, corneal astigmatism can be measured with keratometry or topography. For purposes of this discussion, I refer to the simulated keratometry value of the topography only.

The ORA is equivalent in magnitude to the refractive (Figure 1) and topographic (Figure 2) targets when treating by topography and refractive values, respectively. The maximum correction of astigmatism is achieved when the remaining astigmatism is at its minimum (the minimum target astigmatism) and is equal to the ORA. This remaining astigmatism will be refractive, topographic or a combination. My approach enables one to calculate the ORA as well as the parameters (laser settings) to emphasize the elimination of 100% of T, 100% of R or any combination of T and R equaling 100%, while leaving the absolute minimal amount of astigmatism in the eye's refractive system and its optical correction.

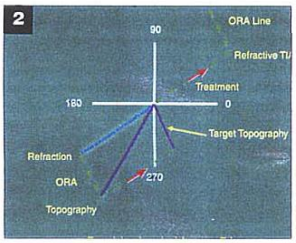
I also have described "optimal treatment," which is the treatment based on calculations that put more surgical emphasis on the elimination of topographic astigmatism the more "unfavorably" the astigmatism falls on the cornea. Using this approach, the surgeon can choose which orientation he or she believes is "unfavorable." Current thinking would suggest favoring with-the-rule (WTR) astigmatism, putting more surgical emphasis on eliminating corneal astigmatism that is calculated in advance to fall against-the-rule (ATR).

Widespread need

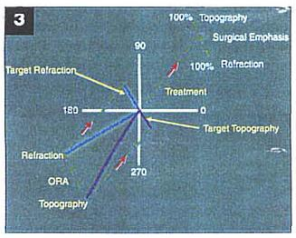
I believe it is common for people to demonstrate disparities between their corneal and refractive astigmatism in magnitude or axis or both, which lends importance to an integrated approach. In my paper "New method of targeting vectors to treat astigmatism" (*J Cataract Refract Surg.* 1997;23(1):65-75), I reported preoperative readings from 100 consecutive patients on whom I subsequently performed photoastigmatic refractive keratectomy. Comparing careful manifest refraction calculated at the corneal plane to simulated keratometry values taken with the TMS corneal topography system (Computed Anatomy Inc., New York), the magnitude of topographic astigmatism exceeded refractive astigmatism in 59 patients; in the remaining 41, refractive astigmatism was greater.



Double-angle vector diagram of treatment by topographical values to achieve a spherical cornea.



Double-angle vector diagram of treatment by refractive astigmatism values to achieve spherical refraction.



Double-angle vector diagram of treatment using both topographical and refractive astigmatism values to leave the minimum achievable astigmatism remaining.

Some of the trends evident from this comparison were extremely relevant. First, it seems that the eye optically tolerates WTR astigmatism better than ATR astigmatism, as refractive astigmatism was on average less than topographic astigmatism in this situation. For ATR corneal astigmatism, mean refractive astigmatism was greater than topographic.

Second, ORA exceeded 1 D in 34 of the 100 eyes and exceeded the preoperative topographic astigmatism in seven eyes. The impact of this finding on the eye demonstrates that, if treatment totally (100%) emphasized the elimination of refractive astigmatism, then 34 patients would be expected to have more than 1 D of corneal astigmatism remaining, and in seven patients, corneal astigmatism would be expected to increase after the surgery if it went according to plan. The incorporation of topographic values into the surgical plan would reduce the effect of these adverse events and leave less corneal astigmatism remaining.

Third, as one would expect, the ORA increased directly in proportion to increasingly different values for both T and R magnitude and axis. As long as there are two fundamentally different ways of measuring astigmatism, then differences will be prevalent and our current treatment modes must address the most effective way to deal with these imperfections.

Some people attribute the differences between corneal and refractive astigmatism to measurement errors; others refer to it as "lenticular astigmatism." In my opinion, these explanations do not explain or address the means to deal with the differences adequately. Astigmatism can be introduced at any or all of the optical interfaces – the front of the cornea, the back of the cornea, the front surface of the lens, the lens itself, the back of the lens, the vitreous and the plane of the retina – as well as the visual cortex of the brain, which is often overlooked as having an overriding conscious control over the amount and orientation of total astigmatism of the eye.

Why not just refraction?

I am one of the first to point out the need for good clinical studies to support or refute the advantages of optimal treatment. At our center, the Melbourne Excimer Laser Group that is associated with Melbourne University, a small study was carried out where optimal treatment appeared to result in better postoperative vision than treatment based solely on refractive astigmatism. The most valuable finding showed that bringing the astigmatic treatment closer to topographic values resulted in a greater reduction of corneal astigmatism after surgery. Surprisingly, there was no consequential increase in refractive astigmatism that would have been expected on theoretical grounds, effectively providing us with "something for nothing." This can be explained by the treatment bias toward WTR corneal astigmatism and the eye's more ready refractive acceptance of this error. I would welcome other research centers attempting to reproduce these findings.

Probably the most common questions I hear about my approach are related to optimal treatment. Why treat anything other than refractive astigmatism and sphere when the goal is to eliminate the need for spectacle correction? To me the answer is obvious – so long as the target spherical equivalent is zero, that patient's eye has minimal dependence on spectacles. However, if you treat this eye by refractive astigmatism values alone, the patient must wear that unavoidable astigmatism – the ORA – on his or her cornea for the rest of their lives and suffer the consequential potential degradation of vision. This concept might be difficult to grasp when the surgical maxim of protecting the cornea from avoidable astigmatism is not fully appreciated.

The rationale for optimal treatment, once understood, is compelling. Treatment of refractive astigmatism without regard to corneal astigmatism can result in a significant amount of remaining corneal astigmatism or even a net increase in corneal astigmatism. Theo Seiler in 1993 reported the increased spherical aberration associated with corneal astigmatism. A number of investigators have reported the possible advantages of WTR versus ATR astigmatism for distance vision.

Whether WTR or ATR astigmatism is ultimately found to be "better," astigmatism analysis is advanced by a methodology that allows the surgeon to favor any preferred orientation and provides a comprehensive, integrated approach to the analysis of corneal and refractive astigmatism. How else can we fully analyze surgical procedures that attempt to improve the refractive status of the eye by altering the shape of the cornea? ■

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