Vector analysis of astigmatism correction: the Alpins method

OCULAR SURGERY NEWS presents the first in a series of articles on astigmatism analysis and correction.

by Noel A. Alpins, FRACO, FRCOphth, FACS
Special to OCULAR SURGERY NEWS

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

An important dialogue is underway in ophthalmology regarding astigmatism analysis in refractive surgery. Although a consensus has not yet been reached, I believe that an editorial in the December 1998 issue of the *Journal of Cataract and Refractive Surgery*, by Douglas D. Koch, MD, helps establish that vector analysis will be part of whatever methodology ultimately is adopted as the general standard of care.

"... vectors differ from astigmatism in that they can only be calculated, not measured like astigmatism."

— Noel A. Alpins, FRACO, FRCOphth, FACS

I have developed a vector analysis approach to examine regular and irregular astigmatism described in a number of articles published since 1993. This article describes my approach in general terms. The mathematics is explained in detail in the original papers (see References). Any calculations have been performed by the ASSORT program and Designer Cornea module, in which I have a financial interest.

Fundamental concepts

The fundamentals of my approach are demonstrated by a golf putt performed on a flat green with no outside influences, such as wind or slope (Figure 1). A golf putt is similar to a vector, which induces corneal steepening possessing magnitude (length) and axis (direction). The intended putt (the path from the ball to the hole) corresponds to target induced astigmatism (TIA), which is the astigmatic change (by magnitude and axis) the surgeon intends to induce in order to correct the patient's preexisting astigmatism. The actual putt (the path the ball follows when hit) corresponds to the surgical induced astigmatism (SIA), which is the amount and axis of astigmatic change the surgeon actually induces with the procedure. If the golfer misses the cup, the difference vector (DV) corresponds to the second putt; that is, a putt that would allow the golfer to hit the cup with the ball on the second attempt, thus providing one parameter of astigmatism surgery that effectively measures the error (by magnitude and axis).

Figure 2 is a double-angle vector diagram (DAVD) used to allow calculations in a 360° sense and permit the use of rectangular coordinates. Line 1 represents a patient's measured preoperative astigmatism by magnitude (length of the line) and axis (an angle from the X-axis representing twice the patient's orientation of preoperative astigmatism). Line 2 defines the target astigmatism; that is, the magnitude and axis of the result the surgeon determines to achieve. Line 3 represents achieved astigmatism; that is, the magnitude and axis of the measured postoperative astigmatism. The dashed lines joined by the ends of these lines are the vectors for TIA, SIA and DV, as has been previously described.

Figure 3 represents the polar coordinates of the case shown in Figure 2. It is important to analyze the situation in a 180° sense, as these coordinates are indeed the surgical vectors. The surgical vectors are directly related to the various meridia as they would be seen superimposed over the eye; the length of the vectors represents the dioptric arithmetic values. The angle and magnitudes of errors are the respective differences between axis and magnitude of the SIA and TIA.

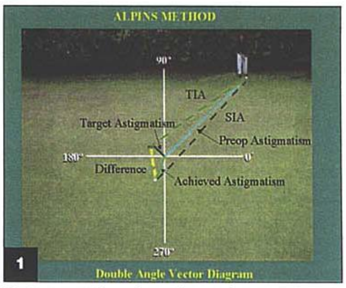
It is important to realize that vectors represent the amount of steepening occurring at that orientation. Also, vectors differ from astigmatism in that they can only be calculated, not measured like astigmatism. This distinction is important, as confusion can arise because the vectors share the same units of diopters and degrees.

Corneal vs. refractive astigmatism

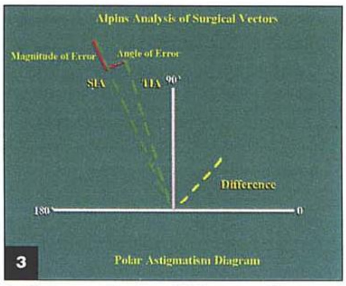
The same basic analytical approach described previously can be performed independently (and simultaneously) on corneal and refractive astigmatism, generating a useful and comprehensive system for planning, performing and analyzing astigmatic refractive surgery. Most people with regular astigmatism demonstrate differences in magnitude and orientation between topographic astigmatism and refractive astigmatism. A future article in this series will deal with this subject in more detail.

Simple relationships

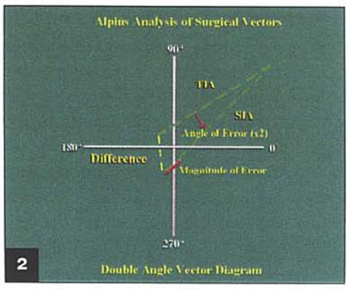
In the early 1990s, when I first began this fascinating journey of discovery in astigmatism analysis and treatment, I soon realized that the subject was poorly understood. Most of the confusion that existed at that time was caused by the persistent attempts to derive an analysis by a comparison between preoperative and postoperative astigmatism values in one way or another. The distinction between the axes of actual treatment (SIA) and attempted treatment (which I have defined as the TIA, near 90° to the preoperative astigmatism) was unclear. Most laser treatment analyses were primarily being performed by refractive astigmatism values and incisional surgery analyses by corneal values so that comparisons could not readily be drawn. Astigmatism analysis has had no consistent framework, which to some degree still exists by the persistence of variations in terminology and parameters.



Vector mapping of a *golf putt demonstrates* fundamentals of the Alpins method of astigmatism analysis.



Analyzing vectors in a 180° sense allows depiction of the actual surgical vectors; that is, the actual axes as superimposed over the eye and vectors whose relative lengths correspond to dioptric measurements.



The target induced astigmatism *(TIA), surgical* induced astigmatism (SIA) and difference vector (DV) correspond to the golf putt analogy in Figure 1 and are calculated from joining: 1) the patient's measured preoperative astigmatism; 2) the targeted astigmatism the surgeon plans to achieve; and 3) the actual measured result of the surgery in this double-angle vector diagram (DAVD).

By employing the analogy of golf putting, the simplicity of astigmatism analysis and its fundamental principles becomes immediately obvious. When attempting to obtain a predetermined astigmatic treatment, basically only two things can go wrong. First, as in golf-putting, the ball can be hit too hard or too soft (comparing magnitude values of SIA and TIA). Second, the ball can be hit off axis in a clockwise or counterclockwise direction (comparing axis values of SIA and TIA).

The correction index (CI), calculated by dividing SIA (actual effect) by TIA (intended effect), reveals if the ball was hit too hard or too soft. The CI is preferably 1.0. It is greater than 1.0 if the ball was hit too hard (an overcorrection occurred) and less than 1.0 if the ball was hit too softly (an undercorrection occurred).

If the first putt misses, the second putt (DV) is an excellent absolute measure of how successful the first putt has been. If one wants to compare the first putts of two golfers, however, one needs a relative measure of success. For example, if two golfers each have second putts of equal length, a relative measure of success would relate this to the length of their intended first putts. The golfer with the longer first putt would be considered more successful. This situation equates to the index of success (IOS), which is the DV divided by the TIA. The IOS provides a relative measure to compare performance.

To complete the trio of relationships required in any comprehensive astigmatism analysis, after comparing the first (SIA) and second (DV) putts to the intended first putt (TIA), one should ask a third slightly more complex question: How effective was the length of the first putt (SIA) in traveling along its intended direction to the hole (TIA)? This will be dealt with in more detail in the next article, which describes the flattening effect and the flattening index (FI) as the third component.

Each of these three indices – the CI, IOS and FI – gives us valuable and separate information necessary for understanding any astigmatism change. The TIA, SIA and DV and the description and calculation of their various relationships, comprise the essence of what has come to be called the Alpins method of astigmatism analysis. ■

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■References:

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