Flattening, steepening and torque are crucial points in astigmatism surgery

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

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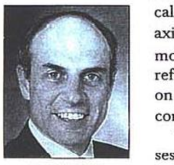
Special to OCULAR SURGERY NEWS

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

The general goal of astigmatism surgery is to flatten the cornea at its steepest meridian, steepen the cornea at its flattest meridian or a combination of both. However, by error or design, the intended (targeted) axis often varies from the achieved (induced) axis of treatment. The overall analytical technique that I have developed, I believe more readily explains the corneal changes occurring. One part of the approach precisely quantifies the amount of useful astigmatic change in the goal of reducing astigmatism and the change wasted in this endeavor that results in undesired rotation of the astigmatism meridian.



Noel A. Alpins

The technique utilizes vector analysis and certain indices that I have described in previous papers (see the references at the end of this article). The approach can be used for both incisional (tissue addition) and non-incisional (tissue ablation) refractive procedures. My calculations performed here have utilized the ASSORT program, in which I have a financial interest.

Resolving the components

Any treatment such as surgically induced astigmatism (SIA) that induces change in the shape of the cornea can be resolved into two components: the effective proportion of the SIA that has some flattening (or steepening) effect at the preoperative astigmatism axis; and one I call torque, which lies 45° clockwise or counterclockwise to the existing astigmatism and quantifies the wasted effect, or the relative ineffectiveness, of the SIA in reducing corneal astigmatism at the intended axis.

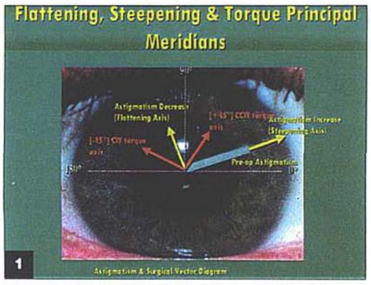
Figures 1 and 2 illustrate flattening, steepening and torque as surgical (polar) vectors and in a double-angle vector diagram (DAVD), respectively. In this example, the preoperative astigmatism is chosen as the axis under examination. At this reference axis, which is the same for any one treatment whether performed by incisional or ablation surgery, the same astigmatic effect occurs when the greatest treatment activity to produce it lies at right angles to one another.

Using, once again, the golf analogy (as in the first article in this series) for interpreting a DAVD, how effective was the length of the first putt (SIA) in traveling along its intended direction to the hole (target induced astigmatism, or TIA)? This is easily examined on paper in Figure 2 by dropping a line from the end of the first putt, perpendicular to the line of its intended path. This calculated value of the effective SIA tells us how much reduction of astigmatism (flattening) was achieved at the preoperative astigmatism axis. When this value also is related to the TIA, we have a third index termed flattening index (FI) to complete the other two indices, the correction index (CI) and the index of success (IOS).

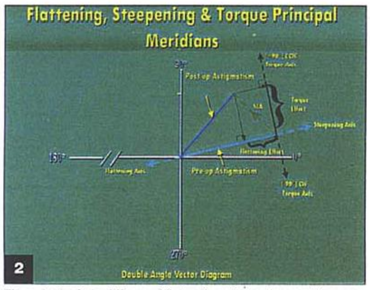
Analytical flexibility

This analytical approach can be applied independently to astigmatism measured topographically, keratometrically or by manifest refraction. Where axis differences exist between the two modes of measurement – corneal or refractive – an on-axis correction based on one will obviously cause an off-axis correction of the other.

The approach provides useful analyses in situations where the intended treatment axis does not coincide with the preoperative meridian of astigmatism such as: when cataract surgery using a temporal incision is performed, but the steepest corneal meridian is oriented elsewhere; when excimer laser astigmatic treatment is based on refractive astigmatism values in eyes exhibiting an axis difference between topographic and refractive astigmatism; and when using my "optimal approach" described in the next article in this series where the treatment axis does not coincide with either refractive or topographic meridians.



The principal meridians of flattening, steepening and torque in relation to the preoperative astigmatism meridian: astigmatism and surgical vector diagram.



The principal meridians of flattening, steepening and torque: double-angle vector diagram.

Flattening, steepening and torque also are useful in a number of other situations:

- To determine the functional effect of incisional or ablative procedures. That is, due to biological factors, a treatment placed at one meridian may act functionally as though it were placed at a different meridian.
- To determine a treatment's steepening effect at any axis of interest.
- To determine a treatment's flattening effect at the preoperative steep meridian.
- To determine the net astigmatism change at the polar axes (with-the-rule and against-the-rule). This is done by using 90° as the reference axis.

Defining terms

An Alpins analysis employs a number of terms including those described in the previous article:

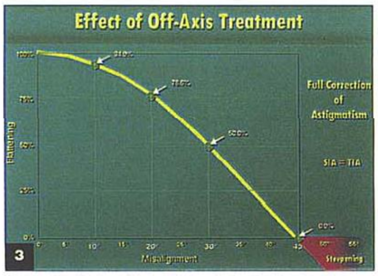
Target induced astigmatism (TIA) – The astigmatic change (by magnitude and axis) the surgeon intends to induce.

Surgically induced astigmatism (SIA) – The amount and axis of astigmatic change the surgeon actually induces.

Correction index (CI) – The ratio of the SIA to the TIA (what the surgery actually induces versus what the surgery was meant to induce), calculated by dividing SIA (actual effect) by TIA (target effect). The CI is preferably 1.0 (it is greater than 1.0 if an overcorrection occurs, and less than 1.0 if there is an undercorrection).

Angle of error (AofE) – The angle described by the vectors of the achieved correction versus the intended correction. The AofE is positive if the achieved correction is on an axis counterclockwise to where it was intended, and negative if the achieved correction is clockwise to its intended axis.

Magnitude of error (MofE) – The arithmetic difference between the magnitudes of the SIA and the TIA. The MofE is positive for overcorrections and negative for undercorrections.



Reduced flattening effect of increasingly misaligned astigmatism treatment.

Difference vector (DV) – The change (by magnitude and axis) that would enable the surgeon to hit the original target on the second attempt. The DV is an absolute measure of success and is preferably 0.

Index of success (IOS) – Calculated by dividing the DV (how far you miss the intended target) by the TIA (the original target effect). The IOS is a relative measure of success and is preferably 0.

Flattening effect – The amount of astigmatism reduction achieved by the effective proportion of the SIA at the intended meridian.

Flattening index (FI) – Calculated by dividing the flattening effect by the TIA and is preferably 1.0.

Coefficient of adjustment (CofA) – Derived by dividing TIA by SIA (the CI inverse) to adjust astigmatism treatment magnitude. Its value is preferably 1.0. The CofA enables the achievement of a full correction of astigmatism magnitude in future treatments based on past experience.

Misaligned treatment

In Figure 3, which is derived from vector analysis, the FI becomes smaller as a function of increasingly misaligned treatment. All other things being equal, however, the SIA is unaffected and thus the CI also is unaffected. Most authors agree that when the misalignment reaches 45°, the flattening effect at the intended meridian becomes zero; that is, no measurable change in astigmatism has occurred at the treatment meridian. Beyond 45°, the FI becomes negative and an increase in astigmatism has occurred.

However, Figure 3 does not conform to the near linear relationship suggested by other authors. Vector analysis indicates that, at 15° off axis, 13% of the flattening effect is lost. Others have suggested that up to 50% of effect is lost at 15° off axis, which severely overstates the loss of flattening effect by misplaced treatment. Vector analysis indicates that treatment would need to be 30° off axis to yield a 50% loss of effect.

If the SIA is unaffected and yet does not reduce astigmatism by flattening the cornea at the preoperative meridian in the intended manner, how is it being spent? In fact, it is affecting the remaining preoperative astigmatism by rotating or torquing it to another meridian. So for any astigmatism change that becomes increasingly off axis, as the flattening effect diminishes, the torque increases until at 45° off axis there is no flattening effect at all, and the SIA treatment is entirely creating torque. In addition to this, a purely torque force has a tendency to increase the remaining astigmatism that it is rotating.

Comprehensive understanding

In general terms, there are three indices that examine the relationship of three separate vectors to the treatment vector (the TIA) and comprise a complete approach to astigmatism analysis: the CI, which is the overall astigmatism correction achieved by the SIA; the IOS, a measure of relative success derived from the DV; and the FI, calculated from the flattening effect achieved by the effective proportion of the SIA.

When examined together, the three provide a comprehensive understanding of any astigmatic change and what proportion of the astigmatism treatment has been effectively applied.

Using this method, favorable changes at the preoperative astigmatism meridian are quantified by flattening effect and ineffective changes are evaluated by torque. The necessary information also available to the surgeon is how efficiently is his or her laser correcting astigmatism (shown by the CI) and how do the astigmatic results of his or her laser compare to other lasers and other techniques (shown by the IOS). I believe this method provides a comprehensive understanding of induced astigmatic change and offers significant advantages by enabling an integrated examination of all changes applicable to keratometry, topography or refraction values. ■

> **"Most authors agree that when the misalignment reaches 45°, the flattening effect at the intended meridian becomes zero."**
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> ***— Noel A. Alpins, FRACO, FRCOpth, FACS***

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