A new method of astigmatism analysis

by Noel Alpins, MD
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Current methods of analysis used in understanding changes in astigmatism do not enable meaningful comparisons of surgical series and techniques when a change in the astigmatic status of the eye is intended. Analytical methods presently available only calculate surgically induced astigmatic change; they do not allow us to compare magnitudes and axes separately for a series of paired groups of procedures. However, we need to know how to choose the best technique to use; we also need to know whether any failure to achieve surgical goals is attributable to the particular patient concerned, or to general technique or machine (e.g., excimer laser) error.

Exact and separate measures

I have devised a new method of astigmatism analysis, which is derived from classical vector analysis techniques. This new method provides exact and separate measures of both magnitude and axis of surgical error. By reducing the error to its component parts, we can group operations together, seek trends, analyze the means and standard deviations and compare them with other techniques, using statistical analysis. Vectors, unlike astigmatism, cannot be measured; they can only be calculated. A vector is a dynamic force that steepens the cornea in a specified direction and fundamentally differs from astigmatism, which is a static entity measurable on a toroidal surface. Even though the two share the same units of measurement, simple arithmetic calculations between them are not valid.

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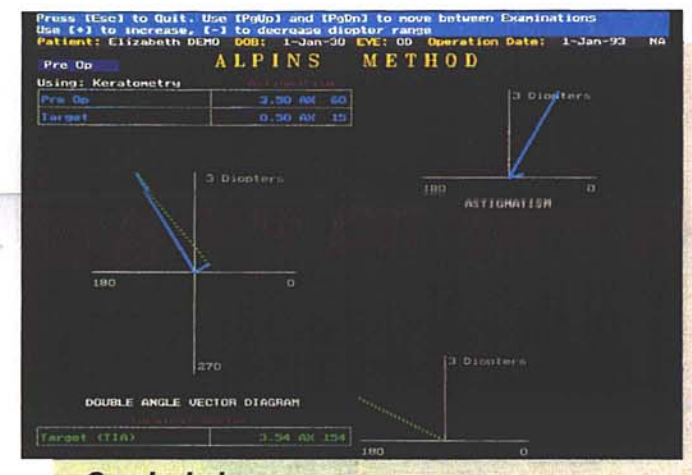
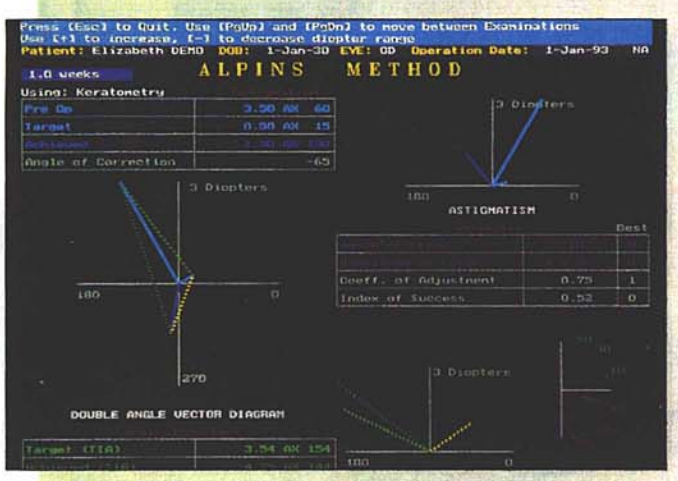
We can, for example, calculate the "difference vector," that is, the magnitude and axis of the astigmatism vector required to obtain the targeted result from the residual astigmatism remaining after initial surgery. This method also provides an indicator measuring surgical success, which is adjusted for the level of preoperative astigmatism, and specific adjustments required to improve future surgery. Vectors are like surgical navigation aids. They indicate both the direction of future surgery and the success of past surgeries.



Surgical plan.



Surgical analysis.

It is important that we have a special goal for each astigmatic procedure; indeed, this is the key dimension that enables this method to overcome the deficiency of the current techniques. We should state and write down our goal for astigmatism surgery, just as we do for many other tasks, so we can examine our success or shortcomings in achieving our initial aim. We can then work out how the surgically induced astigmatism (SIA) differs from our targeted induced astigmatism (TIA). Comparative analyses of surgery are then made possible, as we can determine differences, errors and therefore the correction required for future surgery. For example, we can derive a coefficient, which enables us to adjust magnitudes of future astigmatic correction in view of trends discernible from past surgical results.

Shooting for zero

We tend to assume that we are "shooting for zero" astigmatism, and therefore attempt astigmatism correction equal to the magnitude of preoperative astigmatism. However, there are times when the surgeon would want an amount of residual astigmatism as the operative aim. Sometimes surgical techniques used to treat high degrees of preoperative astigmatism just cannot reach zero astigmatism; in fact, zero astigmatism is achieved in significantly less than 100% of surgery. There will be situations where it would be better to target a small amount of residual with-the-rule astigmatism. For example, in cataract and implant surgery, this would assist in allowing for the against-the-rule decay curve manifested in the postoperative period; in penetrating keratoplasty, where residual astigmatism is prevalent, with-the-rule astigmatism would be optically preferable. With modern refractive surgery utilizing the excimer laser, the eye is treated using the refraction as a treatment parameter, and commonly there exists a variance between corneal and spectacle astigmatism, which results in unavoidable non-zero corneal astigmatism being targeted.

While our goal may or may not be zero astigmatism, we should always plan the axis of any residual astigmatism, should it remain, deliberately or unavoidably. It is generally assumed that any residual astigmatism remaining after failing to achieve the goal of zero astigmatism lies on the same axis as the preoperative astigmatism. If residual astigmatism does deviate from the preoperative axis, it has undergone an axis shift. Rather than just accepting this after the fact, the surgeon could plan for the possibility that unintended residual astigmatism will remain and will lie on a new axis, and use this as an opportunity to redeem the situation by perhaps thinking about targeting instead for a small amount of residual astigmatism in a preferred axis, such as at zero with-the-rule, which is optically and physiologically preferable to the human eye.

The surgeon may choose to nominate any level of postoperative astigmatism, such as, for example, 0.5 D to 0.75 D with-the-rule. By using the TIA vector force calculated using this method, the required surgery can simply be keyed into the appropriate software program of the excimer laser to achieve the intended corneal toroidal shape. Without calculating preoperatively the targeted corneal astigmatism, we cannot determine our errors when analyzing our results. Stating this in simpler terms, if we don't know where the target is, how do we determine by how much we have missed it? For these reasons, I believe that the concept of the TIA vector is the key to future astigmatism surgery using techniques such as the excimer laser.

Simple concepts

The mathematics of this method uses double angles and rectangular coordinates and therefore may appear difficult; however, while the mathematics of the method may seem complex, its concepts are actually simple to understand and easy to use, with the aid of computerization. Furthermore, this method can be useful to all ophthalmic surgeons for all kinds of surgery, not just radial keratotomy and excimer laser surgery, but also, for instance, for cataract surgery.

Modern laser technologies have empowered us with the ability to modify our procedures with degrees of sophistication never before possible; the use of this new method of astigmatism analysis therefore lies not just in its own capabilities, but also in its ability to complement and make best use of the new technologies now available to us. ■