FROM THE EDITOR

Astigmatism analysis: The spectrum of approaches

In this issue, Borasio et al. (page 2030) report on the astigmatic changes induced by clear corneal incisions that are placed temporally or along the steep corneal meridian. Key elements of the study were an incision size of 3.2 mm (although this was not measured intraoperatively) and marking of patients' eyes at the slitlamp biomicroscope to maximize accuracy of incision placement.

As anticipated, the authors found a statistically significant difference in the magnitude of algebraic change in astigmatism in the 2 groups: There was a slight reduction when the incisions were placed along the steep meridian and a slight increase when the incisions were placed temporally. Surprisingly, using the Alpins[1,2] method, they actually found a greater amount of torque when the incisions were placed along the steep meridian. They attribute the latter finding to a possible variability in collagen fibril arrangement in different meridional zones of the cornea.

This study provides clinical support for the theoretical concept that placing incisions along the steep corneal meridian reduces corneal astigmatism. As we use progressively smaller incisions, the benefit from this approach will obviously diminish. This is good news to surgeons who do not wish to place their incisions at meridians that make surgery more awkward.

This study also prompts consideration of methods for analyzing corneal astigmatism induced by cataract and refractive surgery. Three major types of analysis are useful:

1. *Keratometric*: The classic method for analyzing changes in corneal astigmatism is based on keratometric readings. These readings are subjected to one of several analytical approaches, and numbers of different metrics are generated. This is the "bread-and-butter" approach for analyzing corneal astigmatism. It has been used in the vast majority of papers on this topic and has reliably helped us improve clinical outcomes.

A partial list of pioneers in this area include (in alphabetical order) Alpins,[3] Harris,[4] Holladay et al.,[5] Kaye and Patterson,[6] Naeser and Hjortdal,[7] Thibos and Horner,[8] and many others. The Borasio paper demonstrates the elegance and usefulness of the Alpins method. It is gratifying to see that several elements of Alpins' approach have been incorporated into the recommendations of the Astigmatism Project Group of the American National Standards Institute,[9] although I believe that Alpins' work was not acknowledged as fully as was warranted. In addition, Eydelman et al.[9] changed Alpins' terminology, raising the concern that this will create confusion in the literature.

The primary limitation of the keratometric approach is obvious—only 4 points on the cornea are used for analysis. This is a limited sampling of corneal curvature and does little to tell us why changes occur.

2. *Topographic*: Corneal topographic analysis of astigmatic changes addresses a major limitation of the keratometric approach by evaluating a broader region of the anterior corneal surface and, with scanning-slit technology, full-thickness cornea. Again, a variety of approaches can be used and a variety of metrics generated.

One of the most elegant approaches is batch analysis that was described by Rainer et al.[10] With this approach, the corneal topographic surface is divided into small sectors. Postoperative changes in these sectors are averaged over the population studied, and a composite map showing mean changes (with statistical analysis) in each zone is produced. This provides a detailed and sophisticated analysis of corneal topographic changes. It would be fascinating to repeat the study by Borasio et al. with this approach: It could indicate where focal changes occurred and might help to explain the torque that was observed.

A recent advance in corneal topographic analysis is assessment of changes in posterior corneal curvature. Slit-imaging devices are currently the prevalent technology for measuring posterior corneal curvature. As Nawa et al.[11] have shown, however, measurement of posterior corneal curvature with optical devices is subject to the error produced by magnification effects of the anterior corneal surface. Consistent with this theory, Ciolino and Belin[12] have shown that the Pentacam (Oculus, Inc.) and Orbscan (Bausch & Lomb) provide different measurements of posterior corneal curvature. In another article in this issue (pages), Borasio and a different group of colleagues used the Pentacam to develop a formula for calculating corneal refractive power in eyes that have had corneal refractive surgery. They found that Pentacam values had to be modified to more accurately reflect corneal power. This again suggests that slit devices may not provide an accurate measurement of posterior corneal power.

Corneal biomechanics will play an increasingly important role in our analysis of corneal shape changes.[13]

Published by Elsevier Inc.

0886-3350/06/$-see front matter
doi:10.1016/j.jcrs.2006.10.001

Knowledge of a patient's corneal biomechanics could greatly enhance the predictability of the surgical outcome. This takes us back to the issue of torque raised by Borasio et al. in their paper. Would this torque have been reduced if the surgeons had been able to take into account the biomechanical variability in these patients' corneas?

3. *Optical properties*: The fundamental goal of all this effort is to understand how the cornea focuses light. Wavefront analysis of the cornea—anterior and posterior—will supplant keratometric analyses and will provide the critical optical counterpart to corneal topographic analysis. As recently shown by Iseli et al.,[14] this will be combined with wavefront analysis of the eye to maximize patients' quality of vision.

The quest to customize corneal procedures to maximize patients' visual outcomes continues. New studies and new technology are ushering us along this path.

Douglas D. Koch, MD

REFERENCES

1. Alpins NA. A new method of analyzing vectors for changes in astigmatism. J Cataract Refract Surg 1993; 19:524–533
2. Alpins NA. Vector analysis of astigmatism changes by flattening, steepening, and torque. J Cataract Refract Surg 1997; 23:1503–1514
3. Alpins N. Astigmatism analysis by the Alpins method. J Cataract Refract Surg 2001; 27:31–49
4. Harris WF. Optical effects of ocular surgery including anterior segment surgery. J Cataract Refract Surg 2001; 27:95–106
5. Holladay JT, Moran JR, Kezirian GM. Analysis of aggregate surgically induced refractive change, prediction error, and intraocular astigmatism. J Cataract Refract Surg 2001; 27:61–79
6. Kaye SB, Patterson A. Analyzing refractive changes after anterior segment surgery. J Cataract Refract Surg 2001; 27:50–60
7. Naeser K, Hjortdal J. Polar value analysis of refractive data. J Cataract Refract Surg 2001; 27:86–94
8. Thibos LN, Horner D. Power vector analysis of the optical outcome of refractive surgery. J Cataract Refract Surg 2001; 27: 80–85
9. Eydelman MB, Drum B, Holladay J, et al. Standardized analyses of correction of astigmatism by laser systems that reshape the cornea. J Refract Surg 2006; 22:81–95
10. Rainer G, Menapace R, Vass C, et al. Corneal shape changes after temporal and superolateral 3.0 mm clear corneal incisions. J Cataract Refract Surg 1999; 25:1121–1126
11. Nawa Y, Masuda K, Ueda T, et al. Evaluation of apparent ectasia of the posterior surface of the cornea after keratorefractive surgery. J Cataract Refract Surg 2005; 31:571–573
12. Ciolino JB, Belin MW. Changes in the posterior cornea after laser in situ keratomileusis and photorefractive keratectomy. J Cataract Refract Surg 2006; 32:1426–1431
13. Roberts C. Biomechanical customization: the next generation of laser refractive surgery. J Cataract Refract Surg 2005; 31:2–5
14. Iseli HP, Jankov M, Bueeler M, et al. Corneal and total wavefront aberrations in phakic and pseudophakic eyes after implantation of monofocal foldable intraocular lenses. J Cataract Refract Surg 2006; 32:762–771