

The astigmatic armamentarium

by Brad Fundingsland Managing Editor

The various forms and etiologies of astigmatism make treatment a challenge. Yet, recent developments have improved the surgeon's ability to deal with this difficult disorder.

Astigmatism can be assessed by a refraction measurement of the visual system or a keratometry measurement of the corneal curvature. Often, these measurements reveal different astigmatism values. Resolving and understanding these values is the first and, perhaps, most important step to treating astigmatism. In the EW interview on page 46, Noel A. Alpíns, MD, in private practice in Melbourne, Australia, provides his expert analysis of astigmatism diagnosis and

explains the fundamentals behind this complex disorder.

One of the first modern surgical treatments for astigmatism included corneal wedge resections, developed by Richard Troutman, MD, and sutures to modify corneal shape by removing tissue and adding tension at different meridians. As techniques advanced, astigmatism correction evolved into corneal incisions intended to relax steep astig-

matic meridians. These incisions were for patients with existing cylinder or astigmatism induced by cataract incision gape.

In 1991, I. Howard Fine, MD, clinical associate professor, Oregon Health Sciences University, Portland, introduced the clear cornea incision. This allowed the surgeon to use the incision's location, size, and shape to correct existing astigmatism and avoid it.

Today, many techniques and technologies are available or are being investigated for the correction of congenital and induced astigmatism. This comprehensive overview will restock the surgeon's armamentarium for treating this complicated visual disorder.

Pseudophakic astigmatism treatments

Peripheral arcuate incisions

For several years, physicians have tailored their phacoemulsification incisions to match the patient's existing astigmatic condition and account for any induced astigmatism from the incision. This involved moving around the table to place incisions at different axis locations and alternating between clear cornea and scleral incisions. "This has worked well, but it is ergonomically difficult," said Louis D. "Skip" Nichamin, MD, medical director of the Laurel Eye Clinic in Brookville, Pa.

Therefore, Nichamin and others have turned to a consistently placed single-plane, beveled temporal incision for every cataract procedure. "Keeping this

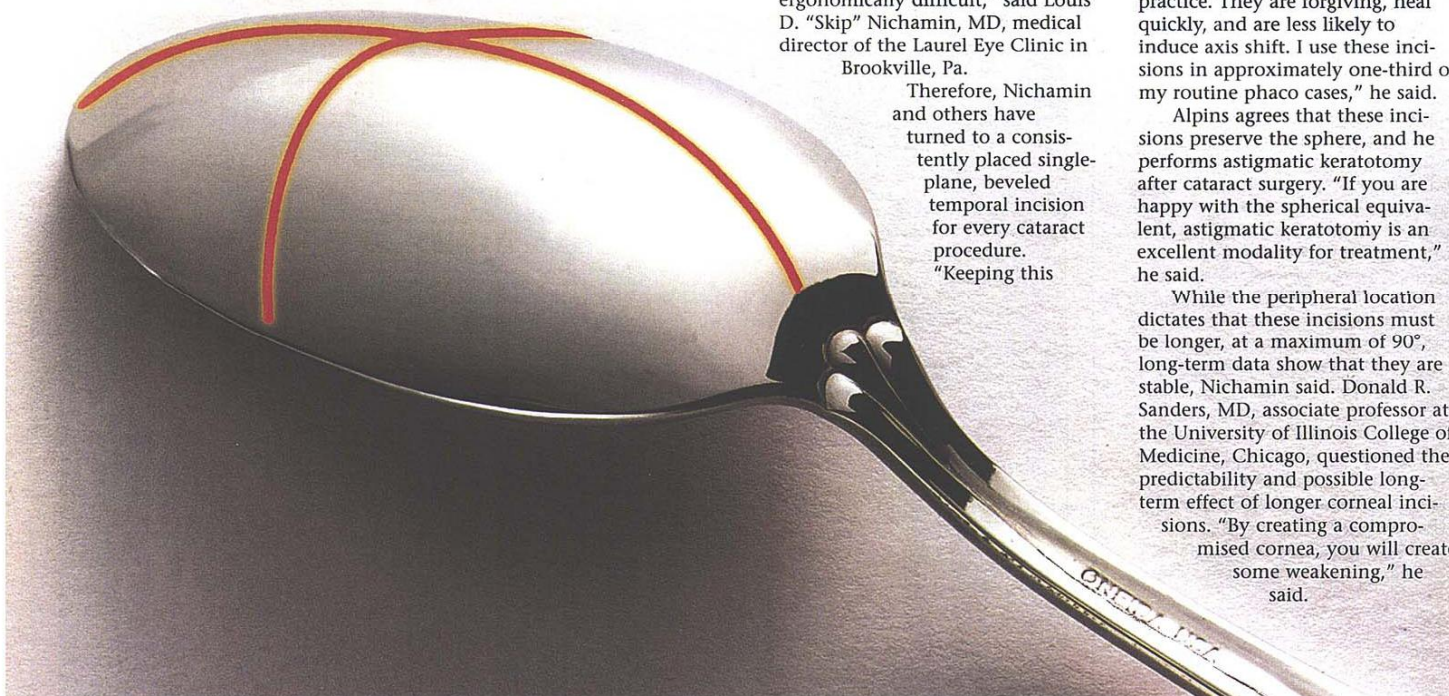
incision in the 3.5-mm range, we are approaching astigmatic neutrality."

Without any induced astigmatism, cataract surgeons can focus on treating existing astigmatism with supplemental relaxing incisions. Corneal transverse and arcuate incisions at smaller optical zones have been effectively used for a number of years, but, unfortunately, occasional problems can occur. Coupling, the term generally used to describe the ratio of flattening that occurs in the incised meridian as compared with the steepening that results in the opposite meridian, tends to be unpredictable with smaller optical zones, thus impacting the accuracy of IOL power prediction, according to Nichamin. If not perfectly centered upon the steep meridian, conventional (7.0-mm optical zone.) incisions could also lead to a significant shift in the resultant astigmatic axis. Perhaps most important, small optical zones could induce irregular flattening and, hence, irregular astigmatism.

Instead, Nichamin advocates peripheral arcuate incisions placed just inside the vascular arcade at the peripheral-most extent of clear cornea. "These intralimbic relaxing incisions have greatly improved my practice. They are forgiving, heal quickly, and are less likely to induce axis shift. I use these incisions in approximately one-third of my routine phaco cases," he said.

Alpíns agrees that these incisions preserve the sphere, and he performs astigmatic keratotomies after cataract surgery. "If you are happy with the spherical equivalent, astigmatic keratotomy is an excellent modality for treatment," he said.

While the peripheral location dictates that these incisions must be longer, at a maximum of 90°, long-term data show that they are stable, Nichamin said. Donald R. Sanders, MD, associate professor at the University of Illinois College of Medicine, Chicago, questioned the predictability and possible long-term effect of longer corneal incisions. "By creating a compromised cornea, you will create some weakening," he said.



"Until we have better modalities of treating mixed astigmatism, I think our primary responsibility is to not create irregular astigmatism. With LRI, we get into less trouble with marking the axis, inducing irregular flattening, etc. I also think that this form of astigmatic keratotomy brings astigmatism surgery into the purview of the general comprehensive ophthalmologist. It's not a particularly demanding or difficult procedure," Nichamin said.

Hyperopic astigmatism

Hyperopic astigmatism patients have tremendous benefits to gain from laser correction. "Hyperopic astigmatism patients who are also presbyopic have really lost their ability to function at near, intermediate, and distance and are some of the happiest patients to get corrected. With laser correction, we can now help restore their vision at all distances," said Daniel S. Durrie, MD, in private practice in Kansas City, Mo.

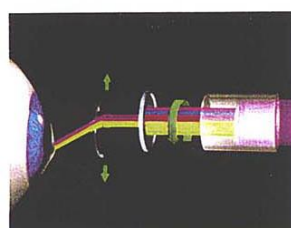
Currently, no excimer lasers are approved by the FDA for the treatment of hyperopic astigmatism. Most approaches under investigation accomplish the treatment by steepening the flat axis by ablating in the periphery.

The FDA study farthest along is with the Visx STAR S2 laser. Approval is possible early this year. Doane presented information at the 1999 ASCRS meeting, revealing correction in 100 eyes from a mean preoperative cylinder of 0.81 D to a mean 6-month postoperative cylinder of 0.43 D.

Vinciguerra, who also won best paper of session honors at the 1999 ASCRS meeting, said that treating hyperopic astigmatism completely with a plus-cylinder approach (steepening the flat axis) leads to a large change in dioptric power and a decrease in the quality of vision as the pupil dilates.

Instead, he believes that bitoric ablation to treat the astigmatism and a spherical hyperopia treatment to treat the remaining sphere is a better approach. He suggested that half the astigmatic correction be placed in the minus cylinder (flattening the steep axis) and half in the plus cylinder (steepening the flat axis). He claims this creates a more homogeneous ablation transition. "While this removes more cornea tissue, it also creates a more physiologically prolate cornea, with less regression and better visual acuity," Vinciguerra said.

Durrie agrees that this is the future of hyperopic astigmatism correction, because it removes the least amount of tissue. He said, "It helps if you think of it like a landscape architect trying to smooth out hills and valleys. The current means of correcting hyperopic astigmatism, by only steepening the flat axis, is the equivalent of hauling all the dirt to the highest hill. If you were a landscape architect, this would not be the best way to smooth things out. Instead you would knock the hills to the midpoint and fill the valleys to the midpoint," Durrie said.



VISX CAP method for irregular astigmatism

Irregular astigmatism

The evolution of videokeratographic measurements and, more recently, wavefront technology, permits surgeons a much greater understanding of irregular astigmatism. Levels of irregularities vary from the small changes found with aberrations to large disparities of conditions such as advanced keratoconus.

The incidence of this disorder depends on what is considered irregular astigmatism. Jack T. Holladay, MD, McNeese professor of ophthalmology at the University of Texas and in private practice in Houston, cited a topographic classification study by George O. Waring, MD, in private practice in Atlanta. Waring found that 18% of patients had asymmetric bow-tie astigmatism and 18% had other irregular astigmatism.

In another study, Alpíns determined that 43% of 100 refractive surgery patients had irregular astigmatism with a topographic disparity of greater than 1 D. After conducting a survey of peer-reviewed literature, Michael C. Knorz, MD, assistant clinical professor, University of Heidelberg, Germany, has found a similar incidence, claiming that 40% of all human corneas show some kind of irregularity.

Excimer laser corrections of irregular astigmatism involve treatments based on topographic or wavefront assessments of the eye. Yet, to this point, none of them have been granted FDA approval.

Videokeratography based irregular ablations

Initial treatment of irregular astigmatism with the excimer laser involved manual decentration of the beam to treat macro-irregularities based on corneal topography. Other treatments involved the use of a fluid mask to protect the valleys of the cornea, while exposing the peaks to laser ablation, again, based on topography maps.

Visx has automated the concept of the decentrated, localized beam to treat irregular astigmatism with its Contoured Ablation Pattern Method (CAP) on its Star S2 SmoothScan lasers. This method allows physicians to center on the cornea as usual and program offset refractive ablations at varying depths and sizes of ellipses, circles, and cylinders, with the assistance of a software package. In the past, creating these various ablation patterns has been a very artistic technique. Now we're able to develop these computer-aided methods to try to improve outcomes," Hardten said.

Table 1 — U.S. FDA-approved indications for excimer lasers

| Laser/Model | PRK myopia | PRK myopic astigmatism | PRK hyperopic astigmatism | PRK hyperopia | LASIK myopia | LASIK myopic astigmatism |
|-----------------------------|--------------|------------------------|---------------------------|---------------|--------------|--------------------------|
| Visx Star S2 | 0 to 12 D | 0 to 4 D | — | 1 to 6 D | 0 to 14 D | 0.5 to 5 D |
| Summit Apex Plus | 0 to 7 D | 0 to 1.5 D | — | 1.5 to 4 D | 0 to 14 D | 0.5 to 5 D |
| Nidek EC 5000 | 0.75 to 13 D | 0.5 to 4 D | — | — | — | — |
| Autonomous LADARVision | 1 to 10 D | 0 to 4 D | — | — | — | — |
| LaserSight LaserScan LSC | 1 to 10 D | — | — | — | — | — |
| Bausch & Lomb Technolas 217 | — | — | — | — | 1 to 7 D | 0 to 3 D |

Note that these are general approved treatment parameters. Contact manufacturers for specific conditions, restrictions, and/or limitations on these numbers.

At the 1999 American Academy of Ophthalmology meeting, Renato A. Neves, MD, of Sao Paulo, Brazil, presented the results of 20 patients with irregular astigmatism due to existing keratoconus induced by refractive surgery. All patients improved their UCVA and best-corrected visual acuity at 6 months postoperatively.

Visx, with Zeiss-Humphrey Systems, has developed special ablation-planning software to test these proposed eccentric ablations within the computer, view theoretical postoperative maps, and determine the best course. The software has been tested internationally and will soon be released in the United States, according to Visx.

Specified irregular treatments can also be obtained with new investigational disks that Summit Technologies is developing. The disks are customized to individual corneas, said Ronald R. Krueger, MD, medical director of refractive surgery at the Cleveland Clinic Foundation in Cleveland. "The disk can be made so that somewhere off in the periphery, you can have a lot more energy coming through than in the center, and it can be specific on a point-wise basis," he said.

The Aesculap-Meditec (Germany) MEL 70 and Bausch & Lomb Keracor excimer lasers are customizing their ablations by integrating a small beam with an individual topographic image, in a method some refer to as topolink. "Topolink is aimed at the ablation of the cornea to obtain a predetermined surface curvature, independent of the existing curvature," said Thomas F. Neuhann, MD, professor, University of Mainz, Munich, Germany. "It is an individually calculated algorithm based on topography."

Neuhann presented results with the Keracor showing 133 patients, with one eye treated with topographically guided laser in-situ keratomileusis, and the fellow eye treated with standard LASIK. After 3 months, 80% of the topolink eyes were within 0.5 D of emmetropia, while 94% were within 1 D. In contrast, 66% of the standard LASIK eyes were within 0.5 D and 86% were within 1 D.

Aesculap-Meditec demonstrated one of the first internationally available topographically guided lasers at the 1999 AAO meeting, using the Topography Customized Ablation (TOSCA). Dieter Dausch, MD, in private practice in Amberg, Germany, presented data using

TOSCA with the MEL 70 laser in 25 eyes. After 12 months, the spectacle-corrected visual acuity improved from 20/32 to 20/25. "I think the corneal tissue-saving effect is very high with the customized ablation, allowing us, in the future, to correct irregular corneas that have thin pachymetry," Dausch said.

Krueger said, "The biggest problem with topographic guided ablation right now is taking that corneal map, accurate or not accurate, and actually linking it to the eye, because cyclotorsions or little centration issues could completely throw that off. Once we overcome that, I think we're going to see some real promising initial results."

Holladay also said that Placido-based videokeratography, based on corneal slope rather than elevation measurements, might be part of the problem. "Looking at power maps for custom ablations is worthless. Elevation maps are needed, because the laser requires height or Z data to accurately place ablations," he said.

Wavefront-based irregular ablations

Wavefront technology is an optical diagnostic concept that involves a low-power laser beam bounced off the retina and processed through some very high-tech optical elements. When analyzed using complex mathematical algorithms, this method provides an extremely precise refractive assessment of the entire eye.

"Basically, wavefront is to a refraction what videokeratometry is to a keratometer. Wavefront technology provides a very sophisticated map of the refraction, with 50 to 200 ray-tracing measurements in any one eye, while corneal topography is several thousand keratometric measurements," Alpíns said.

Visx is developing wavefront diagnostic devices with 20/10 Perfect-Vision Wavefront technology. The technology is intended to improve the accuracy of the refraction that is used for the laser ablations. By using wavefront data as refraction inputs for a laser ablation, much of the human error is removed from the process, according to Visx.

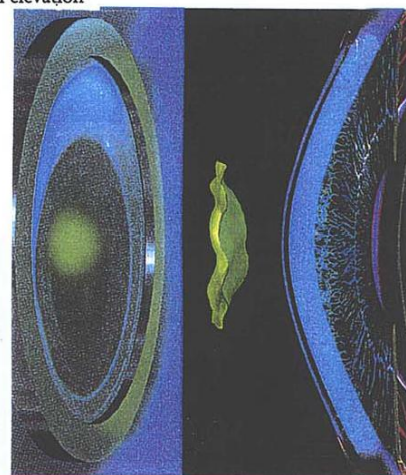
Using wavefront analysis as input data, refractive laser systems will conceivably be able to customize each corneal ablation pattern to remove even the smallest irregularity or aberration. According to the developers of this technology, 20/10 visual acuity will become the new target for surgical correction, rather than 20/20.

Table 2 — Astigmatism treatment method of various excimer lasers

| | |
|---------------------|---|
| Summit Technologies | Shape-transfer with an ablatable mask and Axicon lens |
| Visx (myopia) | Elliptical and spherical ablation with a moving slit |
| Visx (hyperopia) | An orbital lens mechanism - creating an offset seven-beam rotational scanning array |
| Nidek | Flying slit beam |
| Autonomous | Flying, small-spot ablation |
| LaserSight | Flying, small-spot ablation |
| Bausch & Lomb | Flying, small-spot ablation |

Autonomous Technologies (now part of Summit) is at the forefront of ablation-guiding systems based on wavefront images. This technology, called Custom Cornea, is used along with its LADARVision scanning spot laser and tracking system, and is intended to treat these corneal aberrations in the future. Marguerite B. McDonald, MD, professor of ophthalmology at the Refractive Surgery Center of the South, New Orleans, treated the first patients with this technology on Oct. 12; results are pending.

"Our first five patients did very well; we tweaked the algorithm a little and the next few patients have been better yet, often seeing 20/12," McDonald said.



Customized ablation based on wavefront maps

Other developers of wavefront based ablations include WaveLight Laser Technologies and their Allegretto excimer laser. Theo Seiler, MD, of Dresden, Germany, treated the first human patients with this laser in March 1999 and has one patient with a visual acuity of 20/8.

Wavefront-based ablations have a problem, Holladay said, in that irregular astigmatism may result from the cornea or the lens. "If a cataract is forming, then you are ablating based on ongoing change in the crystalline lens, not the cornea. Therefore, you're going to end up having to create new ablations about every 3 months as the cataract changes," Holladay recommends that in cases of congenital lenticular astigmatism where the wavefront refraction is stable for 2 to 3 years, accurate ablations can be performed. Alpíns cites additional problems with these ablations in the EW interview on page 46. ☛

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