

Correcting Corneal Astigmatism With Laser Incisions

Surgeons describe their approaches with the four platforms available in the United States.



BY ERIC D. DONNENFELD, MD

Astigmatic management is the step that most often keeps patients from achieving optimal visual quality after refractive cataract surgery. Residual astigmatism of 0.50 D and sometimes less may result in glare, symptomatic blur, ghosting, and halos. A recent study of 4,540 eyes of 2,415 patients showed that corneal astigmatism was present in the majority of patients undergoing cataract surgery, with at least 1.50 D measured in 22.2% of study eyes.¹ Approximately 38% of eyes undergoing cataract surgery have at least 1.00 D of preexisting corneal astigmatism, and 72% of patients have 0.50 D or more.² The use of manual limbal relaxing incisions (LRIs), although moderately effective, has been an art form with inherent variability in its predictability. LRIs require expertise and entail some risk, and they simply are not performed

by the great majority of ophthalmic surgeons. For these reasons, the need for a technology that improves the safety and effectiveness of corneal relaxing incisions is great.



Femtosecond lasers increase precision by creating reproducible incisions at the desired optical zone, depth, and length, all of which should make incisional treatment more of a science and less of an art.³ In a study of initial results with the LenSx Laser (Alcon), 8-mm arcuate incisions reduced astigmatism by 70%.⁴

When performing laser arcuate incisions, surgeons must first determine their length, their depth, the steep axis of corneal cylinder, and the distance from the visual axis. I employ a 33% reduction of the Donnenfeld nomogram (Figure 1) in conjunction with the LRI calculator

| Femtosecond Laser Nomogram | | |
|--|--|---|
| Donnenfeld Nomogram for Limbal Relaxing Incisions | Nomogram for 8 mm Arc Incisions | |
| 0.50 D | 1 Incision, 1 1/2 Clock Hours (45 Deg. Each) | 1 Incision, 1 Clock Hours (30 Deg. Each) |
| 0.75 D | 2 Incisions, 1 Clock Hour (30 Deg. Each) | 2 Incisions, 2/3 Clock Hour (20 Deg. Each) |
| 1.50 D | 2 Incisions, 2 Clock Hours (60 Deg. Each) | 2 Incisions, 1 1/3 Clock Hours (40 Deg. Each) |
| 3.00 D | 2 Incision, 3 Clock Hours (90 Deg. Each) | 2 Incision, 2 Clock Hours (60 Deg. Each) |
| *Use 5 degrees more for against-the-rule-astigmatism | | 85% Depth |
| *Use 5 degrees more for younger patients | | |
| *Use 5 degrees less for older patients | | |

Figure 1. Laser arcuate incision nomogram for the treatment of astigmatism at 9-mm (left column) and 8-mm (right column) optical zones.

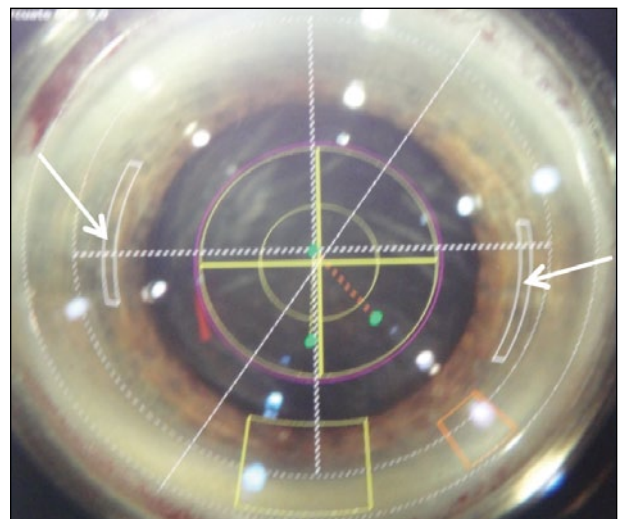


Figure 2. Overlay of the planned arcuate incisions.

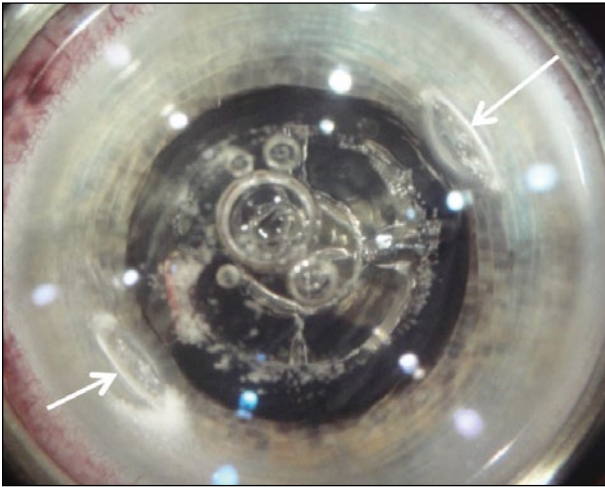


Figure 3. Arcuate incisions shortly after they have been performed.

(www.LRIcalculator.com) to determine the length and axis at which the incision should be placed. I use that particular reduction, because the LRI calculator was for LRIs and I perform the laser incisions at an 8-mm optical zone. The more central incisions of the laser have a greater effect. I preset the depth of my incisions to 85% of the corneal pachymetry in the area of the incision. This information is downloaded onto the laser.

Once the laser has been docked onto the cornea, an overlay of the incisions becomes visible on the surgical screen (Figure 2). A built-in safety measure prevents the intersection of the clear corneal and sideport incisions with the astigmatic incision. Optical coherence tomography imaging of the cornea in the area of the arcuate incision allows me to confirm the planned depth of the incisions. The laser system's software automatically determines the 85% depth of corneal pachymetry at the desired optical zone at the location of the incisions.

The capsulotomy is performed first, followed by lens disruption and then the corneal incisions (Figure 3). At the conclusion of the laser treatment, the patient is brought to the operating microscope, where I open the incisions with a Sinsky hook. A major advantage

of laser arcuate incisions is I can modify the refractive incisions under the operating microscope by employing intraoperative aberrometry and/or after surgery based on the postoperative refraction and keratometry readings. Laser arcuate incisions do not achieve their full refractive effect until they are opened. I have begun to modify the energy, spot size, and separation of the spots to titrate my results. With higher energy and a smaller spot size separation, the majority of the effect is achieved without opening the incisions. With lower energy settings and greater spot size separation, the incisions have a minimal effect until they are opened. Laser incisions are similar to a sheet of postage stamps bound together by serrations; until the serrations are manually torn apart, the stamps remain in a fixed location.

To further refine my results, I have been performing intraoperative aberrometry (ORA System; WaveTec Vision). I remove the cataract, place the IOL, and open one of the laser incisions. Next, I raise the IOP to approximately 25 mm Hg. I then perform intraoperative aberrometry. Based on this reading, I may leave the second laser incision unopened, partially open it, or open it completely. If need be, I will completely or partially open the second incision in the desired axis in the office to increase the effect and adjust the residual astigmatic refractive error. Using this technique, I have been able to improve outcomes and reduce the risk of flipping the astigmatic axis.

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JONATHAN SOLOMON, MD

Laser incisions should provide superior reproducibility and greater predictability than manual arcuate keratotomy. The clinical application of the Lensar Laser System (Lensar) has played a significant role in my refractive cataract offering during the past 16 months.

When correcting less than 1.00 D of against-the-rule astigmatism, I perform a paired-peripheral, nearly full-thickness arcuate incision that, in essence, does not violate the overlying epithelium when unmo-
lest (Figures 1 to 2). Limiting the



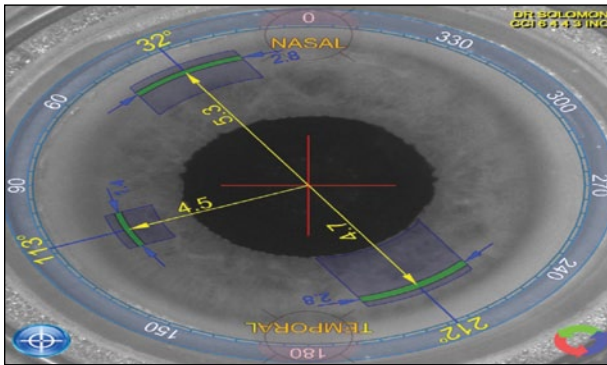


Figure 1. Graphical user interface showing on-axis intrastromal incisions.

dissection to the posterior 90% of the cornea, however, reduces the equivalent dioptric correction and requires an increase in the arc sweep.¹

For greater degrees of astigmatism, I like arcuate incisions for their “titratability.” I start with a modification of the Nichamin nomogram coupled with a residual bed depth of 75 μm (Table). Based on the results of recent studies highlighting the importance of true corneal power,² I determine the magnitude and axis of preoperative astigmatism with a combination of Scheimpflug tomography and Placido topography that is capable of consolidating the contributions of both the anterior and posterior corneal surfaces. The laser allows me to toggle between parameters, which either generates a dissection requiring virtually no manipulation or an incision fit for titration with a blunt instrument. At the surgical microscope with the help of intraoperative aberrometry or later at the slit lamp, I open the incision incrementally, which allows me to refine the effect.

The most compelling changes to my technique of late are as follows. First is the addition of incisions that are centered about the limbus, as opposed to the pupil. I believe that this change reduces variability. The second change is the inclusion of iris registration that transfers the preoperative topography to the Lensar laser-guidance system. Registration allows personalized treatment and provides the benefits of nomogram regression analysis plus the precision of laser alignment and the accuracy of axial orientation.

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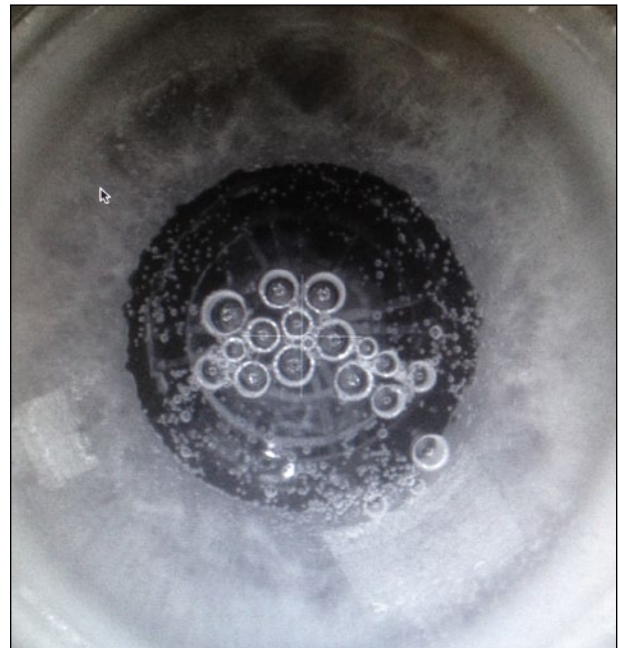


Figure 2. Graphical user interface with astigmatism surgical plan.

| TABLE. DR. SOLOMON'S LASER ARCULATE NOMOGRAM | |
|--|--|
| With-the-Rule Astigmatism, D | 4.5-mm Radius/75-μm Residual Bed/TCP2 |
| 0.75 to less than 1.25 | 35° |
| 1.25 to less than 1.75 | 50° |
| 1.75 to less than 2.25 | 65° |
| Against-the-rule astigmatism, D | 5-mm radius/75-μm residual bed/TCP2 |
| Less than 1.00 (IS) | 45° |
| 1.00 to less than 1.75 (p) | 60° |
| 1.75 to less than 2.25 | 75° |
| Abbreviations: TCP2, total corneal power (ray traced); IS, intrastromal opposite on-axis incision; p, paired incision. | |



JONATHAN H. TALAMO, MD

When deciding between arcuate incisions (AIs) and a toric IOL in normal eyes, I consider the magnitude and location of astigmatism. I also factor in my surgically induced astigmatism (SIA) as well as the contribution of the posterior cornea, which adds about 0.50 D of against-the-rule (ATR) astigmatism.¹ In my hands, SIA is typically 0.30 to 0.50 D. For patients with 1.25 D or less of with-the-rule (WTR) astigmatism or 0.75 D or less of ATR astigmatism, I generally choose to perform laser AIs. Above those thresholds, I prefer a toric IOL. In either case, I find it valuable to confirm the axis and amount of astigmatism with intraoperative aberrometry.

I began performing laser AIs with the Catalys Precision Laser System (Abbott Medical Optics) in 2013. I use the infrared Devon Utility Marker (Covidien) to mark the 6-o'clock position and, depending on the ocular anatomy, sometimes also the 3- and 9-o'clock positions. I typically center treatment on the limbus and make the incisions at a 9-mm optical zone at a depth of 80%. Qualitatively, the incisions are clean, uniform, and well made (Figure 1). I find them to be far more precise and reproducible than manual limbal relaxing incisions (LRIs). My freehand incisions are within 5° of the intended axis. Burkhard Dick, MD, has shown that AIs with the Catalys are within 0.22 ±0.20° of the intended axis, 0.83 ±0.66% of the intended optical zone diameter, and 0.22 ±0.29° of the intended arc length.²

Initially, I simply reduced the Donnenfeld nomogram I was already using for manual LRIs by 30% for anterior penetrating AIs, as others have suggested. I analyzed the results from my first 50 cases using the ASSORT Astigmatism Vector Analysis software. The mean preoperative corneal astigmatism was 1.10 ±0.60 D, which was reduced to 0.60 ±0.40 D of residual refractive astigmatism postoperatively, for a net change of 0.42 ±0.50 D with a correction index of 0.83 D versus what was intended. More than half of the eyes were within 0.50 D of the

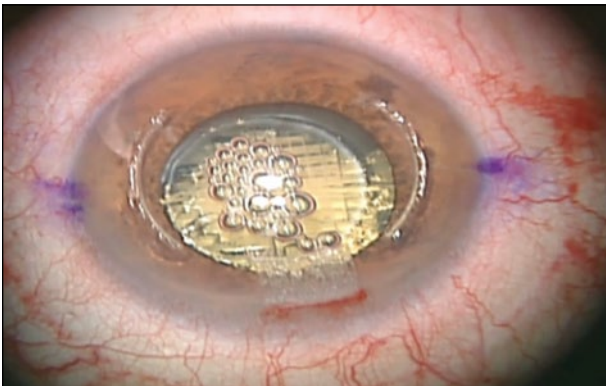


Figure 1. Anterior penetrating AIs.

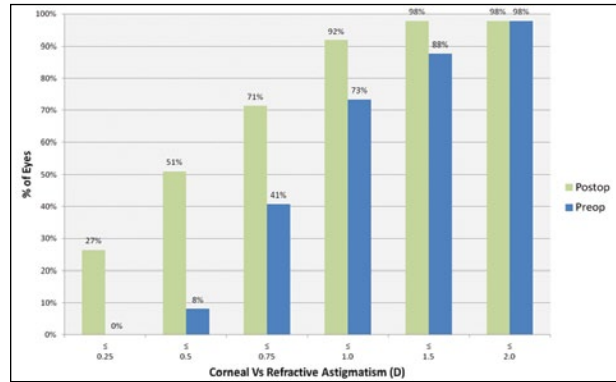


Figure 2. In an initial series of 50 eyes that underwent laser cataract surgery with AIs, 51% had 0.50 D of astigmatism or less postoperatively.

intended astigmatic correction (Figure 2), which compares quite favorably with the limited results published in the literature. In the largest series of manual LRIs with which I am familiar, Gills et al reported that fewer than 25% of eyes were within 0.50 D.³



Although my initial results were relatively good, they suggested that I was undercorrecting by about 17%. My subgroup vector analysis of ATR versus WTR astigmatic correction with laser AIs revealed that using 70% of the Donnenfeld nomogram produced 91% of the intended correction for WTR astigmatism but only 64% for ATR astigmatism. As a result, I now use 70% of the online nomogram for eyes that have WTR astigmatism (60°-120°) and 100% for eyes with ATR astigmatism (150°-180°, 0°-30°). For other axes, I recommend 85%.

When I create anterior penetrating AIs with the laser, intraoperative aberrometry with the ORA System (WaveTec Vision) helps me to decide whether or not to open the incisions fully. The intraoperative measurements allow for some titration of the correction in the event that there is less SIA or a greater effect from the incisions than expected.

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ROBERT J. WEINSTOCK, MD

During my fellowship year in 2001, under the guidance of my father, Stephen M. Weinstock, MD, I learned how to perform limbal relaxing incisions (LRIs). In 2007, I was introduced to a prototype of the intraoperative aberrometer, a tool I now find essential for creating corneal refractive incisions, whether by hand or with a femtosecond laser.

Within months of first using the laser, my outcomes analysis revealed a more consistent and predictable level of astigmatism reduction with these incisions than I could deliver manually with a diamond blade. The laser arcuate incision can be placed at a much more precise depth, optical zone, and axis. Even so, I still manually titrate LRIs with a diamond blade occasionally, as dictated by the ORA System (WaveTec Vision). In addition, I manually perform LRIs on patients who are not good candidates for laser treatment such as those with filtering blebs.

I currently use three femtosecond laser platforms: the Lensar Laser System (Lensar), the LenSx Laser (Alcon), and the Victus (Bausch + Lomb). All three make comparable arcuate incisions on the cornea, allowing me to treat up to 1.50 D of regular astigmatism consistently. I usually address higher amounts of astigmatism with a toric implant. What follows is a description of my current technique with the Victus.

I start by marking the primary horizontal meridian at the limbus, both nasally and temporally, with an ink pen and marking device while the patient is sitting up and fixating on a distant target. This process is completed in holding prior to the laser treatment. It

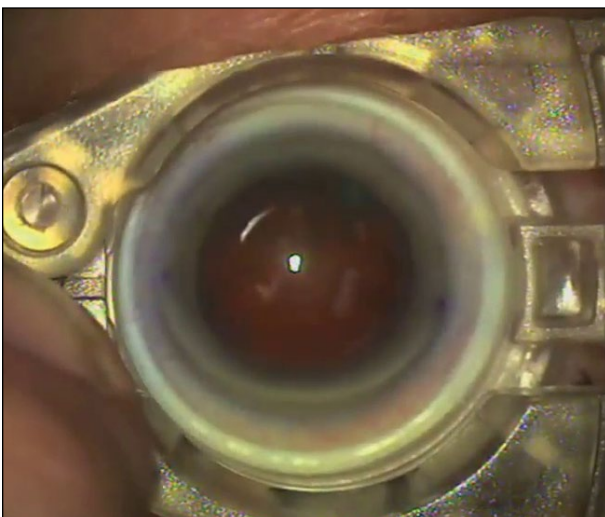


Figure 1. The Victus suction ring on the eye, as seen through the oculars of the built-in microscope.

helps me to account for cyclotorsion and permits registration once the patient is under the laser. The pupil is dilated, and the patient is given topical anesthesia and intravenous sedation just before being brought back to the laser room. With assistance, he or she transfers from the stretcher to the laser system's bed. Then, the patient is positioned with the bed tilted out from the laser such that the eye is in focus through the surgical microscope oculars of the Victus platform.

The assistant hands to me the suction ring, which I place on the eye, and vacuum is applied once I align the corneal limbal marks with the horizontal guides on the ring (Figure 1). I complete this step while looking through the oculars. No speculum is needed, and patients usually experience no discomfort. Seven or eight drops of balanced salt solution are placed in the well of the suction ring. The bed is then swung under the laser head, and I use the joystick to raise the bed up until the suction ring and the patient interface on the laser head meet and the air is displaced by the fluid. The coupling is easily visible on the Victus monitor. Once the pressure bar is in green, I lock the clip on the suction ring, which completes the docking phase.

Next, my assistant uses the mouse to run the laser software, as we analyze the live optical coherence tomography image on the screen and make micro-adjustments to the laser treatment plan. The first treatment under a "soft dock" executes the capsulotomy. Then, the clip is unlocked, the bed is raised slightly to press the patient interface more firmly against the cornea, and the clip on the suction ring is



<http://eyetube.net/?v=aroww>

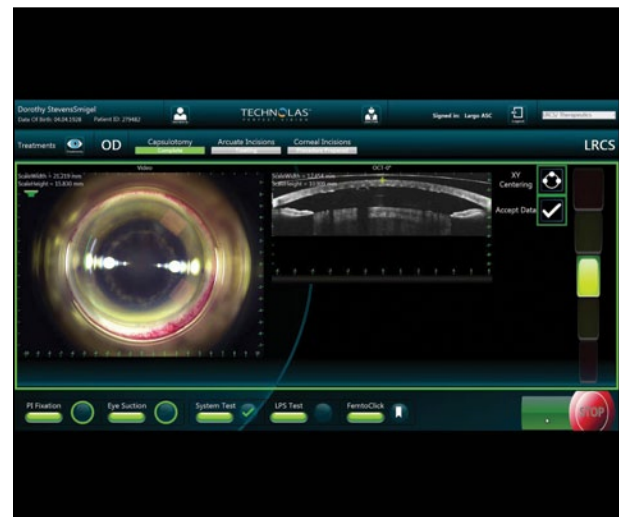


Figure 2. Screen graphical user interface view of the Victus as the laser creates an arcuate incision.

TABLE. WEINSTOCK-PANCHAL LASER LIMBAL RELAXING INCISION NOMOGRAM^{a-d}

| Astigmatism, D | Degree of Arcuate Incision | Number of Incisions ^{e,f} |
|----------------|----------------------------|------------------------------------|
| ≤ 0.30 | 15 | 1 |
| 0.50 D | 20 | 1 |
| 0.75 | 30 | 1 or 2 |
| 1.00 | 40 | 1 or 2 |
| 1.25 | 50 | 1 or 2 |
| 1.50 | 60 | 1 or 2 |
| 1.75 | 70 | 2 |
| 2.00 | 80 | 2 |

^a Optical zone: 10 mm and 90% depth, LenSx Laser (Alcon); 9.5 mm and 85% depth at pachymetry, Victus (Bausch + Lomb) and Lensar Laser System (Lensar).

^b Surgically induced astigmatism: 0.30 D.

^c With-the-rule astigmatism, add 0.50 to 0.60 D.

^d On-axis surgeons, subtract 0.30 to 0.50 D from amount of astigmatism to account for your own surgically induced astigmatism.

^e I prefer to perform two arcuate incisions rather than one when applicable unless the wounds' location interferes with placement.

^f This nomogram is for bimanual, temporal, clear corneal incisions.

locked again. A fresh, live, optical coherence tomography image appears, and the axis and/or optical zone of the corneal arcuate incisions can be altered if desired. The corneal wound(s) can also be adjusted if needed. The laser then quickly completes the arcuate treatment followed by the wounds (Figure 2). The entire process, from the suction ring's placement to the release of vacuum, takes 2 to 3 minutes. The patient is then transferred to the stretcher and wheeled to the OR next door.

When planning treatment with the Victus, I use the Weinstock-Panchal nomogram with 85% treatment depth of local pachymetry and a 4.75-mm radius from the pupillary center (Table). Once surgery is underway, I typically obtain aphakic readings for IOL power selection and astigmatism identification with the ORA. More often than not, I find that the aphakic cylinder reading is less than 0.50 D without my opening the arcuate incisions. If so, I finish the case without touching the laser arcuate incisions. If intraoperative

aberrometry shows greater than 0.50 D of cylinder, however, and it is near the same axis as the arcuate incision, I will use a Kuglen hook to open the incision. Often, I will obtain additional intraoperative aberrometry readings to confirm the effect, titrate the opening of paired incisions, and even add or extend an incision with a diamond blade. I sometimes titrate results with the eye in the pseudophakic state as well.

Since I began performing laser arcuate incisions, I have noticed less residual astigmatism, performed fewer enhancements, and observed less regression. My patients embrace laser astigmatic correction, and it has been an overwhelmingly positive experience for them and for my practice. ■

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