INTRODUCTION

When assessing recent changes in modern cataract and intraocular implant (IOL) surgery, arguably, the single most pressing challenge facing today’s phacoemulsification (phaco) surgeon is the need to achieve predictable and accurate refractive outcomes. Surgeons and patients alike have come to largely measure the success of their surgery by the refractive outcome, and one of the leading causes for litigation in this field is the “refractive surprise.” In addition, the refractive lens exchange has become an important component of the refractive surgeon’s armamentarium. As such, the fields of cataract and refractive surgery have merged to form an amalgam without distinct borders. Improved refractive results have come about by way of improvements in both surgical technique as well as advances in technology. Spherical results, for example, have become more predictable because of increased attention to biometry technique, as well as breakthrough technology such as partial coherence interferometry.

No less important is the astigmatic component of the refractive equation. At one time during the evolution of small incision surgery, it was the surgeon’s goal to not induce astigmatism. Today, in order to fully embrace the concept of “refractive cataract surgery,” one must be able to address and reduce significant preexisting cylinder.

PATIENT SELECTION AND CONSIDERATIONS

Estimates of the incidence of significant, naturally occurring astigmatism vary widely from 7.5% to 75%. It is thought that 3% to 15% of eyes may have 2 or more diopters (D) of
In light of recent experience gained in the field of refractive surgery, many surgeons would agree that astigmatism of greater than 0.5 D will lead to symptoms of ghosting and shadows. Although the older cataract patient may be more tolerant of cylinder, the ambitious refractive cataract surgeon should likely approach an implant patient with the same high goals that he or she might with a younger keratorefractive candidate. Indeed, successful cataract practices are now aiming for both spherical and astigmatic outcomes of $+/\pm 0.5$ D.  

When considering astigmatism correction, one must take into account the location of the cylinder, age of the patient, and status of the fellow eye. Since most patients will drift against-the-rule (ATR) over their lifetime—for example, toward plus cylinder at 180 degrees—many surgeons advocate a less aggressive approach to the reduction of with-the-rule (WTR) cylinder. Some authors have suggested that residual WTR astigmatism may favor better uncorrected distance acuity given that most visual stimuli are of a vertical nature.  

Similarly, it has been contended that ATR cylinder may improve uncorrected near vision. The tenet that residual (myopic) WTR astigmatism is a desirable goal in order to enlarge the conoid of Sturm and hence optimize depth perception has, however, recently been called into question. Currently, with recent refinements in surgical technique, a spherical goal may be most desirable for the majority of patients undergoing implant surgery.

**TREATMENT OPTIONS**

The first decision faced by the surgeon is whether to address preexisting astigmatism at the time of cataract and IOL surgery, or to defer and treat the cylinder separately. One could reasonably argue that for optimal accuracy, sufficient time for wound healing should be allotted and a stable refraction ought to be documented prior to astigmatic correction. This consideration had been more germane with the earlier use of rigid implants and larger incisions. Currently, most surgeons are utilizing foldable IOLs and studies have well documented the nearly neutral astigmatic effect that these incisions bear when kept at or near 3.0mm, as well as their early
As such, many surgeons feel that concomitant treatment of preexisting astigmatism is a more efficient approach and is favored since it will likely save the patient from having to undergo a second procedure.

The next major decision is whether to treat the astigmatism through a lenticular approach, that is, to employ a toric IOL, or to utilize a keratorefractive technique. From a theoretical perspective, it is hard to argue against the use of a toric implant and their effectiveness has been widely reported.\textsuperscript{14} This option has the potential to avoid induced irregular astigmatism from corneal manipulation, and provides the option of reversibility. In the United States the first toric IOL to have received FDA approval was the single-piece plate haptic design manufactured by Staar Surgical. The implant is available in two toric powers of 2.0 and 3.5 D. Propitious outcomes have been obtained with this device even with minimal experience by community-based surgeons.\textsuperscript{15} For surgeons using this particular toric implant, lens rotation is a recognized problem; Sun and coworkers reported a need to return to the operating room for repositioning in 9.2\% of cases.\textsuperscript{14} Ruhswurm further reported axis rotation of at least 25 degrees in 18.9\% in their series.\textsuperscript{16} According to Euclidean geometry, an axis deviation of 5, 10 or 15 degrees will result in 17\%, 33\% and 50\% reduction, respectively, in effect.\textsuperscript{5} Optimal timing of the IOL repositioning would appear to be between one and two weeks following implantation as capsular fibrosis is underway, and may serve to permanently fixate the toric device in the proper meridian. Some surgeons have avoided this particular implant because of its plate haptic design and for the first-generation silicone elastomer from which it is comprised. More recently, the FDA has approved the single-piece AcrySof toric IOL. This hydrophobic acrylic device is available in three toric powers of 1.5, 2.25 and 3.0 diopters which are capable of correcting 1.03, 1.55 and 2.06 diopters respectively at the corneal plane. These newer designs would appear to offer better rotational stability and will likely therefore see increased use.
The notion of reducing astigmatism by way of adjunctive keratorefractive surgery, specifically astigmatic keratotomy, dates back to the mid-1980’s.\textsuperscript{17,18,19} Throughout the 1990’s a number of authors recognized the advantages of moving corneal astigmatic relaxing incisions peripherally toward the limbus.\textsuperscript{20,21,22} These so called limbal relaxing incisions (LRIs) have become the most popular way to manage astigmatism at the time of cataract surgery and will be addressed in detail below.

Another viable option to decrease astigmatism is to manipulate the cataract incision by first placing it upon the steep corneal meridian, and then by varying its size and design, affect a desired amount of wound flattening, and hence a decrease in cylinder.\textsuperscript{23} Specifically, one can increase or decrease the amount of wound flattening by increasing or decreasing the size of the incision. Similarly, wound flattening may be enhanced by moving closer to the visual axis, or by creating a more circum-parallel incision to the limbus. Also, a perpendicular component, or groove, may be added to the incision to further increase wound flattening and “against-the-wound” astigmatic drift.\textsuperscript{24} This approach, however, presents logistical challenges including movement around the surgical table, often producing awkward hand positions. In addition, varying surgical instrumentation may be needed along with a dynamic mindset, and this approach is only effective for relatively small degrees of preexisting cylinder. For these reasons, this technique has largely been supplanted by the use of a consistent and essentially neutral phaco incision, typically located temporally for astigmatic stability, and then adding supplemental relaxing incisions (LRIs). A recent study by Kaufmann, et al. concluded that LRIs in combination with a temporal clear corneal incision provided superior astigmatic outcomes to that of “on-axis” surgery.\textsuperscript{25}

Several other options to reduce astigmatism deserve mention. Lever and Dahan have suggested the novel use of opposing clear corneal incisions to address preexisting cylinder.\textsuperscript{26} In this technique, a second opposite penetrating clear corneal incision is placed over the steep
meridian 180 degrees away from the main incision. This approach is technically simple and requires no additional instrumentation; however, a second substantial penetrating incision is now present, possibly increasing the risk of wound leak or even infection. In addition, single-plane beveled incisions are known not to be as effective, for a given arc length, at flattening the cornea as are more conventional perpendicular relaxing incisions.\textsuperscript{27,24} Yet another important and increasingly popular alternative is that of “Bioptics,” a technique originally described to address residual refractive error following implantation of myopic phakic IOL’s, but one that is just as useful in the setting of pseudophakic lens surgery.\textsuperscript{28,29,30} In this approach, one exploits the advanced technology and exquisite accuracy of the excimer laser. In a staged manner, one may treat both residual spherical as well as astigmatic error following implant surgery. In Zaldivar’s original description, a LASIK flap was created prior to the implant procedure, and then as necessary, the flap was lifted and residual refractive error was corrected with the laser. Today, most surgeons prefer to perform both the flap and laser ablation concurrently following cataract surgery, as needed, thus reducing the number of unnecessary flaps that would otherwise be created. It has been our experience that LASIK may be performed safely following IOL surgery at six weeks, perhaps earlier. Of course, wound stability and healing must be confirmed, along with a stable refractive error. It might be further argued that custom wavefront-guided ablation would be particularly well suited in the pseudophakic eye since the dynamic lens component no longer exists, though obtaining a reliable aberrometry reading may be difficult with some lens designs, i.e. refractive multifocal optics.\textsuperscript{31} For most refractive cataract surgeons, Bioptics has become an integral part of the preoperative discussion with the patient, and in our experience its use is required in approximately 10 percent of cases, depending upon the patient’s preop refractive error. Finally, conductive keratoplasty used in an off-label fashion has also recently been described as a means by which residual hyperopia and hyperopic astigmatism may be effectively reduced following cataract surgery.\textsuperscript{32}
LIMBAL RELAXING INCISIONS

The first description of the astigmatic effect of non-penetrating incisions placed near the limbus dates back to 1898 and is credited to the Dutch ophthalmologist L.J. Lans.\textsuperscript{33} As noted, LRIs have become the most popular technique employed today to reduce preexisting astigmatism at the time of implant surgery, though the use of toric implants is currently increasing.\textsuperscript{34} Although our preference is to utilize a temporal single-plane clear corneal phaco incision, one may utilize LRIs with any type of cataract incision as long as the astigmatic effect is known and factored into the surgical plan. LRIs offer several advantages over astigmatic incisions placed within the cornea, at smaller optical zones. These would include less chance of causing a shift in the resultant cylinder axis. This presumably is due to a diminished need for precise centration upon the steep meridian. More importantly, there is less of a tendency to cause irregular corneal flattening, and hence less chance of inducing irregular astigmatism. Technically, LRIs are easier to perform and more forgiving than shorter and more central corneal astigmatic incisions, and patients generally report less discomfort. Another important advantage gained by moving out to the limbus involves the “coupling ratio” which describes the amount of flattening that occurs in the incised meridian relative to the amount of steepening that results 90 degrees away. It has been our experience that paired LRIs (when kept at or under 90 degrees of arc length) exhibit a very consistent 1:1 ratio, and therefore elicit little change in spheroequivalent, obviating the need to make any change in implant power.

Admittedly, these more peripheral incisions are less powerful, but are still capable of correcting up to 3-4 diopters of astigmatism in the cataract-age population. One must keep in mind that the goal is to reduce the patient’s cylinder, without overcorrecting or shifting the resultant axis. To achieve a given amount of correction, these peripheral intralimbal incisions must be longer in total arc length than more centrally placed corneal astigmatic incisions; however, unlike longer radial keratotomy incisions, they appear to be stable with regard to
refractive effect, and show little sign of inducing problems such as dry eye syndrome or other pejorative effects from corneal denervation. Their stability may be due in part to the proximity of well-vascularized limbal tissue, as well as the differing histologic tissue pattern that exists at this intralimbal location as compared to the central cornea. There are, of course, potential complications with any surgical technique and these are addressed below.

**The Plan:**

Perhaps the most challenging aspect of astigmatism surgery involves the determination of the quantity and exact location of the cylinder that is to be corrected, and thereby formulating a surgical plan. Traditionally, most authors have recommended correcting astigmatism based upon keratometry measurements only, assuming any other refractive components would be lenticular in nature and eliminated by cataract extraction. I have found, however, that it is helpful to study as many preoperative parameters as is possible. Unfortunately, such preoperative measurements—keratometry, refraction, corneal topography and newer modalities such as the Pentacam—do not always correlate. Lenticular astigmatism may indeed account for some of this disparity, particularly in cases where there is a wide variance between refraction and corneal measurements; however, some discrepancies are likely due to the inherent shortcomings of traditional measurements of astigmatism. Standard keratometry, for example, measures only two points in each meridian at a single optical zone of approximately 3 mm.

When confounding measurements do arise, one may compromise and average the disparate readings; for example, if refraction shows 2 D of astigmatism and keratometry reveals only 1 D, it would be reasonable to correct for 1.5 D, especially if the cataract were not too dense and the refraction was reasonably reliable, or if it were based upon a historical refraction obtained prior to cataract formation. Alternatively, if pre-operative calculations vary widely, one may defer placing the relaxing incisions until a stable refraction post-implantation is obtained, and then correct, as needed, any remaining astigmatism; LRIs may be safely performed in the
office in an appropriate treatment-room setting. Corneal topography can be very helpful when refraction and keratometry do not agree, and it is increasingly becoming the overall guiding measurement upon which the surgical plan is based. Topography is also helpful in detecting subtle corneal pathology such as keratoconus fruste which would likely negate the use of LRIs, or subtle irregular astigmatism such as that caused by epithelial basement membrane dystrophy.

**Nomograms:**

Once the amount of astigmatism to be corrected has been determined, a nomogram must be consulted to determine the appropriate arc length of the incisions. A number of popular nomograms are currently available.\(^{35}\) Our nomogram of choice originated from the work of Dr. Stephen Hollis and incorporates concepts taught by Spencer Thornton, M.D., particularly his age modifiers.\(^{24}\) As seen in the nomogram, a patient is considered to be “spherical” if they have up to 0.75 D of with-the-rule or 0.50 D of against-the-rule astigmatism, in which case a single-plane temporal clear corneal incision is used without additional wound manipulation (Table I). If the patient has more than this amount of cylinder, one determines whether it is WTR (45 -135 degrees) or ATR (0 - 40 or 140 -180 degrees) and then consults the appropriate section of the nomogram. One aligns the patient’s age with the amount of preoperative cylinder to be corrected and finds the suggested arc length that the incisions should subtend.

Paired incisions are preferred to optimize symmetric corneal flattening and are expressed in degrees of arc rather than chord length. This is done in order to diminish over and under corrections for unusually small or large corneas, since corneal diameter may significantly impact the relative length of the arcuate incision and its resultant effect (Fig. 1). This nomogram, which has been designed specifically for the cataract patient, is based upon the use of an empiric blade depth setting of 600 microns. Individual surgeon technique and blade style may impact results, and thereby require adjustment of the nomogram. It is by design conservative in nature with the intent of substantially decreasing a patient’s astigmatism, but also avoiding overcorrection. This
has been borne out by clinical study.\textsuperscript{22,36} A second, slightly more aggressive nomogram (NAPA) is now being used more frequently, particularly in the setting of refractive lens exchange surgery and when presbyopia-correcting IOLs are used, as well as in conjunction with LASIK for the correction of higher levels of astigmatism (Table II). In this setting where optimal precision is mandated, pachymetry is performed over the entire arc length of the intended incision site, and a diamond blade with an adjustable micrometer is set to 90\% of the thinnest reading obtained. The NAPA nomogram, pachymetry, and adjusted blade depth settings may certainly be used with the “routine” cataract patient, but some surgeons feel that the small compromise that is made in using an empiric blade depth setting is acceptable in this older patient population in light of increased OR efficiency.

Once again, refinements to the blade depth setting and nomogram adjustments are often necessary depending upon individual surgeon technique, the instruments used and, in particular, the style of the blade. As a final note, in eyes that have previously undergone radial keratotomy, the length of the incisions should be reduced by approximately 50\%, and in eyes that have undergone “significant” prior keratotomy surgery, it may be best to avoid additional incisional surgery and employ a toric IOL or laser technology instead.

\textbf{Surgical Technique:}

Some surgeons prefer to perform LRIs at the conclusion of surgery in the event that a complication occurs necessitating a modification to the phaco incision. For routine cases, however, our preference is to place these relaxing incisions at the outset of surgery in order to minimize epithelial disruption. The one exception to this rule occurs in the case of high ATR astigmatism wherein the nomogram calls for a temporal arcuate incision of greater than 40 degrees of arc. Since the temporal arc will be superimposed upon the phaco incision, if it is extended to its full arc length at the start of surgery, significant gaping and edema may result secondary to intraoperative wound manipulation. In this setting, the temporal incision is first
made by creating a two-plane grooved phaco incision (at 600 microns or to a depth as
determined by pachymetry). Following IOL implantation and prior to viscoelastic removal,
while the globe is still firm, the relaxing incision is extended to its full arc length as dictated by
the nomogram. When an LRI is superimposed upon the phaco tunnel, the keratome entry is first
accomplished by pressing the bottom surface of the keratome blade downward upon the outer or
posterior edge of the LRI. The keratome is then advanced into the LRI at an iris-parallel plane.
This angulation will promote a dissection that takes place at mid-stromal depth which will help
assure adequate tunnel length and a self-sealing closure.

Proper centration of the incisions over the steep corneal meridian is of utmost
importance. Increasing evidence supports the notion that significant cyclotorsion may occur
when assuming a supine position.\textsuperscript{37} As previously noted, an axis deviation of only 15 degrees
may result in a 50\% reduction of surgical effect.\textsuperscript{5} This reduction in effect holds true for both
relaxing incisions and toric IOLs. For this reason, most surgeons advocate placing an orientation
mark at the 12:00 or 6:00 limbus while the patient is in an upright position. This is particularly
important when employing injection anesthesia wherein unpredictable ocular rotation may occur.
I personally prefer placing multiple radial marks using a dedicated marking instrument to assure
proper orientation. An additional measure that may be employed to help center the relaxing
incisions is to identify the steep meridian (plus cylinder axis) intraoperatively using some form
of keratoscopy. The steep meridian over which the incisions are to be placed corresponds to the
shorter axis of the reflected corneal mire. A simple hand-held device such as the Maloney
(Storz, Katena) or Nichamin (Mastel Precision) keratoscope works well, or a more robust and
well-defined mire may be obtained through an elaborate microscope-mounted instrument such as
the Mastel Ring of Light (Mastel Precision). One then utilizes a Mendez Ring or similar degree
gauge which is aligned with the previously placed limbal orientation mark, and the desired
meridian over which the incisions are to be centered is determined and marked.
The LRI should be placed at the most peripheral extent of clear corneal tissue, just inside of the true surgical limbus. This holds true irrespective of the presence of pannus or blood vessels. If bleeding occurs, it may be ignored and will cease spontaneously. One must avoid placing the incisions further out at the true surgical limbus in that a significant reduction of effect will likely occur due to both increased tissue thickness and a variation in tissue composition; these incisions are, therefore, really *intra*-limbal in nature. In creating the incision, it is important to hold the knife perpendicular to the corneal surface in order to achieve consistent depth and effect. Good hand and wrist support is important, and the blade ought to be held as if one were throwing a dart such that the instrument may be rotated between thumb and index finger as it is being advanced, thus leading to smooth arcuate incisions. Typically, the right hand is used to create incisions on the right side of the globe, and the left hand for incisions on the left side. In most cases it is more efficient to pull the blade toward oneself, as opposed to pushing it away. A lightly moistened corneal surface will help to prevent epithelial disruption, but may mask an unintentional perforation.

The extent of arc to be incised may be demarcated in several different ways. One simple method makes use of a modified Fine-Thornton fixation ring (The Nichamin Fixation Ring and Gauge, available from Mastel Precision, Storz, Rhein Medical). This instrument serves to fixate and position the globe in order to optimize incision placement, as well as to delineate the extent of arc to be incised. One visually extrapolates from the limbus to marks on the surface of the ring. Each incremental mark is 10 degrees apart, and bold hash marks (180 degrees) opposite to each other serve to align and center the incision over the steep meridian. This approach obviates the need to ink and physically mark the cornea. If one desires, particularly when first gaining experience with LRIs, a two-cut R.K. marker may be used to place ink marks upon the cornea to show the exact extent of arc that is to be incised, in conjunction with the fixation ring/gauge (Fig 2). Alternatively, various press-on markers are available, such as those made by Rhein Medical
(Dell-Nichamin Marker, Nichamin-Kershner Marker or the Ruminson Marker). ASICO and other instrument companies offer a full line of dedicated markers, rings and blades for performing LRI’s.

As noted, in the setting of concomitant cataract surgery, an empiric blade depth setting of 600 microns has been traditionally employed. More recently, adjusted blade depth settings based upon pachymetry are favored for optimal precision. Various knives have been designed specifically for this application, ranging from disposable steel blades to exquisite gemstone diamond knives. Synthetic diamond materials are also available and vary in quality from nearly perfect single crystal materials that rival natural occurring gemstones, but are often yellow in color, to less expensive polycrystal fused materials that are typically less durable and whose edges are laser cut which may yield less precise cutting characteristics. Some of these less expensive designs are intended for limited reuse. Our preference is for high quality diamond blade technology which incorporates a single small and arced footplate for enhanced visualization at the limbus. Two models are available, one with a pre-set depth of 600 microns, and the other with an adjustable micrometer handle (Mastel Precision) (Figures 3A & 3B). Similar designs are available from Rhein Medical, Storz, ASICO and other manufacturers (Fig. 4).

Another less common method of creating peripheral relaxing incisions is to use a device such as the Terry/Schanzlin Astigmatome (Oasis Medical) which circumvents the need to make a “free-hand” incision. This trephine-like device has been designed to create consistent and symmetric peripheral arcuate corneal relaxing incisions. It utilizes a vacuum speculum that mates with various reusable templates that are selected based upon the amount of astigmatic correction that is desired. The incision is created by simply rotating a disposable steel blade unit that fits inside of the template.

**Complications:**
As discussed, LRIs are proving to be a safer and more forgiving approach to managing astigmatism as compared to more central corneal incisions. Nonetheless, as with any surgical technique, potential complications exist, and several are listed in Table III. Of these, the most likely to be encountered is the placement of incisions upon the wrong axis. When this occurs, it typically takes the form of a 90 degree error with positioning upon the opposite, flat meridian. This, of course, results in an increase and likely doubling of the patient’s preexisting cylinder. Compulsive attention is required in this regard. The surgeon ought to consider employing safety checks to prevent this frustrating complication from occurring such as having a written plan that is brought into the OR and is kept visible and properly oriented. Incisions are always placed upon the plus (+) cylinder axis, and opposite to the minus (-) cylinder axis.

Although very rare when utilizing a blade depth setting of 600 microns, corneal perforation is possible. This may be due to improper setting of the blade depth, or as a result of a defect in the micrometer mechanism. This latter problem may arise after repeated autoclaving and many sterilization runs. Periodic inspection and calibration is therefore warranted, even with preset single depth knives. When encountered, unlike radial microperforations, these circumferential perforations will rarely self-seal and will likely require placement of temporary sutures.

Enhancement Techniques:

As mentioned, LRIs lend themselves well to in office “touch-ups.” Although some surgeons will place or extend incisions at the slit-lamp, it is our preference to use a small operating microscope and to perform the procedure within a dedicated treatment room. It has been our experience that this provides far better surgical control as well as patient comfort. In the case of residual astigmatism without prior incisional correction, one uses the same technique and nomogram as described above.
In the case of an under-correction following previous LRIs, one should inspect the length and positioning of the incisions. As indicated, placement of the incisions too far out into the true surgical limbus and beyond clear cornea will often lead to under-correction. If the arc length and location appear to be adequate, one ought to suspect that the patient has an unusually thick cornea. This occurs most frequently in hyperopic eyes. In this situation, pachymetry should be performed and the incisions may be re-deepened or extended. When faced with an overcorrection, one should resist the temptation to place additional incisions in the opposite meridian. This can lead to an unstable cornea with unpredictable refractive results, or worse, induce irregular astigmatism. Rather, one should consider non-incisional modalities such as PRK or LASIK. We also have had good results in this setting using conductive keratoplasty, off-label, particularly if the over correction involves hyperopic astigmatism.\(^{31}\)

To correct unusually high levels of astigmatism, LRIs may be used in conjunction with a toric IOL or excimer laser surgery (bioptics). In several rare cases we have combined all three modalities and safely corrected up to 9 D of preexisting astigmatism!

**Cases Studies**

**Case 1.** A 68-year-old male presented for right cataract surgery. His refraction was \(-1.00 +2.25 \times 80\), and was recorded as reliable, consistent with his modest cataract density. Keratometry readings were \(44.75 \times 75\) and \(43.00 \times 75\). Corneal topography confirmed slightly more than 2.00 D of regular and slightly oblique cylinder. Consulting the standard cataract nomogram, a plan was devised for a pair of LRIs to be centered over the 75 degree axis, with each incision delineating 45 degrees of arc. A single-plane phaco incision was used and maintained at a size of under 3.2mm.

**Case 2.** This is a 79-year-old woman who presented with a very dense left cataract. Her refraction was recorded at \(-2.25 +2.75 \times 125\) with a difficult end point. Her manual keratometry and topography measurements were consistent and revealed slightly less than 1.75 D at 120
degrees. Because of the questionable refraction, greater value was placed on the corneal measurements. Based upon the standard cataract nomogram, the plan was for paired LRIs of 40 degrees to be placed over the steep 120 degree axis.

**Case 3.** A 48-year-old bilateral hyperope presented for a refractive surgical consultation. The refraction in his left eye was found to be +3.25 +1.75 x 85. Keratometry was somewhat flat but confirmed WTR cylinder as did corneal topography. Based upon the patient’s age, refraction and somewhat shallow anterior chambers, the decision was made to proceed with a refractive lens exchange. The NAPA nomogram called for LRIs of 55-60 degrees with intraoperative pachymetry. Intraoperative keratoscopy confirmed the steep 85 degree meridian.

**REFERENCES**


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34. Toric IOLs represent 5% of the market. Market Scope; 2009:Q2.


Intralimbal Relaxing Incision Nomogram for Modern Phaco Surgery
Empiric blade-depth setting of 600 microns
Louis D. “Skip” Nichamin, M.D. ~ Laurel Eye Clinic, Brookville, PA

**SPHERICAL**
(up to +0.75 X 90 or +0.50 X 180)
"Neutral" temporal clear corneal incision (ie., 3.5 mm. or less, single plane, just anterior to vascular arcade)

**AGAINST-THE-RULE**
(Steep Axis 0-44°/136-180°)

**WITH-THE-RULE**
(Steep Axis 45°-135°)

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**Incision Design** The temporal incision, if greater than 40° of arc, is made by first creating a two-plane, grooved phaco incision (600 µ depth), which is then extended to the appropriate arc length at the conclusion of surgery.

"Neutral" temporal clear corneal incision along with the following peripheral arcuate incisions.

When placing intralimbal relaxing incisions following or concomitant with radial relaxing incisions, total arc length is decreased by 50%
Table II

The “NAPA” Nomogram
Nichamin Age & Pachymetry-Adjusted
Intralimbal Arcuate Astigmatic Nomogram
Louis D. “Skip” Nichamin, M.D. ~ The Laurel Eye Clinic, Brookville, PA

WITH-THE-RULE
(Steep Axis 45°-135°)

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<td>50</td>
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<tr>
<td>2.50</td>
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<tr>
<td>3.00</td>
<td>90</td>
<td>90</td>
<td>85</td>
<td>80</td>
<td>70</td>
<td>65</td>
</tr>
</tbody>
</table>

AGAINST-THE-RULE
(Steep Axis 0-44°/136-180°)

<table>
<thead>
<tr>
<th>PREOP CYLINDER (Diopters)</th>
<th>20-30 yo</th>
<th>31-40 yo</th>
<th>41-50 yo</th>
<th>51-60 yo</th>
<th>61-70 yo</th>
<th>71-80 yo</th>
</tr>
</thead>
<tbody>
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</table>

Blade depth setting is at 90% of the thinnest pachymetry
### Table III

<table>
<thead>
<tr>
<th>Potential Problems</th>
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</thead>
<tbody>
<tr>
<td>Infection</td>
</tr>
<tr>
<td>Weakening of the globe</td>
</tr>
<tr>
<td>Perforation</td>
</tr>
<tr>
<td>Decreased corneal sensation</td>
</tr>
<tr>
<td>Induced irregular astigmatism</td>
</tr>
<tr>
<td>Misalignment/axis shift</td>
</tr>
<tr>
<td>Wound gape and discomfort</td>
</tr>
<tr>
<td>Operating upon the wrong (opposite) axis!</td>
</tr>
</tbody>
</table>
Figure 1

**Nomogram Design: Degrees of Arc Vs. Millimeters**

- For 10 mm:
  \[2r \pi = 31.4\text{mm}\]
  \[90^\circ \text{ of arc} = 7.85\text{mm}\]

- For 13 mm:
  \[2r \pi = 40.84\text{mm}\]
  \[90^\circ \text{ of arc} = 10.21\text{mm}\]

Figure 2

Image of various tools, possibly dental or medical instruments.
Figure 4