



DVD

Chapter 170

Incisional Keratotomy

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Introduction

First conceptualized by Lans,¹ incisional keratotomy is widely used for treating astigmatism, although it is now only infrequently used for treating myopia. The current methods of refractive keratotomy derive from the work of Fyodorov in Russia in the mid-twentieth century.

Radial incisions cause the peripheral cornea to bulge outward, producing central flattening. Astigmatic keratotomy (AK) and peripheral corneal relaxing incisions (PCRIs) cause flattening of the cornea in the incisional meridian and steepening 90 degrees away. Somewhat arbitrarily, 'AK' generally refers to incisions made in an 8-mm or smaller zone, whereas 'PCRI' is used if the zone is 9 mm or greater.

The Prospective Evaluation of Radial Keratotomy (PERK) study was the first scientific investigation of incisional keratotomy.² In this study, 435 eyes were treated with a standardized testing procedure, surgical technique, and instrumentation. With a remarkable 10 years of follow-up after the surgery, major findings of the PERK study included the effect of age on treatment, the approach to titrating and enhancing the outcome, and the long-term complications, the most prevalent of which is progressive hyperopic shift.³

A number of surgeons in the early 1980s, among them Fenzl, Lindstrom, Martin, Neumann, Nordan, Tate, Terry, and Thornton, began investigating surgical techniques to correct naturally occurring astigmatism. In 1983, Osher began a study that addressed the correction of pre-existing astigmatism by combining transverse relaxing incisions with cataract surgery. He presented preliminary results at general meetings as early as 1984.

Osher's original technique consisted of placing paired straight corneal relaxing incisions centered on the steep meridian at a 7–10.5-mm diameter optical zone at the end of surgery.⁴ Other surgeons have tried to amplify the effect by varying incision length, number of incisions, optical zone size, and incision depth. Merlin introduced arcuate incisions, and Thornton and Lindstrom became leading advocates while refining diamond blade technology.

Lindstrom⁵ found that the coupling ratio, the amount of flattening in the incised meridian divided by the amount of steepening in the opposite meridian, was approximately 1:1 when a straight 3-mm keratotomy or a 45–90-degree arcuate

keratotomy was used at the 5–7-mm diameter optical zones. The maximal effect of either straight or arcuate incisions occurred when incisions were placed around a 5–7-mm-diameter optical zone. Although most of the effect was achieved with the first pair of incisions, a 20–30% additional effect could be attained with a second pair of incisions. The effect could not be increased by placing more than four relaxing incisions in the cornea.

Thornton⁶ described what he believed was the geometric advantage of arcuate incisions, which is the most common method now performed. He stated that true 1:1 coupling can occur only when the corneal circumference is unchanged, which is achieved only with short, concentric arcuate incisions. A straight transverse incision increases the overall corneal circumference, creating a flatter cornea and necessitating a compensatory addition of power to the intraocular lens (IOL). Furthermore, a shorter arcuate incision achieves the same result as a longer straight incision. As mentioned previously, the term AK had been often used when describing treatments planned within an 8-mm or small zone. While this is a somewhat arbitrary distinction, PCRIs will be discussed as a separate topic since they are often planned as a treatment in a 9-mm or greater zone.

While radial keratotomy has been replaced by laser refractive surgery for the treatment of myopia, it is still occasionally used to treat small amounts of myopia. Astigmatic keratotomy and peripheral relaxing incisions, on the other hand, remain mainstream methods of treating astigmatism, either in virgin eyes or eyes that have undergone prior surgery. They are an intrinsic component of refractive cataract surgery as surgeons strive to provide optimal uncorrected vision to patients with pre-existing astigmatism.

Incisional Keratotomy in Cataract Surgery

Patient selection

People with 0.75 diopter (D) or more of astigmatism usually require some kind of optical correction. Astigmatic errors of 1–2 D may reduce uncorrected visual acuity to the 20/30 or 20/50 level, whereas an astigmatic error of 2–3 D may produce uncorrected visual acuity between 20/70 to 20/100.⁷

Up to 95% of eyes have some degree of measurable, naturally occurring astigmatism. The incidence of clinically significant astigmatism reported in the literature varies between 7.5% and 75%.⁷ From 3% to 15% of eyes may have astigmatic refractive errors greater than 2 D.⁸ The incidence of postcataract surgery astigmatism greater than 2 D may be as high as 25–30%.^{9,10}

In a patient with little or no pre-existing astigmatism, cataract surgery should be designed to be as astigmatically neutral as possible. For patients with significant degrees of pre-existing astigmatism, two approaches can be employed as a function of the type of cataract incision. The surgeon can either (1) operate on the steep corneal meridian and select the type of incision that will give the desired amount of against-the-wound flattening, or (2) make a small incision, either clear cornea or scleral tunnel, take into account how much astigmatic change it would cause, and supplement it with a corneal relaxing incision or a toric IOL. Incisional keratotomy can also be used postoperatively to further modify the result.

Careful patient selection is crucial in avoiding postoperative surprises and unhappy patients. An accurate history and a preoperative evaluation that include careful examination of the patient's ocular surface and tear break-up time will help identify patients with dry eye disorders such as Sjögren's, which might exclude them from safely having PCRI. Anecdotal evidence has suggested that PCRI in patients with pre-existing moderate to severe dry eye could exacerbate dryness and discomfort, presumably due to decreased corneal sensation from cutting corneal nerves. Careful topographic screening is recommended to rule out any progressive ectatic corneal dystrophy, such as keratoconus or pellucid marginal degeneration.

As a rule of thumb, some form of astigmatic surgery can be considered when a standard cataract operation will result in 0.75 D or more of postoperative astigmatism and the patient desires reduced spectacle dependence. One must also consider the status of the fellow eye and might elect not to reduce the astigmatism in the surgical eye if the fellow eye has a large amount of astigmatism at a similar meridian and no surgery is planned for this eye. The rationale, surgical methods, and risks should be discussed with the patient preoperatively. These issues are discussed in greater detail later in this chapter.

Surgeons vary in their preferred location for astigmatic incisions in cataract patients. Some prefer astigmatic keratotomy, typically at an 8-mm zone, whereas others primarily use PCRI at 9 mm or more peripherally. Numerous nomograms exist depending on the technique and incisional zone. For treating postkeratoplasty astigmatism, astigmatic keratotomy inside or in the graft–host junction is generally preferred, since more peripheral incisions are generally ineffective in reducing the large amounts of astigmatism that are often encountered in these eyes.

Planning

Each surgeon must take into account the amount of induced astigmatism from his or her technique and alter the surgical plan accordingly. When creating the surgical plan, some authors would argue that mild residual with-the-rule

Table 170.1 Nomogram for peripheral corneal relaxing incisions to correcting keratometric astigmatism during cataract surgery

Pre-op astigmatism (D)	Age (years)	Number	Length (degree)	
WTR*	0.75–1.00	<65	2	45
		≥65	1	45
	1.01–1.50	<65	2	60
		≥65	2	45 (or 1 × 60)
			2	80
		≥65	2	60
ATR/oblique*	1.00–1.25	–	1	35
		–	1	45
	1.26–2.00	–	1	45
		–	2	45

* Combined with temporal 2.2-mm clear-corneal incision.

astigmatism is desirable (at least when using monofocal implants), since most patients will drift towards against-the-rule over their lifetime, and this residual with-the-rule astigmatism may increase depth of focus by enlarging the conoid of Sturm.¹¹ Therefore, the surgeon may prefer to be more conservative for the correction of with-the-rule (WTR) versus against-the-rule (ATR) cylinder. However, in a prospective study investigating optical features that allow pseudophakic pseudoaccommodation, Porter and Cohen found that, in a 17-patient subgroup that had preoperative against-the-rule astigmatism, 4 of 6 patients who retained some against-the-rule astigmatism postoperatively displayed the greatest amount of pseudophakic pseudoaccommodation.¹² This would suggest that further study may be needed to elucidate which type of astigmatism may be more beneficial postoperatively.

The length and number of PCRI or astigmatic keratotomies are determined according to nomograms based on factors such as age and preoperative corneal astigmatism. The PCRI nomogram in Table 170.1 is designed for the use in combination with 2.2–2.7-mm temporal clear cornea incisions and placement of the PCRI at the end of surgery. It is conservative in order to minimize the risk of overcorrections. Another PCRI nomogram, courtesy of Dr. Louis Nichamin, is shown in Table 170.2. PCRI can cause a mild hyperopic shift of approximately 0.2 D,¹³ and this should be considered when selecting the IOL power. It is critical to note that the location of the incisions, whether performed in the horizontal or vertical meridian, must be taken into account, since it has been noted that PCRI made in the horizontal meridian have a much greater effect. A popular nomogram for astigmatic keratotomy at the 7-mm zone is shown in Table 170.3.

When adopting a nomogram for one's personal use, it is advisable to closely follow the surgical technique that was used to generate the nomogram. One can later modify this based on one's own surgical outcomes. As with any corneal incision, accurate topography to determine the steep meridian and careful placement of the incisions are necessary to achieve a desirable outcome.

Table 170.2 Nichamin nomogram for peripheral corneal relaxing incisions

Intralimbal relaxing Incision

Nomogram for modern phaco surgery

Empiric blade-depth setting of 600 microns (μm)

Louis D. 'Skip' Nichamin, M.D. – Laurel Eye Clinic, Brookville, PA

Spherical(up to $+0.75 \times 90$ or $+0.50 \times 180$)**Incision design** 'Neutral' temporal clear corneal incision (i.e. 3.5 mm. or less, single plane, just anterior to vascular arcade)**Against-the-rule**(Steep axis $0-44^\circ/136-180^\circ$)**Paired incisions in degrees of arc***

Pre-op cylinder	30–40 yr old	41–50 yr old	51–60 yr old	61–70 yr old	71–80 yr old	81–90 yr old	91+ yr old
Nasal limbal arc only*						35°	
+0.75 to +1.25	55°	50°	45°	40°	35°		
+1.50 to +2.00	70°	65°	60°	55°	45°	40°	35°
+2.25 to +2.75	90°	80°	70°	60°	50°	45°	40°
+3.00 to +3.75	90°	90°	85°	70°	60°	50°	45°
	o.z. = 8 mm	o.z. = 9 mm					

Incision designThe temporal incision, if greater than 40° of arc, is made by first creating a two-plane, grooved phaco incision (600 μm depth), which is then extended to the appropriate arc length at the conclusion of surgery.**With-the-rule**(Steep axis $45-135^\circ$)**Paired incisions in degrees of arc**

Pre-op cylinder	30–40 yr old	41–50 yr old	51–60 yr old	61–70 yr old	71–80 yr old	81–90 yr old	91+ yr old
+1.00 to +1.50	50°	45°	40°	35°	30°		
+1.75 to +2.25	60°	55°	50°	45°	40°	35°	30°
+2.50 to +3.00	70°	65°	60°	55°	50°	45°	40°
+3.25 to +3.75	80°	75°	70°	65°	60°	55°	45°

Incision design

'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%.

Post-Penetrating Keratoplasty Astigmatism

After keratoplasty, incisions can be placed just central to or in the graft–host junction. One must be cautious to avoid zones of less than 6 mm, as these may greatly increase the risk of inducing irregular astigmatism. Incision lengths can range from 45 to 90 degrees in length and can be planned in at least three ways: (1) follow a nomogram such as the Lindstrom nomogram in Table 170.2; (2) perform intra-operative with keratometry or other measurements and

gradually lengthen incisions until there is a slight overcorrection,¹⁴ or (3) use a fixed length and location; for all corneas, recognizing that corneas with greater amounts of astigmatism may experience a correspondingly greater response to a given type of incision.¹⁵ Since the result can be unpredictable due to the scarring at the graft–host junction, a conservative approach is advisable to avoid wound gape and overcorrection. Some advise centering the incisions on the visual axis, regardless of the graft centration.¹⁶ Topography is helpful in deciding incision placement and

Table 170.3 Arc-T 7-mm nomogram

2 × 30°							2 × 45°						
Age	1 × 30°	1 × 45°	1 × 60°	1 × 90°	2 × 60°	1 × 90°	Age	1 × 30°	1 × 45°	1 × 60°	1 × 90°	2 × 60°	1 × 90°
20	0.40	0.80	1.20	1.60	2.40	3.20	48	0.68	1.36	2.04	2.72	4.08	5.44
21	0.41	0.82	1.23	1.64	2.46	3.28	49	0.69	1.38	2.07	2.76	4.14	5.52
22	0.42	0.84	1.26	1.68	2.52	3.36	50	0.70	1.40	2.10	2.80	4.20	5.60
23	0.43	0.86	1.29	1.72	2.58	3.44	51	0.71	1.42	2.13	2.84	4.26	5.68
24	0.44	0.88	1.32	1.76	2.64	3.52	52	0.72	1.44	2.16	2.88	4.32	5.76
25	0.45	0.90	1.35	1.80	2.70	3.60	53	0.73	1.46	2.19	2.92	4.38	5.84
26	0.46	0.92	1.38	1.84	2.76	3.68	54	0.74	1.48	2.22	2.96	4.44	5.92
27	0.47	0.94	1.41	1.88	2.82	3.76	55	0.75	1.50	2.25	3.00	4.50	6.00
28	0.48	0.96	1.44	1.92	2.88	3.84	56	0.76	1.52	2.28	3.04	4.56	6.08
29	0.49	0.98	1.47	1.96	2.94	3.92	57	0.77	1.54	2.31	3.08	4.62	6.16
30	0.50	1.00	1.50	2.00	3.00	4.00	58	0.78	1.56	2.34	3.12	4.68	6.24
31	0.51	1.02	1.53	2.04	3.06	4.08	59	0.79	1.58	2.37	3.16	4.74	6.32
32	0.52	1.04	1.56	2.08	3.12	4.16	60	0.80	1.60	2.40	3.20	4.80	6.40
33	0.53	1.06	1.59	2.12	3.18	4.24	61	0.81	1.62	2.43	3.24	4.86	6.48
34	0.54	1.08	1.62	2.16	3.24	4.32	62	0.82	1.64	2.46	3.28	4.92	6.56
35	0.55	1.10	1.65	2.20	3.30	4.40	63	0.83	1.66	2.49	3.32	4.98	6.64
36	0.56	1.12	1.68	2.24	3.36	4.48	64	0.84	1.68	2.52	3.36	5.04	6.72
37	0.57	1.14	1.71	2.28	3.42	4.56	65	0.85	1.70	2.55	3.40	5.10	6.80
38	0.58	1.16	1.74	2.32	3.48	4.64	66	0.86	1.72	2.58	3.44	5.16	6.88
39	0.59	1.18	1.77	2.36	3.54	4.72	67	0.87	1.74	2.61	3.48	5.22	6.96
40	0.60	1.20	1.80	2.40	3.60	4.80	68	0.88	1.76	2.64	3.52	5.28	7.04
41	0.61	1.22	1.83	2.44	3.66	4.88	69	0.89	1.78	2.67	3.56	5.34	7.12
42	0.62	1.24	1.86	2.48	3.72	4.96	70	0.90	1.80	2.70	3.60	5.40	7.20
43	0.63	1.26	1.89	2.52	3.78	5.04	71	0.91	1.82	2.73	3.64	5.46	7.28
44	0.64	1.28	1.92	2.56	3.84	5.12	72	0.92	1.84	2.76	3.68	5.52	7.36
45	0.65	1.30	1.95	2.60	3.90	5.20	73	0.93	1.86	2.79	3.72	5.58	7.44
46	0.66	1.32	1.98	2.64	3.96	5.28	74	0.94	1.88	2.82	3.76	5.64	7.52
47	0.67	1.34	2.01	2.68	4.02	5.36	75	0.95	1.90	2.85	3.80	5.70	7.60

Find patient age, then move right to find result closest to refractive cylinder without going over.

length, particularly if the astigmatism is asymmetric. Compression sutures may also be used 90 degrees away from the steep meridian to augment the effect of an incision.

After PRK or LASIK

Astigmatic keratotomy or peripheral corneal relaxing incisions can also be used as an adjunct to treat residual astigmatism after PRK or LASIK (Fig. 170.1). Kapadia et al.¹⁷ studied the effectiveness of paired, arcuate transverse keratotomy before and after spherical PRK treatments. Astigmatic keratotomy was performed prior to PRK in 37 eyes with 1.50 D of astigmatism. The decrease in the astigmatism was significant, decreasing from $+2.40 \pm 0.6$ D preoperatively to 0.60 ± 0.60 D postoperatively. A second group of 86 eyes underwent AK after PRK. This group showed a significant decrease in astigmatism, $+1.50 \pm 0.60$ D to $+0.40 \pm 0.40$ D, 6 months postoperatively. Wang et al.¹⁸ reported that in a group of 33 PRK and LASIK patients treated with PCRIs, the percentage of eyes with an uncorrected visual acuity of 20/20 improved from 6% to 60%. This improvement remained stable up to 1 year. Coupling may be less predictable at higher amounts of astigmatism. When combining refractive surgery and relaxing incisions, the stability of one procedure should be ensured before performing the second procedure.

Alignment

Accurate astigmatic surgery is highly sensitive to precise meridional alignment. Vector analysis demonstrates that a misalignment of only 15 degrees results in a 50% reduction in astigmatic correction, while a 30-degree misalignment results in no change in magnitude and induces a large shift in the astigmatic axis.¹⁹ Errors greater than 30 degrees result in a net increase in the magnitude of the astigmatism.

Computerized corneal topography is helpful in identifying both the meridian and amount of astigmatism. Numerous technologies are available for this purpose, and different devices will often give different measurements. It is often helpful to compare readings from different machines to find the most consistent meridional reading. If the amount of astigmatism on the maps is slightly asymmetrical, the lengths of the paired incisions can be varied.

Perhaps the greatest value of topographic devices is to rule out ectatic disorders such as keratoconus or pellucid marginal degeneration, which are relative contraindications for relaxing incisions. We have achieved good results with small PCRIs in selected eyes of patients with forme fruste keratoconus, but systematic study is required, and the effect of incisions in corneas with frank keratoconus is unknown. If there is considerable disagreement among measurements with different technologies or at different visits before cataract surgery, it may be advisable to wait and do any relaxing incisions postoperatively.

Various approaches can be taken to minimize alignment errors. When possible, we make small drawings of the patient's eyes preoperatively, ensuring that they are vertically oriented at the slit lamp. We look for prominent conjunctival, corneal, or iris features that can be used as

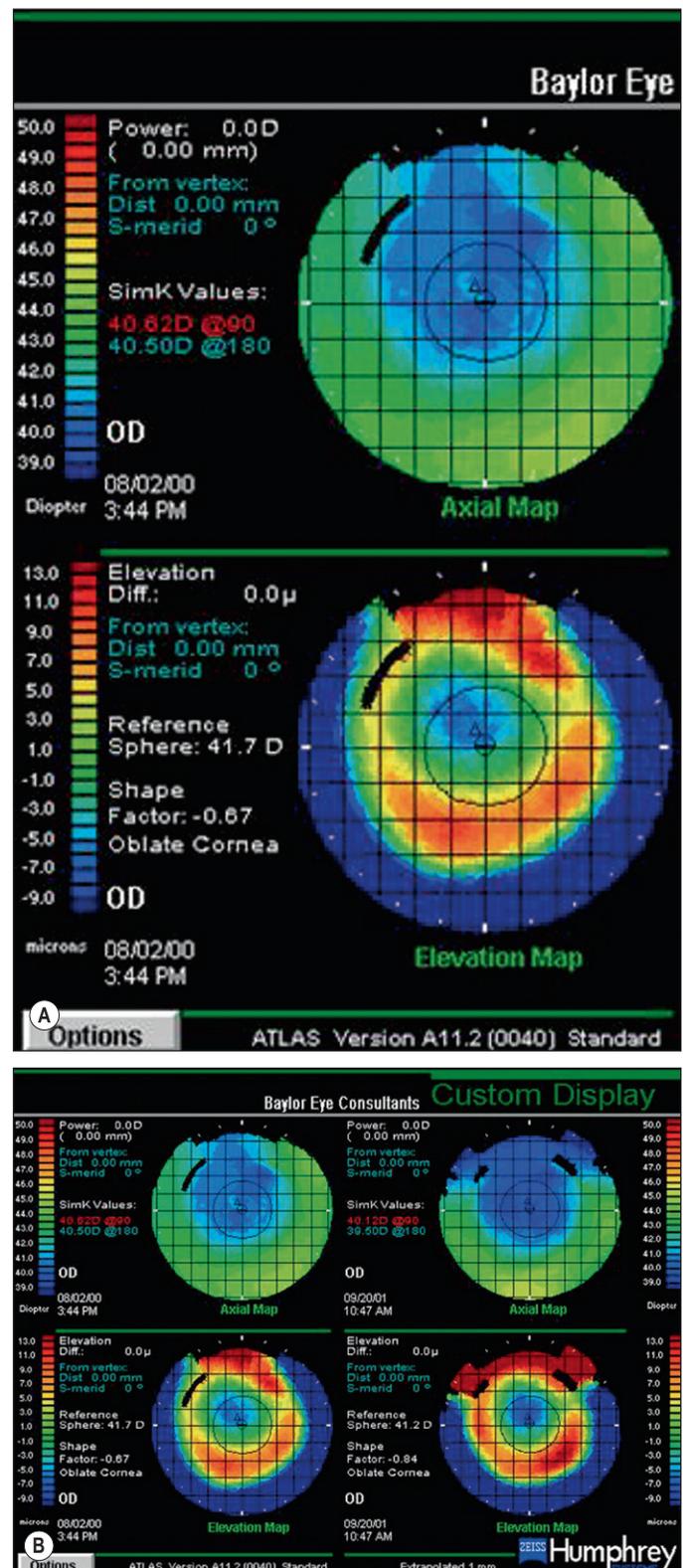


Fig. 170.1 (A) Axial topographic map of a post-LASIK patient with uncorrected visual acuity of 20/20 and refraction of $-0.25 + 0.75 \times 135$; patient complained of halos and difficulty driving at night. (B) A single 50-degree PCRI was made at 135 degrees inferonasally and acuity improved to 20/16 and patient's complaints resolved.

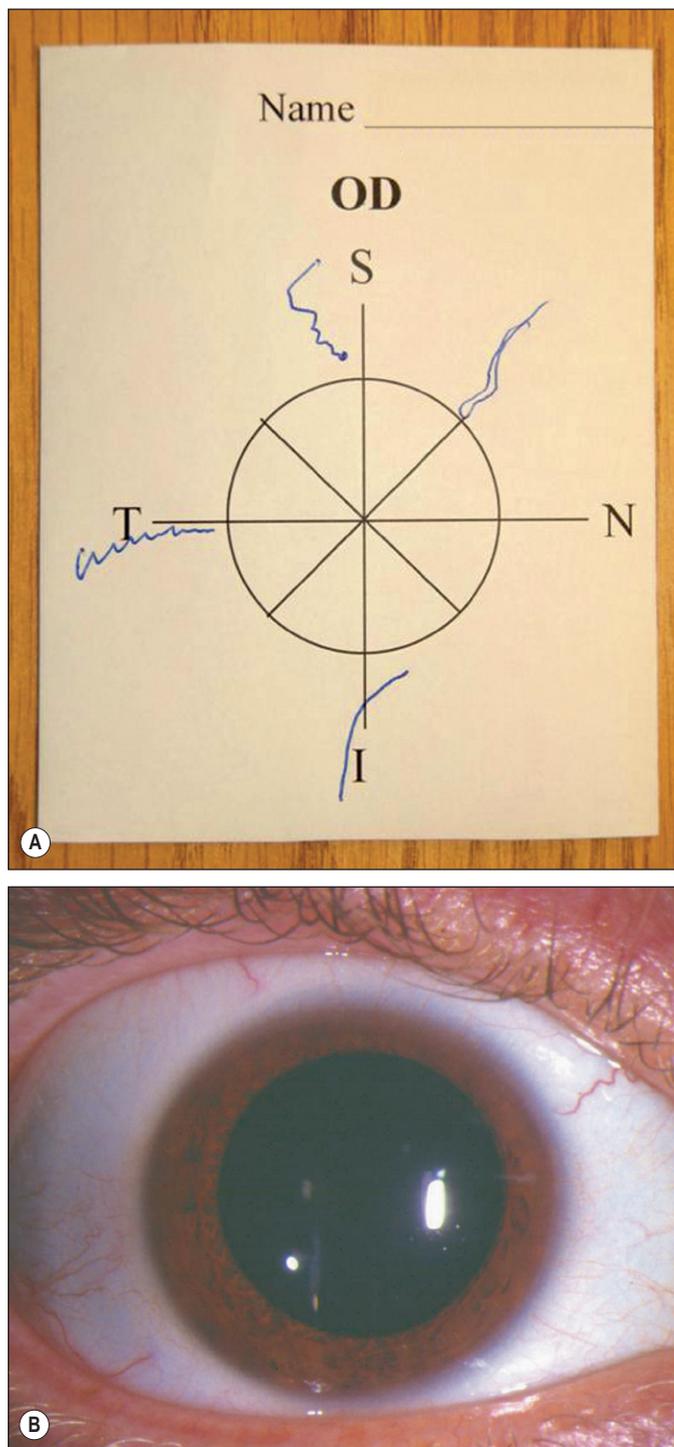


Fig. 170.2 (A and B) Example of preoperative drawing made at slit lamp to help orientation intraoperatively.

landmarks in the operating room even when the patient is dilated. Landmarks at the 90- or 180-degree meridians are especially helpful (Fig. 170.2). It may not be advisable to mark the patient when he or she is already on the operating room table, since a small percentage of patients' eyes rotate when supine. Swami et al.²⁰ demonstrated that 8% of eyes (20/240) had a deviation of greater than 10 degrees when moving from an upright to a supine position.



Fig. 170.3 Marking of the 6 and 12 o'clock positions preoperatively to help with intraoperative orientation. (Courtesy of Stephen C. Pflugfelder, MD.)

Alternatively, the eye can be marked in the preoperative area. After topical anesthetic drops are administered, the patient is asked to sit upright and look straight ahead. A gentian violet marking pen can be used to mark the 6 and 9 o'clock or 6 and 12 o'clock positions while looking straight ahead (Fig. 170.3).

Another option is to perform intraoperative keratoscopy or keratometry to identify the major meridian and the amount of astigmatism. The surgeon must make sure that these measurements correlate with the preoperative keratometric and corneal topographic readings.

Instrumentation

Equipment needed for corneal relaxing incisions includes an operating microscope, an instrument to mark the incisional meridian (e.g. Sinsky hook), a fixation forceps or a fixation ring, a degree marker, various zone and incision markers, a sterile marking pen or ink pad, and, depending on one's technique and the surgical indication, an ultrasonic pachymeter for intraoperative measurements. Numerous markers are available, including the Lindstrom arcuate marker (Katena Products, Denville, NJ), the Koch PCRI marker (ASICO, Inc., Chicago, IL [Fig. 170.4]), and the Mastel arcuate marker (Mastel Precision Inc., Rapid City, SD [Fig. 170.5]). Some marking devices are also designed to serve as a physical guide for the diamond knife.

A large number of blade types and designs are available. Blade materials include reusable true and synthetic diamonds and other gemstones, and single-use steel blades. For more central corneal incisions, an adjustable micrometer knife is desirable. For routine PCRI, we use either a triangular or thin trapezoidal blade with a single footplate, which allows good visibility while making the incision (Fig. 170.6). With this type of blade set at 600 microns (μm) depth for incisions made at the 9-mm zone, we have found consistent results and no perforations. We have experienced microperforations using 600 microns (μm) trapezoidal blades with a broad base, since one can get greater depth than expected if



Fig. 170.4 Marker used to delineate 45-, 60-, and 80-degree incision lengths (Courtesy Accutome Inc.).

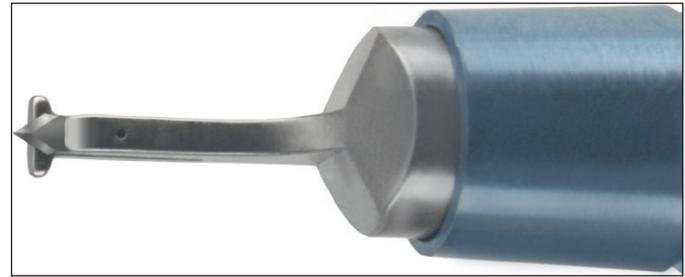


Fig. 170.6 Diamond blade with single footplate (Accutome, Inc., Malvern, PA).

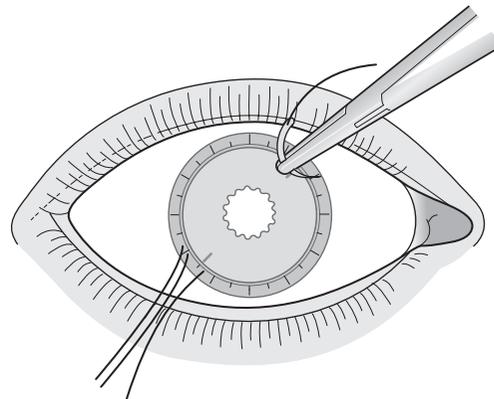


Fig. 170.7 Marking of steep meridian intraoperatively using a Sinskey hook.

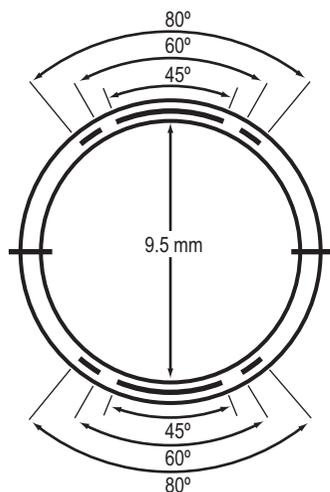


Fig. 170.5 Mastel marking system including ring with degree marks, gauged diamond blade with single footplate, and instrument to mark incision meridian.

the knife is rocked or tilted along the blade axis. Extreme care should be taken in knife selection, calibration, and maintenance to ensure reproducible cuts.

Surgical Techniques

After aligning the degree marker to the preoperative marks made at the limbus, the steep corneal meridian can be marked with a marker or hook stained with ink (Fig. 170.7). The extent of the incision can be guided by the marker, ink marks made with an instrument such as a Sinskey hook, or by marks on the ring that is used to stabilize the globe and guide the blade. With corneal fixation forceps to grasp tissue at the limbus or a ring with degree marks held in one hand, the knife in the other hand is set into the cornea, pausing for 1 second. The knife is then guided slowly through the desired incision length. Successful treatment of astigmatism can still be achieved even with a slightly irregular incision (Fig. 170.8).

If arcuate keratotomy is being performed in an 8-mm or smaller zone, many surgeons perform intraoperative pachymetry at the incision site and set the diamond blade to the desired depth, typically 90% of the thinnest measurement. Multiple nomograms exist, depending on what treatment zone is preferred by the surgeon.

Generally, the eye is prescribed antibiotic drops for 5 days. If the incision is performed in conjunction with cataract

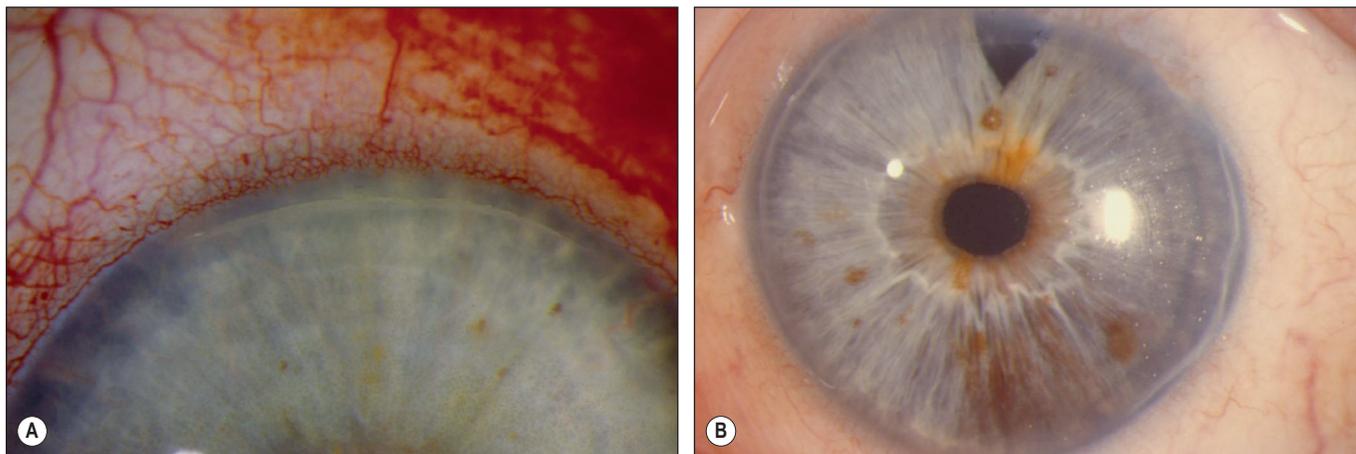


Fig. 170.8 (A) Peripheral corneal relaxing incision placed just inside limbus. (B) Irregular-appearing corneal relaxing incision with 20/20 acuity and no patient complaints.

surgery, the normal postoperative drop regimen is appropriate. Patching and cycloplegia are not routinely used. For corneal graft patients, we recommend also prescribing a topical corticosteroid to reduce the risk of inducing graft rejection.

Results

Werblin and Krider²¹ evaluated the results of a multicenter study of 159 eyes which underwent arcuate keratotomy following the Casebeer nomogram. In order to evaluate the results of the arcuate incisions, radial keratotomy was delayed for at least 1 month. The mean preoperative refractive cylinder was 2.8 D. At 1 month postoperatively, 43% of the eyes had a residual refractive cylinder within 0.5 D of plano, 71% were within 1 D, and only 6% were overcorrected by more than 1 D.

A study in eyes undergoing phacoemulsification evaluated the efficacy of paired intraoperative arcuate keratotomy incisions combined with a 3.5-mm clear corneal incision on the steep meridian.²² The arcuate incisions were performed in the steep meridian at the 7.0-mm optical zone with a double-edged diamond blade set at 100% of the thinnest paracentral pachymetric reading based on a Lindstrom nomogram. In 17 eyes, the mean preoperative keratometric astigmatism was reduced from 2.28 D to 1.02 D at 8 weeks. A control group of 17 eyes with preoperative keratometric astigmatism of 2.04 D underwent phacoemulsification with only the 3.5-mm clear corneal incision on the steep meridian, and had a reduction in keratometric astigmatism to 1.55 D. This difference in mean astigmatic correction of 1.26 D in the arcuate eyes compared to a correction of only 0.48 D in the eyes with only the clear corneal incision on the steep meridian was statistically significant.

In a study by Osher,⁴ the optical zone was varied according to his nomogram, and all eyes except one with amblyopia enjoyed a best-corrected visual acuity comparable to that of a control population that had not received AK. However, the uncorrected vision was excellent with acuity of 20/40 or

better achieved in 76%. These patients would have been unlikely to achieve this visual result had their cylinder not been reduced by AK. Comparison of preoperative and postoperative keratometry measurement showed that the IOL selected would have been unchanged in 87% of eyes. Although 13% showed a power change between 0.5 and 1 D, it was reassuring to find that the surgical change in the cornea influenced the IOL power less than 1 D in all cases.

Wang, Misra, and Koch reported results of a large series of 93 eyes that underwent combined clear corneal phacoemulsification and PCRI.¹³ PCRI significantly decreased pre-existing astigmatism. At 4 months postoperatively, the percentage of the eyes with keratometric astigmatism of ≤ 1 D increased to 51% from 6% preoperatively. Overcorrection of 1 D or more occurred in two eyes of two patients; both were over 80 years old. One of the two eyes had a corneal diameter of 10.5 mm, which might have contributed to the overcorrection because of both the shorter distance between the PCRI and the center of the cornea and the longer arc length relative to the corneal circumference. For this reason, measuring PCRI length by degrees instead of millimeters was recommended. There were no ocular perforations in the series, suggesting a good safety profile for using a guarded diamond knife set at a depth of 600 microns (μm) when PCRI are performed at the conclusion of cataract surgery.

The safety of making corneal incisions closer to the visual axis has been well studied. The ARC-T Study Group found that arcuate keratotomy for treating naturally occurring astigmatism was safe even though overcorrections or undercorrections were frequent.²³ Complications were uncommon but did include irregular astigmatism that resulted in 31 of the 160 eyes in the study losing either 1 or 2 lines of spectacle-corrected acuity (2 eyes and 29 eyes, respectively).

A study by Poole and Ficker¹⁵ showed that in 50 patients who underwent paired arcuate keratotomies after keratoplasty, 60% improved by one line of best corrected Snellen acuity. They also noted that 10 patients who were previously unsuitable for LASIK due to their large amount of astigmatism were brought down into a range that would allow them

to have laser refractive surgery; for some others, the reduction in astigmatism enabled them to wear contact lenses more easily. Finally, in the above noted study by Wilkins et al.,¹⁴ postkeratoplasty eyes were treated with standardized, paired arcuate keratotomies at a 6-mm zone that were 60 degrees in length and 600 microns (μm) in depth. The mean cylinder was reduced from -10.99 ± 4.26 diopters to -3.33 ± 2.18 . The authors noted that there was a strong correlation between the magnitude of preoperative cylinder and the magnitude of astigmatic change. This decrease in astigmatism was of a greater magnitude than noted in other studies, most likely due to the smaller optical zone used.

Complications

Possible complications of corneal relaxing incisions include over- or undercorrection, infection, abrasions, perforations, or irregular astigmatism. While the nomograms listed here have been used with good reliability, each surgeon may need to develop his or her own nomogram to achieve optimal results, depending on changes in technique and equipment used. Meticulous attention to the proper alignment and amount of astigmatism to be corrected is obviously essential to achieving the best possible result.

Use of postoperative antibiotics to prevent possible infection is standard procedure. Proper follow-up will allow recognition of any late-onset infections. If a large abrasion occurs during the making of incisions, a bandage contact lens can be placed overnight for patient comfort.

One of the most concerning postoperative complications is perforation. In our experience to date, no perforations have occurred when using the technique described above. In addition to careful screening to exclude patients with peripheral corneal thinning, proper calibration of instruments and periodic inspection are important to avoid any problems that may increase the risk of perforation. Due to the vertical shape of the incisions, microperforations are rarely self-sealing and usually require suturing, although in

rare instances they can be treated with a contact lens or pressure patch.

Longer incisions may be prone to wound gape, particularly long incisions in the horizontal meridian. Incisions may also gape if the cornea is subjected to additional stress, as we saw in a patient with Fuchs' dystrophy who developed wound gape following penetrating keratoplasty (Fig. 170.9).

More recently, some anecdotal evidence has suggested that longer PCRIs made in the horizontal meridian could also contribute to the development of central corneal epitheliopathy due to decreased sensation (Fig. 170.10). The use of punctal plugs and close postoperative follow-up could help to detect this before it causes damage to the corneal surface. Careful optimization of the tear film preoperatively, and extra counseling of the patient, may be required for those who require longer PCRIs in the horizontal meridian.

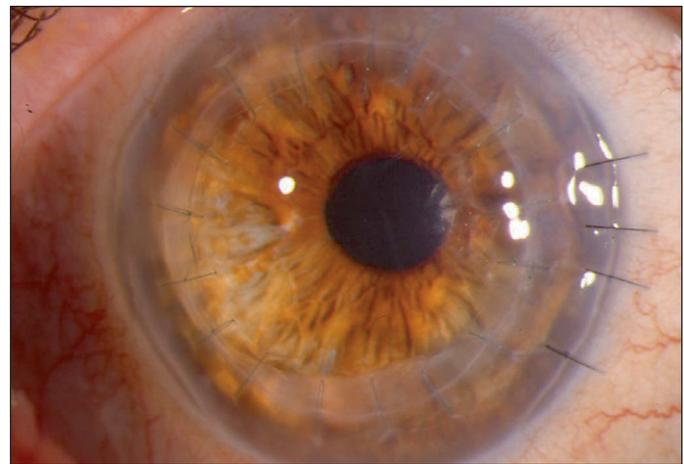


Fig. 170.9. Peripheral corneal relaxing that required suturing due to wound gape induced by penetrating keratoplasty for Fuchs' dystrophy.

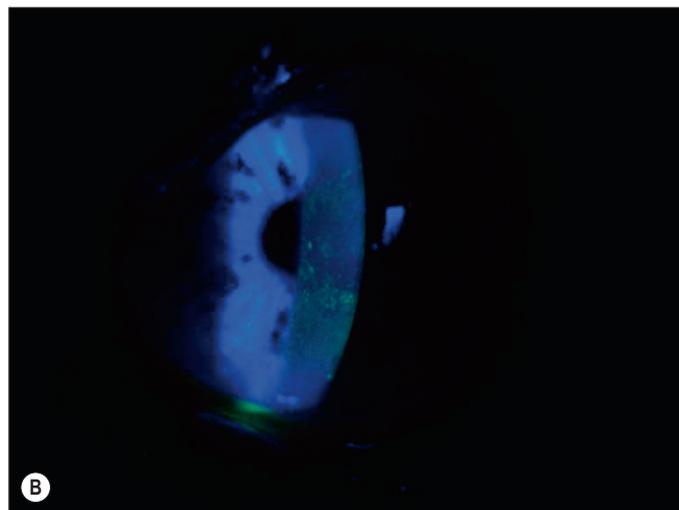
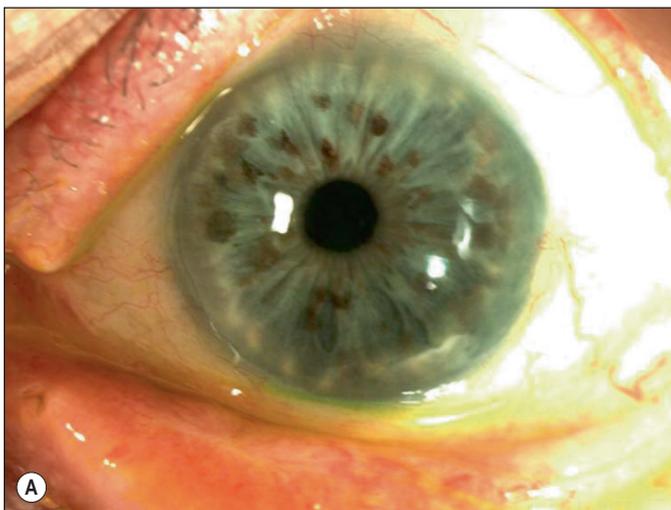


Fig. 170.10 (A) Large horizontal peripheral corneal relaxing incisions. (Courtesy of Stephen C. Pflugfelder, MD.) (B) Epitheliopathy noted after relaxing incisions seen in A. (Courtesy of Stephen C. Pflugfelder, MD.)

Summary

While laser refractive surgery has replaced incisional keratotomy as the main method of treating myopia, incisional keratotomy remains a safe and highly effective method of reducing astigmatism in cataract, post LASIK/PRK, and in corneal graft patients. Meticulous planning and technique are necessary to ensure optimal patient outcomes. As patient expectations increase, excellent uncorrected visual acuity will become the primary goal of any surgery. With experience, each surgeon will be able to develop his or her own nomograms that will be tailored not only to the surgeon's equipment and technique but also to the visual demands of the patient.

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