

Single and dual limbal relaxing incisions in correcting corneal astigmatism during cataract surgery



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ABSTRACT

Introduction: Correcting astigmatism during cataract surgery to achieve optimal visual outcomes is important. Various techniques, such as limbal relaxing incisions (LRIs), are used to correct astigmatism. LRIs are effective for mild to moderate astigmatism but have limitations in correcting larger astigmatism. This study aimed to review the effectiveness of single and dual LRI in correcting astigmatism during cataract surgery.

Methods: This literature review utilized databases from 2010 until 2022. The keywords “corneal astigmatism”, “limbal relaxing incision”, and “cataract surgery” were used to collect 12 journals that had relevant topics.

Results: LRIs are a form of partial-thickness keratotomy used to correct astigmatism during cataract surgery. The incisions for LRIs are made in the peripheral cornea, following a nomogram based on the patient’s astigmatism, age, and the location of the steep axis of astigmatism. LRIs can be performed as single or dual incisions, with dual LRIs offering greater astigmatism correction. In the case of irregular astigmatism, LRIs can be adjusted to the topography of the cornea because the lengths of coupled incisions can vary.

Conclusion: The effectiveness between single and dual LRIs was the same, but paired LRIs have a superior effect in correcting greater astigmatism. LRIs remain a valuable tool for cataract surgeons to manage astigmatism and improve visual outcomes in cataract surgery patients.

Keywords: cataract surgery, corneal astigmatism, limbal relaxing incisions.

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INTRODUCTION

A cataract is any condition of lens opacity resulting from lens hydration (fluid addition), denaturation of lens proteins, or a combination of both, leading to impaired vision.¹ Astigmatism, a common eye condition caused by irregularly shaped corneas or lenses, often coexists with cataracts. Correcting astigmatism is crucial during cataract surgery to achieve optimal visual outcomes.² A review between 1996 and 2015 revealed that 47% of eyes had pre-existing astigmatism greater than 1.0 D, varying in severity. The range of mild astigmatism (<1.5 D) was found to be between 74.6% and 89.6%, the range of moderate astigmatism (>1.5- <2.5 D) was between 8.1% and 14.9%, and the range of significant astigmatism (>2.5 D) was between 2% and 6.8%. Correction of astigmatism during cataract surgery aims to minimize residual astigmatism and reduce the need for glasses.^{3,4} It has

been demonstrated that patients with astigmatism of 1.0 D or higher benefit from correction either during or after cataract surgery, as astigmatism can cause visual acuity to drop to 20/25 with 0.75 D and 20/40 with 1.5 D. When undergoing cataract surgery, residual astigmatism of 0.5 D or less is typically the aim of astigmatism correction.^{4,5}

During cataract surgery, the selective placement of the phacoemulsification incision, the corneal relaxation incidence, the limbal relaxing incision (LRI), and the toric intraocular lens implantation (IOL) are some of the techniques used to correct astigmatism. LRI techniques to deal with mild to moderate astigmatism are a therapeutic choice. The advantage of the technique is a low risk of irregular astigmatism and relatively easy to perform.⁶⁻⁸ Some of its advantages that there are limitations on the size of astigmatism that can be overcome is limited. In practice, LRI techniques can

be done using single or dual incisions. The dual incision technique has a superior effect in correcting larger astigmatism in cataract patients.^{9,10} This study aimed to review the effectiveness of single and dual LRI in correcting astigmatism during cataract surgery.

METHODS

This literature review cited reliable sources such as Scopus and Google Scholar. It utilized databases from 2010 until 2022. The keywords “corneal astigmatism”, “limbal relaxing incision”, and “cataract surgery” were used to collect 12 journals that had relevant topics. The Prisma flowchart of this literature review is shown in Figure 1.

The reports were considered eligible if they met the following inclusion criteria: (1) Subject are patient with senile cataract who has corneal astigmatism, (2) Undergo phacoemulsification, (3) Primary outcome

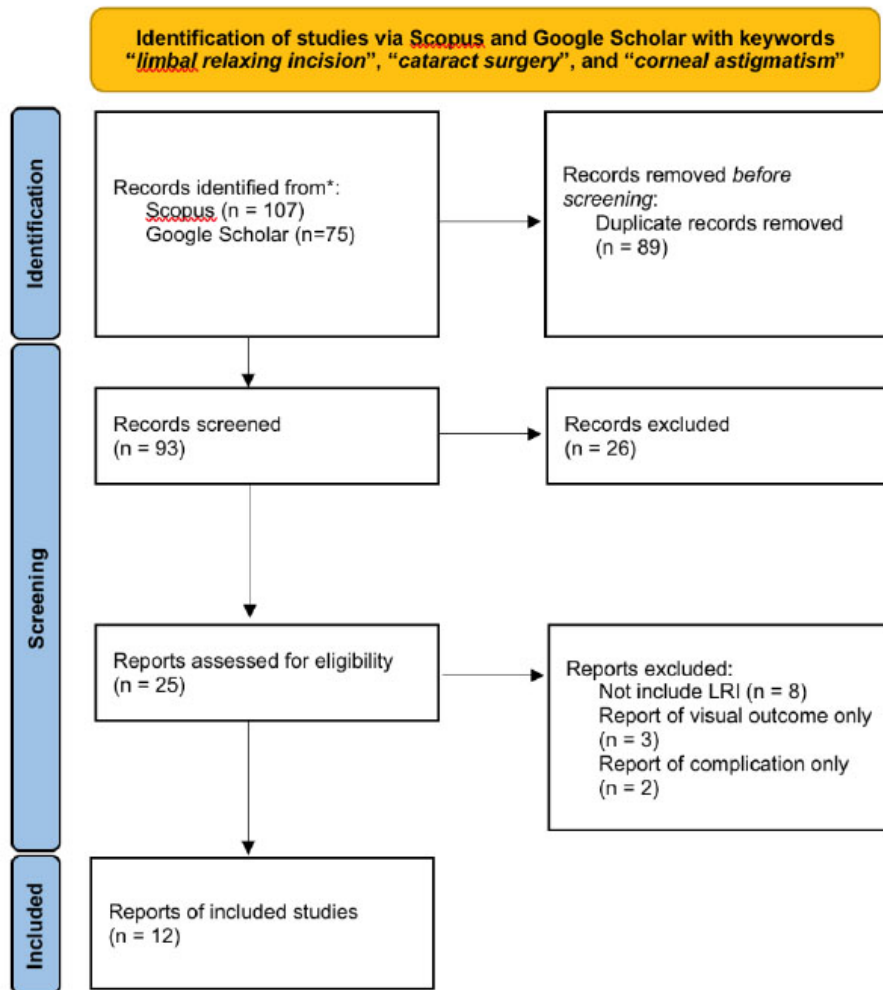


Figure 1. PRISMA flow was used in this literature review.

is residual corneal astigmatism from the baseline. The search was limited to articles with the human sample, subject area of medicine and neuroscience, published in English, and available full-text reviews and articles.

RESULTS

Corneal Astigmatism in Cataract

Cataracts develop due to oxidative stress on the lens, causing lens proteins to become opaque. Astigmatism primarily results from irregularities in the cornea, leading to unequal refraction of light rays and blurred vision. The combination of cataracts and astigmatism can significantly impact visual quality.^{5-7,11} The cornea and lens are the two main components that affect the eye's ability to refractive index. The curved surface of the cornea, which is the first structure light enters the eye through, is primarily responsible for the

eye's overall refractive power because the density difference at the air-cornea interface is significantly larger than the density difference between the fluid surrounding the lens.^{9,11}

Refractive errors occur when the eye cannot effectively focus on distant objects. The regularly curved corneal surface focuses light rays on a single point in a normal eye. The cornea is typically not perfectly round, steepest in one meridian and flattest in the perpendicular meridian. Significant differences in the bending power of each meridian can result in blurry vision, a condition known as corneal astigmatism. Irregular corneal curvature causes light rays to undergo unequal refraction.^{7,11}

Limbal Relaxing Incisions

LRIs or Peripheral Corneal Relaxing Incisions (PCRIs) are a form of partial-

thickness keratotomy used to correct astigmatism during cataract surgery. When addressing astigmatism during cataract surgery, LRIs are frequently used. Based on the patient's age, astigmatism, and the location of the steep axis of astigmatism, a nomogram is used to guide the incisions for LRIs, which are made in the peripheral cornea. By lessening the cornea's sharp curvature, LRIs enable the eye to heal into a more spherical form. LRIs can be done as single or double incisions; astigmatism correction is better with a double LRI.¹⁰ Because the lengths of coupled incisions can vary, LRIs can be tailored to the cornea's topography in the event of irregular astigmatism. Furthermore, manual incision for LRI can be substituted with femtosecond laser-assisted cataract surgery (FLACS) technology.¹²

LRI Calculator

An online LRI calculator is available at www.lricalculator.com, which helps determine the location and length of LRIs based on patient-specific parameters. The calculator can adjust LRI length to compensate for Surgically Induced Astigmatism (SIA) and can be used in degrees or clock hours according to the surgeon's preference. This tool is effective, predictable, safe, and cost-efficient for addressing corneal astigmatism.^{5,13,14}

There are two normograms used in the LRI Calculator: the DONO (Donnenfeld Normogram) and the NAPA (Nichamin Age and Pachymetry Adjusted Normogram). On the DONO normogram, the maximum length recommended for LRIs is 90 degrees (3 hours). Each 90-degree LRI provides a correction of about 1.5 D. The faecal insert, and LRI should not overlap. This barrier limits the maximum number of corrections if there is an overlap between a phaco and an LRI, whereas, on the NAPA Normogram, a phaco and LRI can overlap. This requires the use of the NAPA overlapping incision technique. Using this technique, a portion of the LRI is made in advance and completed at the required length and location of the phaco incision. The phaco incision is then done through this wound. The LRI bow then extends to the corresponding length determined by the normogram.¹³

Surgical techniques

Precise determination of the steep meridian or axis of astigmatism is crucial when performing LRI. The steep

meridian is determined using the manifest refraction's cylinder plus axis. LRI is typically performed at the beginning of cataract surgery while the corneal

epithelium is intact, and intraocular pressure can be predicted. Patients are seated, and the cornea is marked at the 12 o'clock and 6 o'clock positions. LRI

Table 1. Intervention and result of each study

No	Author	Year	Group 1	Group 2	Group 3	Follow-up Duration	Result	
1	Mingo-Botín et al. ⁶	2010	Toric IOLs	Peripheral Corneal Relaxing Incision	-	3 Months post-operatively	Both groups experienced decreased refractive astigmatism, and toric IOL implantation proved more reliable and successful, leading to increased spectacle independence.	
2	Freitas Go et al. ⁷	2014	LRIs (Donnenfelds Normogram)	Toric IOLs	-	1, 3, and 6 months postoperatively	slightly better refractive outcomes favoring the toric IOL group (not statistically significant)	
3	Bhalla et al. ⁸	2016	Opposite Clear Corneal Incisions With no corneal astigmatism,	Opposite Clear Corneal Incisions With with-the-rule (WTR) astigmatism	Opposite Clear Corneal Incisions with against-the-rule (WTR) astigmatism		In both groups, there was a reduction of over 50% in astigmatism.	
4	Khokhar et al. ⁹	2006	Paired Clear Corneal Incisions	Opposite Clear Corneal Incisions	Single Clear Corneal Incisions	-	1, 4, and 12 weeks post-operatively	Paired OCCIs were predictable and effective for correcting corneal astigmatism in cataract surgery.
5	Lake et al. ¹¹	2019	Toric IOLs	LRIs	-	Collected data from 10 relevant studies	Toric IOLs are probably superior compared with LRIs for providing astigmatism within 0.5 D	
6	Mohammad-Rabei et al. ¹⁷	2016	LRIs	extended-on-axis incision, EOAI	Toric IOLs	1,8, and 24 weeks postoperatively.	There was no significant difference in correcting astigmatism.	
7	Núñez et al. ¹⁶	2019	-	-	-	-	Compare consensus on the management of astigmatism during cataract surgery, including LRIs. LRIs can be single or paired, potentially correcting up to 1.5 D of astigmatism.	

No	Author	Year	Group 1	Group 2	Group 3	Follow-up Duration	Result
8	Hirnschall et al. ¹⁸	2014	Toric IOLs	PCRI (Donnenfelds Normogram)	-	1 hour, 1 month, and 6 months postoperatively	Both interventions reduced astigmatism; however, toric IOLs are superior to correct higher astigmatism and are more predictable.
9	Lee et al. ¹⁹	2016	Toric Foldable IOLs	LRI	-	6 months postoperatively	Both interventions reduced astigmatism and had comparable visual outcomes.
10	Kim et al. ²²	2010	Single LRI (Gills Normogram)	Dual LRI (Gills Normogram)	-	1 day, 1 weeks, and 1 month postoperatively	Effect of single LRIs as effective as paired LRIS when combined with cataract incision
11	Gangwani et al. ²⁰	2014	Multifocal IOLs	toric PCRI (Donnenfelds Normogram)	-	3 months postoperatively	Refractive astigmatism decreased in both groups.
12	Nanavaty et al. ²¹	2017	Toric IOLs	PCRI (Donnenfelds Normogram)	-	1, 3, 6, and 12 months postoperatively	There was no difference in visual acuity.

incisions are made near the limbus in the peripheral cornea using a diamond or metal knife. The incision depth is usually about 600 microns but varies between 450 and 650 micrometers.^{14,15} Each patient has a different corneal thickness; 600 µm is the most commonly used incision depth. A pachymeter measurement should be taken at the cutting site to avoid unintentional perforation into the anterior chamber.¹⁵

Surgical Outcomes

A total of 12 studies using relevant search terms in various databases are included in this review. Ten studies are original articles, 1 study is a meta-analysis, and 1 study is a review article.^{11,16} Most studies (7 of 12) divided the samples into two groups according to corneal astigmatism management.^{6,7,17-21} This first group consists of toric IOLs and the second group consists of LRIs/PCRIs intervention. Only 1 study compares the single and dual LRIs.²² Two studies divided the intervention into opposite clear corneal incision (OCCI) and single clear corneal incisions with no normogram used.^{8,9} Also, 4 studies are using the Donnenfeld normogram for LRI intervention.^{7,18,20,21}

Table 1 shows each study's interventions, follow-up duration, and results.

Complications

LRI has several advantages, including affordability, ease of execution, and minimal risk of overcorrection. However, it has limitations, such as a relatively large incision size, reduced predictability and stability compared to toric IOLs, and potential complications, including infection, overcorrection, undercorrection, and corneal perforation.^{10,20} Incision on the limbus can also cause a sensation of a foreign object, decreased cornea sensitivity, and dry eye disease after surgery.¹⁶ LRIs are contraindicated in conditions like keratoconus, autoimmune diseases, peripheral corneal diseases, corneal ectasia, severe dry eye related to rheumatoid disease, and previous corneal incisional surgeries.¹⁰

DISCUSSION

Studies on LRIs are limited but generally show favorable results in patients with astigmatism undergoing cataract surgery. LRIs have been found to reduce astigmatism

effectively, and the choice between LRIs and toric intraocular lenses (IOLs) depends on various factors. Toric IOLs may provide superior results for certain patients, but LRIs are effective for low to moderate and irregular astigmatism. LRI is particularly useful when combined with toric IOLs or when toric IOL implantation is contraindicated.¹⁰ Compared to LRIs and CCRIs, toric IOLs can correct greater degrees of astigmatism.²³ It has been discovered that toric IOLs yield consistent outcomes, with the lowest post-operative astigmatism for pre-operational astigmatism ranging from 1.0 to 3.0 D.⁶ Furthermore, patients typically recover more quickly from toric IOLs because they do not require additional surgical injuries (unlike LRI).¹⁷

A literature review demonstrated the benefits of FLACS over manual incision, including increased predictability, precision, and application in challenging cataract cases like traumatic, white, anterior space, and subluxation cataracts. Femtosecond lasers can cut corneas with precise depth and length, lowering the risk of corneal perforation in astigmatic patients undergoing treatment.¹² LRI is

most predictable when used to correct astigmatism up to 1.5 D, though it can correct astigmatism up to 3.0 D. LRI, like other astigmatism correction techniques, is to achieve residual astigmatism within 0.5 D or less.¹⁶ Asthma correction with LRIs is safe and effective up to 2.5 D. The primary benefit of the LRI pertains to night vision issues, potentially linked to avoiding a mid-peripheral corneal incision.¹⁵ In a study, patients with mixed astigmatism experienced absolute changes in refractive astigmatism of 1.72 ± 0.81 D following LRI. Astigmatism dropped by 44%, or 0.91 D. The astigmatic correction caused by inscriptions in the horizontal meridian is approximately twice that of those in the vertical meridians.²⁴

A meta-analysis study conducted by Lake et al. that compared the use of LRI surgical techniques with toric IOL in dealing with astigmatism during phacoemulsification cataract surgery found no significant differences in improved postoperative vision acuity and quality of life.¹¹ Similar results were found in a non-randomized prospective study conducted by Mohammad-Rabei et al. comparing the use of LRIs, extended-on-axis incision and toric intra-ocular lens techniques in cataract patients with astigmatism with keratometry results ≥ 1.25 D. It was found that there were no significant differences between groups in the reduction of astigmatic rates during phacoemulsification surgery.¹⁷ In a bilateral prospective randomized study conducted by Hirschschall et al. in patients with bilateral cataracts with astigmatism, IOL toric installation was performed in one eye and IOL + LRI non-toric installation in the other.¹⁸ In this study, it was found that the use of toric IOLs (1.74 ± 0.64 D) was superior to the LRIs (1.27 ± 0.76 D) in the correction of astigmatism ($p = 0.042$). In a retrospective study by Lee et al. of cataract patients with moderate astigmatism (2.00-3.00 D) and severe astigmatism (3.00-4.00 D). After receiving LRIs, an improvement rate of 1.33 ± 0.61 D ($p = 0.001$) was found in the moderate astigmatism group and an improvement ratio of 2.16 ± 0.66 D in the severe astigmatism group ($p = 0.003$).¹⁹ They also evaluated the astigmatism improvement of cataract patients receiving toric IOLs. As a

result, toric IOLs seemed superior to LRIs ($p < 0.001$). Donnenfeld nomogram used for LRIs used in the study conducted by Gangwani et al., Freitas et al., Hirschschall et al., and Nanavaty et al. showed there were no differences between toric IOLs and LRIs; therefore, toric IOLs still superior to correct higher astigmatism.^{7,18,20,21} In a retrospective study conducted by Kim et al. in patients receiving LRIs during cataract surgery for astigmatism with the rule ≥ 1.5 D. This study compared single and pair inscriptions on LRI. It was found that a single inscription of LRI + a clear corneal inscription was able to lower the astigmatism rate by 47%. Whereas a pair inscription with LRI with a transparent cornea inscription reduced the level of astigmatism by 48%.²²

The limitation of this study is that there is no single, most precise tool or intervention for measuring and adjusting corneal astigmatism after cataract surgery. It is necessary to agree on the best methods for managing astigmatism during cataract surgery because there is no clear astigmatic planning and treatment strategy. However, this literature review resumed most interventions to correct corneal astigmatism that can be an option for surgeons for correcting corneal astigmatism during cataract surgery.

CONCLUSION

LRIs are a valuable surgical technique used to correct astigmatism during cataract surgery. LRIs offer a cost-effective and relatively safe method for reducing astigmatism, particularly in low to moderate and irregular astigmatism cases. They can be performed as single or dual incisions and are especially useful when combined with toric intraocular lenses (IOLs) or when toric IOL implantation is impossible.

The use of online LRI calculators aids in determining the precise location and length of incisions, enhancing the predictability of outcomes. However, LRIs have limitations, including reduced predictability and stability compared to toric IOLs, larger incision sizes, and the potential for complications such as overcorrection, under-correction, infection, and corneal perforation.

The choice between single and dual LRIs should be made based on the severity of astigmatism and the surgeon's expertise. The effectiveness between single and dual LRIs was the same, but paired LRIs have a superior effect in correcting greater astigmatism. Overall, LRIs remain a valuable tool for cataract surgeons to manage astigmatism and improve visual outcomes in cataract surgery patients.

AUTHOR CONTRIBUTION

AIA: Conceptualization, Data curation, Formal analysis, Project administration, Funding acquisition, Investigation, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review, editing. MAI: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Resources, Validation, Visualization, Writing – original draft, Writing – review, editing. HE: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Resources, Software, Validation, Visualization, Writing – review, editing.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ETHICAL APPROVAL

Not Applicable.

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