International Medical Case Reports Journal

Dovepress
Taylor & Francis Group

Open Access Full Text Article

CASE SERIES

Five Years Follow-Up Outcomes of Femtosecond Laser-Assisted Cataract Surgery on Patients with Preexisting Corneal Astigmatism

Thi Minh Khanh Pham[1], Xuan Hiep Nguyen[2], Thi Thu Thuy Pham[1], Tran Thanh Hoang[3]

[1]Department of Ophthalmology, Hanoi Medical University, Hanoi, Vietnam; [2]Eye Center, Tam Anh Hospital, Hanoi, Vietnam; [3]Hospital Director, Hadong Eye Hospital, Hanoi, Vietnam

Correspondence: Thi Minh Khanh Pham, Department of Ophthalmology, Hanoi Medical University, Number 1 Ton That Tung, Dong Da District, Hanoi, Vietnam, Tel +84-969085588, Email minhkhanh279@gmail.com

Purpose: Evaluating the long-term clinical efficacy and safety of femtosecond laser-assisted cataract surgery for correcting corneal astigmatism.

Patients and Methods: In this cohort study on follow-up records from preoperative, postoperative 1 week, 1 month, 3 months, 1 year, 3 years, and 5 years, thirty-four eyes with cataract and corneal astigmatism (>0.50D) were treated with corneal arcuate incisions and femtosecond-laser assisted cataract surgery in Vietnam National Eye Hospital, from January 2017 to February 2023.

Results: The rate of postoperative refraction spherical equivalent was within ± 0.50D and ± 1.0D at 3 months (in 91.2% and 100% of the eyes, respectively). The average of preoperative corneal astigmatism was 1.63 ± 0.886D, decreased to 0.53 ± 0.628D in the third month after surgery and stable to 5 years. Surgically induced astigmatism was 1.09 ± 0.413D, which indicated under-correction. However, no complications were recorded.

Conclusion: The femtosecond laser-assisted cataract surgery is safe and long effective in correcting the corneal astigmatism in patients with preexisting corneal astigmatism.

Keywords: femtosecond laser, corneal astigmatism, cataract, arcuate incision

Introduction

Astigmatic management is crucial to achieving the best visual quality after refractive cataract surgery. Previous studies have shown that preoperative corneal astigmatism is quite common in patients undergoing cataract surgery.[1] Postoperative residual astigmatism of 0.50D or more can cause reduced visual acuity, especially in patients who received multifocal or extended depth-of-focus intraocular lenses.[2] Therefore, treating corneal astigmatism during cataract surgery can not be indispensable.

There are several methods to reduce postoperative astigmatism. Each method has its advantages and limitations. Toric intraocular lens (IOLs) are pretty expensive. Furthermore, if the rotation of the IOL occurs after surgery, it will significantly increase the degree of astigmatism.[3] Excimer laser correction of residual astigmatism after cataract surgery requires additional surgery with high costs, can cause complications, and is limited to patients with thin corneas.[4]

Corneal incisions to correct astigmatism in cataract surgery have been used for a long time. The advantages of this method are that it is easy to perform and low cost. However, previous limbal corneal incisions made by surgeons using diamond knives left many risks, such as misdirected incisions, the possibility of corneal perforation, and insufficient or uneven depth, reducing the effectiveness of astigmatism correction as well as unpredictable results.[5] Nowadays, the application of femtosecond laser in cataract surgery has helped to create arcuate corneal incisions that can be precisely customized in position, size, depth, and length of the incisions.[6] Thereby, surgery increases the effectiveness of astigmatism correction, increases visual acuity, and reduces dependence on glasses for patients.[7] However, long-term outcomes of this method are rarely reported. Several previous studies have shown the stability of postoperative refraction

Received: 13 November 2024
Accepted: 10 March 2025
Published: 20 March 2025

after one year (Denise M. Visco),[8] two years (Sandhu U),[9] and seven years (Wendelstein JA).[10] Our study evaluated five years of results of this method in addition to determining the stability of postoperative refraction and regression of corneal incisions and also evaluated possible late complications such as fibrosis, contraction, deformation of the incision, rolling of the incision edge, or epithelial invasion into the incision.

Materials and Methods

Study Design and Patient

This retrospective study included thirty-four eyes that underwent femtosecond laser-assisted cataract surgery at Vietnam National Eye Hospital (VNEH) from January 2017 to February 2023. This study was approved by the local ethics committee and the tenets of the Declaration of Helsinki. Each patient wrote an informed consent form in accordance. Selection criteria were patients with preoperative corneal astigmatism of over 0.5D who underwent phacoemulsification surgery combined with the use of a femtosecond laser (LenSx, Alcon, USA) to create the arcuate corneal incisions to correct astigmatism and implanted a foldable intraocular lens, with complete follow-up records to assess the conditions before surgery, during surgery, and after surgery at 1 week, 1 month, 3 months, 1 year, 3 years. Exclusion criteria were patients with severe systemic diseases, mute, deafness, slow consciousness, poor coordination, were not able to follow up, did not have enough follow-up records, or did not agree to participate in the study.

Materials

We collect the follow-up records before surgery, during, and after surgery at 1 week, 1 month, 3 months, 1 year, and 3 years. At present, to evaluate the results after 5 years, we used the Snellen vision acuity chart, autorefraction, topography with OPD-Scan III, and other equipment available at Vietnam National Eye Hospital.

Procedure

Each patient has a monitoring record. At present, the patients who met the selection criteria were invited for an explanation, a guide to sign an informed consent, and an examination. The patients were conducted complete ophthalmologic examination, including uncorrected distance visual acuity (UDVA) and best-corrected distance visual acuity (CDVA), tonometry, slit-lamp examination, funduscopy, corneal topography (OPD-Scan III). All results recorded before surgery, during surgery, and after surgery, 1 week, 1 month, 3 months, 1 year, and 3 years in the old monitoring records and current examination results will be filled in their research form.

Evaluated Parameters

Uncorrected distance visual acuity (UDVA), spherical refraction, cylindrical refraction, manifest refraction spherical equivalent (MRSE), corneal astigmatism before and after surgery 1 week, 1 month, 3 months, 1 year, 3 years, and 5 years, correction index of surgery by the ratio between surgical-induced astigmatism and target-induced astigmatism were recorded (target induced astigmatism value equal to preoperative corneal astigmatism). We assessed the rate of MRSE within ± 0.50D and ± 1.0D, the rate of possible complications, such as dislocated incision, tear of incision, inadequate depth incision, corneal perforation, folded edge of incision, penetrating the epithelium into the incision, fibrosis, contraction, deformation of incision.

Statistical Analysis

Data analysis was performed with SPSS 22.0. The number data were presented as X ± SD, and percentage data were expressed in %. A P-value less than 0.05 was considered statistically significant. Student's *t*-test was applied to compare corneal astigmatism, UDVA, MRSE preoperative, 1 week, 1 month, 3 months, 1 year, 3 years, and 5 years postoperative. We used the chi-square test to compare the rate of a group of UDVA postoperative at each follow-up time. Fisher's exact test was used when the data were small to do the chi-square test.

Results

Our study included 34 eyes of 26 patients, in which the proportion of men (65%) was twice as high as that of women (35%). The mean age was 49.96 ± 15.233 years old at the time of surgery. The most common age was between 20 and 60 years old (77%).

UDVA gradually improved over time, with 13 eyes having UDVA of 20/25 or better in the first week after surgery. At the 3 months after surgery, this number increased to 23 eyes (67.6%) with $p < 0.001$ and was stable for 5 years after surgery ($p > 0.05$) (Figure 1).

The average preoperative corneal astigmatism was 1.63 ± 0.886D. Corneal astigmatism decreased to 0.88 ± 0.679D, 0.69 ± 0.733D, and 0.53 ± 0.628D at the follow-up times of 1 week, 1 month, and 3 months after surgery, respectively, with $p = 0.001$. From the third month onwards, the corneal astigmatism was stable, the change was insignificant with $p > 0.05$ (Table 1).

The average surgical-induced astigmatism was 1.09 ± 0.413D, lower than the target-induced astigmatism of 1.63 ± 0.886D, correction index of surgery was 0.67 (ratio between surgical-induced astigmatism and target-induced astigmatism). This result is shown in Figure 2, indicating that there is still under-correction in the treatment.

The residual refraction after surgery was very low, with the mean spherical refraction and MRSE being less than 0.05D and −0.30D; the refraction was stable immediately after surgery from 1 week to 5 years ($p > 0.05$). The mean residual cylindrical refraction after surgery decreased significantly in the first month after surgery with −0.56 ± 0.394D ($p = 0.001$). The change in cylindrical refraction at subsequent follow-up times had no statistically significant difference ($p > 0.05$) (Table 2).

Over 95% of eyes have an MRSE postoperative within ± 1.0D. Approximately 90% of eyes have an MRSE postoperative from the third month onwards within ± 0.50D (Table 3).

The study also recorded that there were no complications related to the creation of arcuate corneal incisions using a femtosecond laser to treat corneal astigmatism during surgery, such as dislocated incision, tear of incision, inadequate

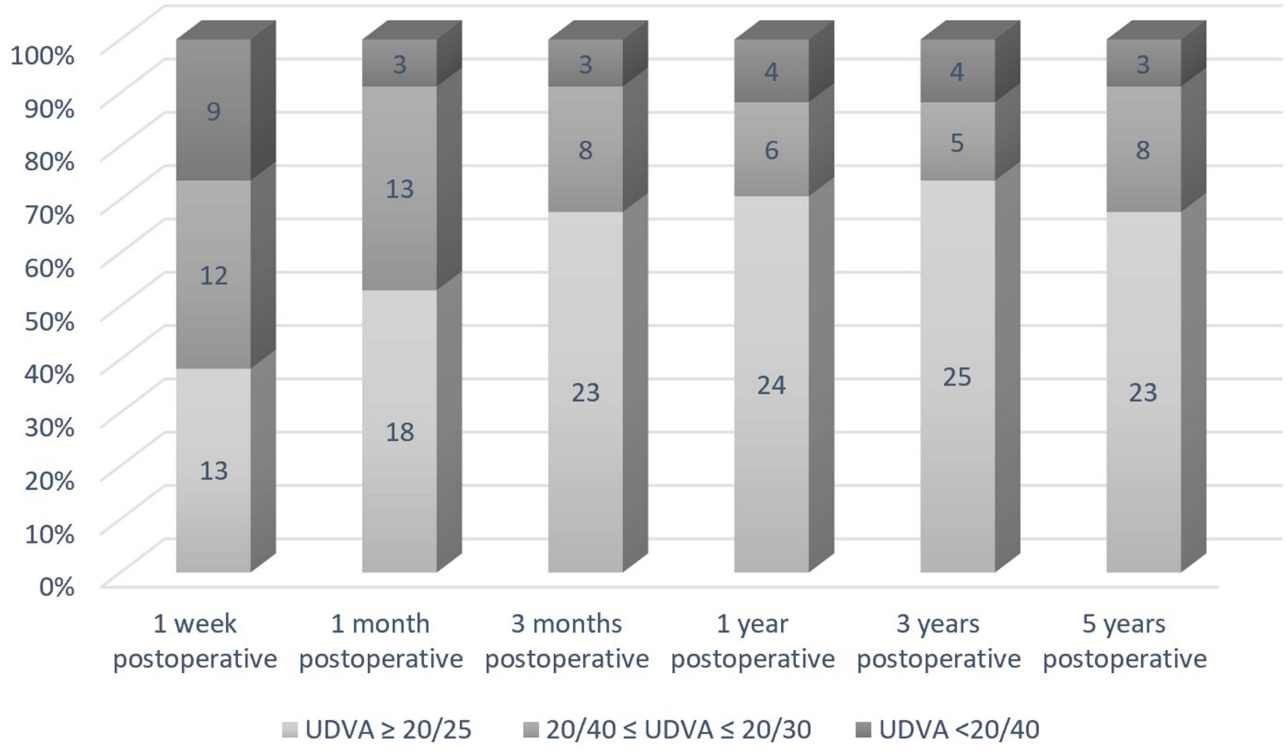

Figure 1 Uncorrected distance visual acuity postoperative.
Abbreviation: UDVA, uncorrected distance visual acuity.

https://doi.org/10.2147/IMCRJ.S506198

Table 1 Corneal Astigmatism Before and After Surgery

Corneal Astigmatism	X ± SD (D)	p
Preoperative (1)	1.63 ± 0.886	
1 week postoperative (2)	0.88 ± 0.679	p (1–2) < 0.001
1 month postoperative (3)	0.69 ± 0.733	p (2–3) < 0.001
3 months postoperative (4)	0.53 ± 0.628	p (3–4) = 0.001
1 year postoperative (5)	0.57 ± 0.637	p (4–5) = 0.391
3 years postoperative (6)	0.55 ± 0.629	p (5–6) = 0.578
5 years postoperative (7)	0.55 ± 0.624	p (6–7) = 0.966

depth incision, corneal perforation, folded edge of incision, penetrate the epithelium into incision, fibrosis, contraction, deformation of incision, etc.

Discussion

Our results in Table 1 show that the average corneal astigmatism after surgery 3 months (0.53 ± 0.628D) has decreased significantly compared to before surgery (1.63 ± 0.886D) with p = 0.001. From the third month onwards to 5 years, the average corneal astigmatism results were stable, with no significant changes (p > 0.05). Denise M. Visco's study (2019) also showed that corneal astigmatism postoperative decreased significantly in the third month and was stable for up to 1 year of follow-up.[8]

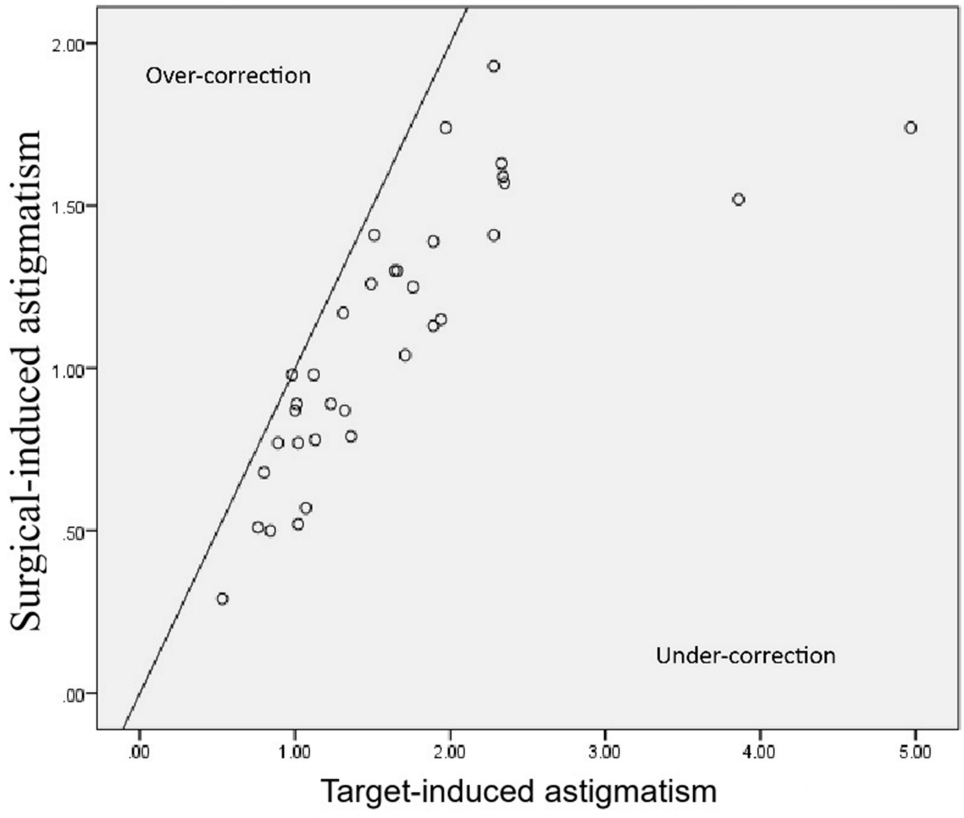

Figure 2 The scatter plot of target-induced astigmatism and surgical-induced astigmatism.

Table 2 Average of Postoperative Refraction

	Spherical Refraction X ± SD (D)	Cylindrical Refraction X ± SD (D)	MRSE X ± SD (D)
1 week postoperative (1)	0.04 ± 0.340	−0.68 ± 0.494	−0.29 ± 0.349
1 month postoperative (2)	0.01 ± 0.323	−0.56 ± 0.394	−0.26 ± 0.342
3 months postoperative (3)	0.02 ± 0.271	−0.51 ± 0.364	−0.25 ± 0.320
1 year postoperative (4)	0.01 ± 0.301	−0.49 ± 0.379	−0.21 ± 0.380
3 years postoperative (5)	0.02 ± 0.271	−0.46 ± 0.371	−0.22 ± 0.330
5 years postoperative (6)	0.04 ± 0.247	−0.46 ± 0.390	−0.24 ± 0.288
p	(1–2), (2–3), (3–4), (4–5), (5–6) > 0.05	(1–2) = 0.001 (2–3), (3–4), (4–5), (5–6) > 0.05	(1–2), (2–3), (3–4), (4–5), (5–6) > 0.05

Abbreviation: MRSE, manifest refraction spherical equivalent.

Table 3 Manifest Refraction Spherical Equivalent Postoperative Within ±0.50D and ±1.0D

Manifest Refraction Spherical Equivalent	± 0.50D (%)	± 1.0D (%)
1 week postoperative	79.4	100
1 month postoperative	82.4	97.1
3 months postoperative	88.2	97.1
1 year postoperative	88.2	97.1
3 years postoperative	88.2	100
5 years postoperative	91.2	100

The average of surgical-induced astigmatism was 1.09 ± 0.413D, with a correction index (CI) of surgery of 0.67 (ratio between surgical-induced astigmatism and target-induced astigmatism). Thus, the results obtained showed that there was still under-correction (Figure 2). Our results are similar to those of some other authors when performing corneal astigmatism correction using arcuate corneal incisions by femtosecond laser, which also had under-correction with a CI of surgery of only 0.73. However, this result was still higher than the old method when incising the cornea with a diamond knife, which only achieved a surgical CI of 0.48.[11] Yong-Soo Byun pointed out that the under-correction results in cataract surgery using a femtosecond laser depended on many factors, including the biomechanical properties of the cornea and the morphology of astigmatism. In the group of patients with preoperative reverse or crossed astigmatism, the surgical CI will be higher than that of patients with preoperative with the rule astigmatism. If the patient has a well-elastic cornea, the surgical result will likely be under-corrected, while if the cornea is poorly elastic, the result will be over-corrected.[12] Therefore, to achieve the expected corneal astigmatism correction effect, the formula for calculating the position, size, depth, and length of the arcuate corneal incision must consider both corneal biomechanics and preoperative morphological corneal astigmatism. In the scope of our study, due to limited resources, these factors could not be evaluated.

The UDVA in the study group of patients was 20/25 or more, accounting for a very high proportion from the third month after surgery in 67.6% (Figure 1), and this result did not change statistically significantly at subsequent follow-up times ($p > 0.05$). Denise M. Visco's study also showed that up to 90% of patients had UDVA 20/30 or more in the third month after surgery, and the results were stable for up to 1 year of follow-up.[8] The UDVA results were relatively

consistent with the mean spherical refraction and MRSE values obtained after surgery from the first week, which were 0.04 ± 0.340D and - 0.29 ± 0.349D, respectively. This value was stable for up to 5 years of follow-up (Table 2).

The effectiveness of surgery was also considered through the rate of MRSE within ±0.50D, reaching over 80% from the first month after surgery and over 90% within ±1.0D. This result was stable through follow-up periods up to 5 years after surgery (Table 3). Abu-Ain also recorded the MRSE rate after 3 months of surgery within ±1.0D, reaching 97%, and ±0.50D, reaching 86% in the study evaluating the effectiveness of limbal corneal incisions in cataract surgery.[13]

As in many other studies,[8,14] our study found no surgical complications related to arcuate incisions created by femtosecond laser. Concerns about scarring of corneal incisions that could reduce the effectiveness of astigmatism correction over time were not seen in this study. The idea that corneal incisions for astigmatism correction could cause structural abnormalities of the cornea and affect visual function was also ruled out after the study of Monaco et al.[15] The authors showed that after 3 years of follow-up, limbal corneal incisions did not cause any significant changes that increased higher-order aberrations of the cornea. There were no changes in the central cornea, so the visual acuity, refraction, and visual quality of the patient after surgery were stable for a long time.

The advantage of this study is that it has evaluated the long-term results (5 years) of a new, modern technique. However, the stable effectiveness has made many people sceptical because there has yet to be any previous study evaluating the long-term effectiveness. The limitation of the study is that the sample size is small, and the resources are lacking, so it is not possible to analyze and evaluate the related factors affecting the effectiveness of surgery. Therefore, a large enough study in the future is needed to evaluate in detail the factors affecting surgery, thereby finding a more accurate formula to calculate the size, location, depth, and length of the corneal incisions to achieve optimal treatment results after surgery.

Conclusion

Corneal astigmatism correction in cataract surgery using a femtosecond laser to create arcuate corneal incisions is a new, modern, safe, and highly effective method. The surgery made the preoperative corneal astigmatism reduction, good UDVA, and postoperative MRSE within ±0.50D reached over 80% from the first month and was stable for up to 5 years. This study has provided further evidence of the safety and long-term effectiveness of the surgery. However, due to some limitations of the study, a more extensive study in the future with a larger sample size and more evaluation of factors affecting surgical results is needed. From there, clinicians will have more knowledge and supporting tools to achieve the best results in surgery.

Ethical Approval

The local ethics committee approved the protocol, and the tenets of the Declaration of Helsinki were followed throughout the study. Our study was approved by the Hanoi Medical University Institutional Ethical Review Board (IRB-VN01.001/IRB00003121/FWA 00004148) and accepted by the Institutional Ethics Committee of Vietnam National Eye Hospital. All patients understood and voluntarily participated in this study and consented to publish the data.

Acknowledgments

We would like to thank Hanoi Medical University and Vietnam National Eye Hospital for supporting us throughout the research process.

Funding

This research did not receive any financial support.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Ferrer-Blasco T, Montés-Micó R, Peixoto-de-Matos SC, González-Méijome JM, Cerviño A. Prevalence of corneal astigmatism before cataract surgery. *J Cataract Refract Surg*. 2009;35(1):70–75. doi:10.1016/j.jcrs.2008.09.027
2. Chang JSM, Liu SCT, Ma NTC, Ng JCM. Comparative analysis of tolerance to experimentally induced astigmatism with three types of multifocal intraocular lenses. *Clin Ophthalmol*. 2024;18:139–149. doi:10.2147/opth.S429630
3. Ahmed IIK, Rocha G, Slomovic AR, et al. Visual function and patient experience after bilateral implantation of toric intraocular lenses. *J Cataract Refract Surg*. 2010;36(4):609–616. doi:10.1016/j.jcrs.2009.10.044
4. Bayramlar H, Dağlioğlu MC, Borazan M. Limbal relaxing incisions for primary mixed astigmatism and mixed astigmatism after cataract surgery. *J Cataract Refract Surg*. 2003;29(4):723–728. doi:10.1016/s0886-3350(02)01821-7
5. Budak K, Friedman NJ, Koch DD. Limbal relaxing incisions with cataract surgery. *J Cataract Refract Surg*. 1998;24(4):503–508. doi:10.1016/s0886-3350(98)80292-7
6. Abbey A, Ide T, Kymionis GD, Yoo SH. Femtosecond laser-assisted astigmatic keratotomy in naturally occurring high astigmatism. *Br J Ophthalmol*. 2009;93(12):1566–1569. doi:10.1136/bjo.2008.149971
7. Wang J, Zhao J, Xu J, Zhang J. Evaluation of the effectiveness of combined femtosecond laser-assisted cataract surgery and femtosecond laser astigmatic keratotomy in improving post-operative visual outcomes. *BMC Ophthalmol*. 2018;18(1):161. doi:10.1186/s12886-018-0823-1
8. Visco DM, Bedi R, Packer M. Femtosecond laser-assisted arcuate keratotomy at the time of cataract surgery for the management of preexisting astigmatism. *J Cataract Refract Surg*. 2019;45(12):1762–1769. doi:10.1016/j.jcrs.2019.08.002
9. Sandhu U, Osborn AR, Dang DH, et al. Refractive astigmatism outcomes of femtosecond laser-assisted arcuate keratotomies combined with femtosecond laser-assisted cataract surgery: two-year results. *Curr Eye Res*. 2024;49(9):961–971. doi:10.1080/02713683.2024.2353268
10. Wendelstein JA, Hoffmann PC, Schwarzenbacher L, et al. Lasting effects: seven year results of the castrop nomogram for femtosecond laser-assisted paired corneal arcuate incisions. *Curr Eye Res*. 2022;47(2):225–232. doi:10.1080/02713683.2021.1975761
11. Roberts HW, Wagh VK, Sullivan DL, Archer TJ, O'Brart DPS. Refractive outcomes after limbal relaxing incisions or femtosecond laser arcuate keratotomy to manage corneal astigmatism at the time of cataract surgery. *J Cataract Refract Surg*. 2018;44(8):955–963. doi:10.1016/j.jcrs.2018.05.027
12. Byun YS, Kim S, Lazo MZ, et al. Astigmatic correction by intrastromal astigmatic keratotomy during femtosecond laser-assisted cataract surgery: factors in outcomes. *J Cataract Refract Surg*. 2018;44(2):202–208. doi:10.1016/j.jcrs.2017.11.018
13. Abu-Ain MS, Al-Latayfeh MM, Khan MI. Do limbal relaxing incisions during cataract surgery still have a role? *BMC Ophthalmol*. 2022;22(1):102. doi:10.1186/s12886-022-02327-9
14. González-Cruces T, Cano-Ortiz A, Sánchez-González MC, Sánchez-González JM. Cataract surgery astigmatism incisional management. Manual relaxing incision versus femtosecond laser-assisted arcuate keratotomy. A systematic review. *Graefes Arch Clin Exp Ophthalmol*. 2022;260(11):3437–3452. doi:10.1007/s00417-022-05728-0
15. Monaco G, Scialdone A. Long-term outcomes of limbal relaxing incisions during cataract surgery: aberrometric analysis. *Clin Ophthalmol*. 2015;9:1581–1587. doi:10.2147/opth.S89024