ARTICLE

Toric intraocular lens implantation vs femtosecond laser–assisted arcuate keratotomy for correction of moderate astigmatism in cataract surgery

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Purpose: To compare toric intraocular lens (TIOL) implantation and femtosecond laser–assisted arcuate keratotomy (FSAK) during phacoemulsification surgery in correction of moderate astigmatism.

Setting: Clinical research study.

Design: Prospective randomized comparison study.

Methods: Patients with age-related cataract and moderate preoperative corneal astigmatism of 1.25 to 3.0 diopters (D) were randomized into a TIOL implantation group and an FSAK group with symmetrical paired corneal arcuate keratotomies. The preoperative evaluation included corrected distance visual acuity (CDVA), corneal topography, autokeratometry, and ocular biometry. Postoperative examinations were performed at 1 month and 3 months and included CDVA and uncorrected distance visual acuity, manifest refraction, autokeratometry, and corneal topography. Vector analysis of astigmatic changes was performed using the Alpins vector method.

Results: This study comprised 75 eyes from 67 patients. The mean residual refractive astigmatism at 3 months was −0.63 ± 0.55 D in the TIOL group and −0.90 ± 0.53 D in the FSAK group ($P = .037$) and was ≤1.00 D in 32 eyes (84%) and 25 eyes (64%), respectively. There were no statistically significant differences between the 2 groups in difference vector, angle of error, magnitude error, or correction index in the 3-month follow-up. The index of success was 0.32 ± 0.33 D in the TIOL group and 0.48 ± 0.29 D in the FSAK group ($P = .029$).

Conclusions: TIOL implantation showed better results in correcting moderate astigmatism. Despite this, FSAK is shown to be a safe technique for reducing astigmatism.

J Cataract Refract Surg 2022; 48:887–893 Copyright © 2021 Published by Wolters Kluwer on behalf of ASCRS and ESCRS

The growing prospects of visual recovery and attainment of emmetropia in patients who have had cataract surgery are setting new postsurgery refraction benchmarks.

One of the main obstacles preventing a considerable improvement in uncorrected distance visual acuity (UDVA) is the presence of astigmatism postoperatively. An uncorrected astigmatism of 1.00 diopters (D) can decrease visual acuity (VA) by up to 1.5 lines of vision, causing a reduction in visual function.[1] It is estimated that the incidence of corneal astigmatism greater than 1.00 D stands at 35% in patients with cataracts, with 20% of patients having corneal astigmatisms exceeding 1.50 D.[2] In fact, the EUREQUO database shows that more than 30% of pseudophakic patients presented residual astigmatism greater than 1.00 D.[3]

Various strategies have been developed to correct preoperative corneal astigmatism: toric intraocular lens (TIOL) implantation, limbal/corneal relaxing incisions, opposite clear corneal incisions, arcuate keratotomy (AK), and excimer laser treatment.[4–7] Of them, TIOL implantation has been the procedure of choice because of its greater predictability (mild residual astigmatism) and safety compared with other treatments, such as nontoric IOL implantation with relaxing or arcuate incisions, and because it offers greater independence from spectacles and greater patient satisfaction, thanks to a substantial improvement in VA at different levels of contrast and at both far and near distances.[4,8,9] However, TIOLs may present an increased risk for misalignment and may be contraindicated in cases of small pupils, pseudoexfoliation, and phacodonesis.

Submitted: September 10, 2021 | Final revision submitted: December 15, 2021 | Accepted: December 16, 2021

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0886-3350/$ - see frontmatter
https://doi.org/10.1097/j.jcrs.0000000000000879

The emergence of femtosecond laser–assisted cataract surgery makes it possible to create not only more precise capsulotomies that could improve refractive results but also high-precision penetrations or intrastromal corneal incisions because of greater control of incision depth, size, and centering. As demonstrated in several studies, femtosecond laser–assisted arcuate keratotomy (FSAK) provides a highly effective and safe way of reducing mild-to-moderate astigmatism when compared with manual incisions and maintains correction stability over time.[10–14] Various studies have modified the nomograms for manual limbal relaxing incisions (Donnenfeld, Wallace, Nichamin) to apply them in FSAK, obtaining a significant decrease in preoperative astigmatism, the reduction being greater with open penetrating incisions than with intrastromal incisions.[12–18]

Exhaustive bibliographic review indicates that there are only 2 relevant studies that compare the reduction in astigmatism in patients treated with FSAK vs conventional phacoemulsification with TIOL implantation.[19,20] Both are retrospective studies, and the penetrating AK incisions were not opened. In our experience, the corrective effect of FSAKs on astigmatism is greater if they are opened.

The aim of this paper was to compare the correction of regular corneal astigmatism moderated using these 2 techniques.

METHODS

This prospective randomized and nonmasked comparison study was performed at the High-Definition Cataract Surgery Unit (ARCCA) of the Nuestra Señora de Gracia Hospital (Zaragoza, Spain). Inclusion criteria were patients aged between 60 and 80 years who had received age-related cataract surgery (≥3 according to the Lens Opacities Classification System III) and who presented regular bowtie moderate preoperative corneal astigmatism (1.25-3.0 D). Exclusion criteria were amblyopia, corneal ectasia topographic features, ocular disorders such as corneal scars, previous ophthalmological treatment, systemic diseases such as diabetes, small palpebral fissures, small/insufficiently dilating pupils, and intraoperative or postoperative complications. This study was approved by the Clinical Research Ethics Committee of Aragon and adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all patients.

This study comprised 75 eyes from 67 patients who underwent cataract surgery between January 1, 2019, and December 31, 2020. All patients were randomized into 2 groups: 37 eyes received femtosecond laser–assisted phacoemulsification and FSAK; 38 eyes were enrolled in the TIOL group.

The preoperative evaluation included corrected distance visual acuity (CDVA), measured using ETDRS charts (Precision Vision) adjusted to a 4 m distance under mesopic illumination (84 cd/m^2), anterior and posterior segment examination, corneal topography using the Pentacam HR (Oculus Optikgeräte GmbH), autokeratometry using the KR-8900 (Topcon Medical Systems, Inc.), and ocular biometry measured with the IOLMaster 700 (Carl Zeiss Meditec AG).

Postoperative examinations were performed at 1 month and 3 months after IOL implantation and included mesopic UDVA and CDVA using ETDRS charts, subjective manifest refraction, autokeratometry, and corneal topography with the Pentacam.

Based on a preliminary study conducted by the authors, the sample size needed to detect differences of at least 0.25 D of refractive astigmatism was calculated, applying a bilateral test with an α risk of 5% and β risk of 10% (ie, with a power of 90%). From these data, it was concluded that at least 61 eyes would be necessary.

Surgical Technique

The phacoemulsification procedure was performed by the same surgeon using topical anesthesia (proparacaine hydrochloride 0.5%). All patients were marked on the horizontal 0- to 180-degree axis while sitting at the slitlamp preoperatively to avoid cyclotorsion errors. A self-sealing 2.75 mm temporal main incision and a 1.5 mm side port were made with diamond keratomes in all cases.

In the FSAK group, the phacoemulsification and femtosecond laser platforms used were the Stellaris PC (Bausch & Lomb GmbH) and Technolas Victus SW V3.3 (Bausch & Lomb GmbH), respectively. After manually aligning the horizontal marks with the suction ring, anterior capsulotomy (size 5.5 mm) and lens fragmentation into 4 radial cuts (cake pattern) were performed with a femtosecond laser, and then, FSAK was performed. Symmetrical paired corneal arcuate keratotomies were programmed in an 8.5 mm diameter optical zone, with 80% depth corneal local pachymetry guided by optical coherence tomography. FSAK was located at the steeper corneal meridian and was determined by limbal centering. The arc length of the arcuate incisions was planned using the nomogram created by Wendelstein et al., who modified Oshika nomogram based on age.[16] The FSAK parameters were laser pulse energy 1.7 μJ, spot spacing 5 μJ, and line spacing 2 μJ, and the side cut was set at 90 degrees. After femtosecond laser–assisted cataract surgery, a foldable aspheric nontoric IOL was implanted (Eye-CEE One, Bausch & Lomb GmbH) with a refractive target of emmetropia to −0.25 in all cases.

At the end of surgery, all corneal arcuate incisions were opened. No adverse events were reported.

The TIOL group underwent conventional phacoemulsification cataract extraction using the Whitestar Signature (Abbott Medical Optics, Inc.) platform and subsequent foldable aspheric TIOL implantation (Tecnis Toric ZCT, Abbott Medical Optics, Inc.).

Appropriate TIOL power and axis position were calculated with a toric calculator (Tecnis Toric Calculator, Abbott Medical Optics, Inc.). Typical surgically induced astigmatism (SIA) of 0.25 D was included in the TIOL calculations. The cylindrical power of the toric intraocular lens was selected to estimate a residual astigmatism close to zero. Before IOL implantation, additional marks were made on the patients' limbus using the Mendez marker to place the TIOL in the position indicated by the Tecnis Toric Calculator.

Once the TIOL was implanted in the capsular bag, the IOL was rotated clockwise to approximately 15 degrees short of the desired position. The residual ophthalmic viscosurgical device was removed, and the IOL was rotated clockwise again to align it more precisely with the intended axis.

Statistical Analysis

Refractive astigmatic changes were evaluated using the Alpins vector method in the ASSORT software (v. 5.64, Assort Pty Ltd.). Statistical analysis was performed using the SPSS 20.0 for Windows software (SPSS, Inc.). First, variable normality was checked using the Kolmogorov test. Comparisons between groups were performed using independent *t* tests. A *P* value of less than 0.05 was considered statistically significant. The Bonferroni adjustment was used to adjust the probability of the *P* value in statistical tests of multiple comparisons, dividing the usual significance level (of 0.05) by the total number of comparisons made.

RESULTS

In this study, 75 eyes were recruited from 67 patients: 38 eyes in the TIOL group and 37 eyes in the FSAK group. All patients were monitored for 3 months. In the TIOL group, 24 eyes (63%) showed with-the-rule (WTR) corneal astigmatism, and 14 eyes (37%) had against-the-rule (ATR) astigmatism. In the FSAK group, WTR astigmatism was found in 21 eyes (57%),

ATR astigmatism in 13 eyes (35%), and oblique astigmatism in 3 eyes (8%). None of the patients in either group dropped out of the study.

There were no statistically significant differences in the preoperative characteristics of the sample between the group of eyes implanted with TIOLs and the group of eyes that received FSAK, both groups being comparable across all parameters. The baseline parameters of the groups are tabulated in Table 1.

Visual Acuity

Although there was no criterion to exclude eyes with CDVA below 20/40, all eyes had CDVA of 20/40 or greater at 3 months postoperatively. The scores ranged from 20/40 (0.3 logMAR) to 20/15 (−0.12 logMAR).

There were no statistically significant differences between the 2 groups in UDVA or CDVA at 1 month or 3 months postoperatively (Table 2). VA was slightly greater in the group implanted with TIOLs at both 1 and 3 months postoperatively, with UDVA after 3 months being 0.10 ± 0.09 logMAR in the TIOL group and 0.16 ± 0.12 in the FSAK group.

Refraction and Residual Astigmatism

The residual refractive astigmatism values in the 2 groups did not show any statistically significant differences at either 1 month or 3 months postoperatively (Table 2). Three months postoperatively, the TIOL group maintained residual refractive astigmatism of ≤0.50 D in 21 eyes (55%) and of ≤1.00 D in 32 eyes (84%). In the FSAK group, these values were 14 eyes (38%) and 25 eyes (68%), respectively (Figure 1). The mean residual refractive cylinder in WTR astigmatisms was −0.68 ± 0.58 D in the TIOL group and −0.69 ± 0.41 D in the FSAK group. There were no statistically significant differences. The ATR astigmatisms showed a mean residual cylinder of −0.55 ± 0.50 D in the TIOL group and of −1.23 ± 0.59 D in the FSAK group, with statistically significant differences between them ($P = .038$).

The spherical equivalent (SEQ) values were closer to emmetropia in the TIOL group (−0.20 ± 0.38 D) than those in the FSAK group (−0.54 ± 0.55 D) at 3 months postoperatively, showing statistically significant differences ($P = .003$) (Table 2). All eyes in the TIOL group maintained a SEQ of ±1 D at 3 months postoperatively.

Keratometry

The postoperative reduction in keratometric astigmatism, at both the anterior and total surface level, was statistically significant in the FSAK group when compared with that in the TIOL group ($P < .001$), in which it remained unchanged (Table 3). In the FSAK group, mean WTR and ATR keratometric astigmatism were 0.88 ± 0.29 D and 0.92 ± 0.49 D, respectively. The mean total corneal astigmatism was 0.83 ± 0.43 D in WTR astigmatisms and 1.23 ± 0.52 D in ATR astigmatisms. There were no statistically significant differences between them at 3 months postoperatively.

There were no statistically significant differences in mean anterior keratometry (simulated keratometry [SimK]) or total mean power (total corneal refractive power [TCRP]) between the 2 groups during postoperative follow-up (Table 2). Neither were there statistically significant differences in the changes produced in SimK and TCRP in both groups in the preoperative period (Table 3).

Vector Analysis

Table 4 summarizes the results of vector analysis of the astigmatic refractive correction performed in the 2 groups using the Alpins method. The mean target-induced astigmatism (TIA) and SIA values were higher in the TIOL group than that in the FSAK group (2.12 ± 0.34 D vs 1.88 ± 0.33 D and 2.26 ± 0.58 vs 1.78 ± 0.60 D, respectively), presenting statistically significant differences between the 2 groups and even fulfilling the Bonferroni adjustment criterion in the case of SIA.

There were no statistically significant differences in difference vector (DV), angle of error, or magnitude error between the 2 groups at 3 months postoperatively.

The correction index, represented as the ratio between SIA and TIA, with an optimal value of 1.0, showed hypercorrection of refractive astigmatism in the TIOL group and hypo correction in the FSAK group, presenting statistically significant differences at 1 month ($P = .013$) but not at 3 months ($P = .068$) postoperatively.

The index of success, calculated as the ratio between the DV and TIA and indicates a better result the closer it is to 0, presented statistically significant differences between the 2 groups at both 1 month ($P = .022$) and 3 months ($P = .029$) postoperatively; its mean value was closer to 0 in the group implanted with TIOLs.

Table 1. Comparison of Baseline Parameters Between the TIOL and FSAK Groups.

Parameter	TIOL (n = 38), mean ± SD	FSAK (n = 37), mean ± SD	*P* Value
Age (y)	70.42 ± 8.26	73.08 ± 6.56	.128
UDVA	0.50 ± 0.18	0.55 ± 0.11	.191
CDVA (logMAR)	0.38 ± 0.21	0.44 ± 0.14	.111
Keratometric astigmatism (D)	2.12 ± 0.34	1.98 ± 0.35	.087
SimK (D)	44.80 ± 2.05	44.31 ± 1.55	.247
TCA (D)	2.16 ± 0.39	1.96 ± 0.55	.081
TCRP (D)	44.73 ± 2.07	44.39 ± 1.67	.431

FSAK = femtosecond laser–assisted arcuate keratotomy; SimK = simulated keratometry; TCA = total corneal astigmatism; TCRP = total corneal refractive power; TIOL = toric intraocular lens
*Bonferroni adjustment criterion $P \leq .007$

Table 2. Comparison of Astigmatism, Visual Acuity, and Refraction Over Time Between Groups.

Parameter	TIOL, mean ± SD	FSAK, mean ± SD	*P* Value
UDVA (logMAR)			
1 mo postop	0.12 ± 0.09	0.15 ± 0.11	.175
3 mo postop	0.10 ± 0.09	0.16 ± 0.12	.031
CDVA (logMAR)			
1 mo postop	0.04 ± 0,08	0.04 ± 0.09	.994
3 mo postop	0.02 ± 0,06	0.03 ± 0.08	.498
SEQ (D)			
1 mo postop	−0.26 ± 0.39	−0.48 ± 0.58	.064
3 mo postop	−0.20 ± 0.38	−0.54 ± 0.55	.003
Refractive astigmatism (D)			
1 mo postop	−0.68 ± 0.59	−0.96 ± 0.58	.045
3 mo postop	−0.63 ± 0.55	−0.90 ± 0.53	.037
Keratometric astigmatism (D)			
1 mo postop	2.25 ± 0.55	0.95 ± 0.53	<.001*
3 mo postop	2.14 ± 0.47	0.89 ± 0.37	<.001*
SimK (D)			
1 mo postop	44.75 ± 2.00	44.27 ± 1.57	.255
3 mo postop	44.78 ± 2.04	44.23 ± 1.50	.204
TCA (D)			
1 mo postop	2.34 ± 0.64	1.15 ± 0.57	<.001*
3 mo postop	2.24 ± 0,53	0.56 ± 0.50	<.001*
TCRP (D)			
1 mo postop	44.74 ± 2.07	44.42 ± 1.59	.455
3 mo postop	44.74 ± 2.13	44.21 ± 1.57	.167

FSAK = femtosecond laser–assisted arcuate keratotomy; SEQ = spherical equivalent; SimK = simulated keratometry; TCA = total corneal astigmatism; TCRP = total corneal refractive power; TIOL = toric intraocular lens
*Bonferroni adjustment criterion $P \leq .003$

Complications

There were no intraoperative or postoperative complications in any of the procedures.

DISCUSSION

Recent meta-analyses indicate that TIOL implantation is the procedure of choice because of its greater predictability (mild residual astigmatism) and safety when compared with other treatments such as nontoric IOL implantation with manual relaxing or arcuate incisions.[8,21,22] Good results in correction of astigmatism after cataract surgery have also been reported after the development of new nomograms used in FSAK because of the latter's greater precision and fewer complications when compared with manual arcuate keratotomy.[12,14–16]

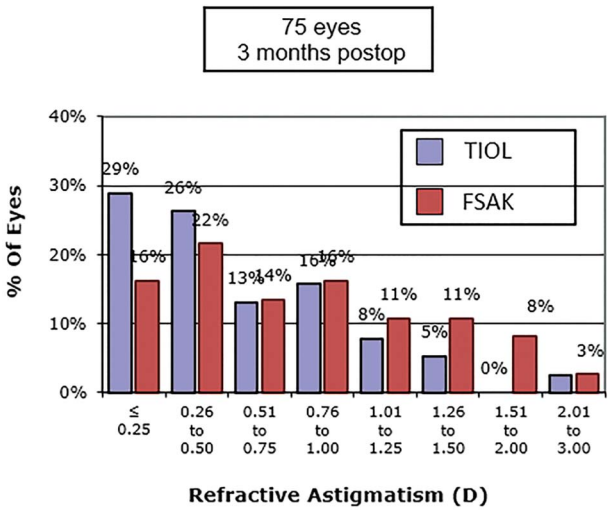

Figure 1. Percentage of eyes with postoperative residual refractive astigmatism. FSAK = femtosecond laser–assisted arcuate keratotomy; TIOL = toric intraocular lens

Although TIOL implantation corrects a wide range of astigmatisms, treating moderate astigmatism with FSAK merits further investigation as a possible alternative, particularly since very few articles compared the 2 techniques.[19,20,23] In this study, good UDVA and CDVA results were obtained with both procedures. Similarly, both achieved a clinically significant reduction in refractive astigmatism when compared with the preoperative corneal astigmatism. However, at 3 months postoperatively, UDVA was significantly higher in the TIOL group because of better correction of refractive astigmatism and obtained a SEQ closer to emmetropia than the FSAK group, where it was more negative (−0.54 ± 0.55 D). This myopization of the SEQ in both groups is explained by hypocorrection of the refractive astigmatism and by selection in the surgical plan of the IOL power predicted by the first negative SEQ value.

The mean anterior keratometry (SimK) and total mean power (TCRP) remained stable postoperatively, although the FSAK group showed a slight decrease in corneal power that did not amount to a clinically significant difference and did not affect the SEQ. These results match the conclusions of the clinical trial conducted by Faktorovich et al. in which astigmatic keratotomy had a minimal effect on the postoperative SEQ.[24]

Table 3. One-Month and 3-Month Postoperative Vs Preoperative Corneal Power and Astigmatic Changes: Comparison Between Groups.

Parameters	TIOL, mean ± SD	FSAK, mean ± SD	*P* Value
Keratometric astigmatism (D)			
1 mo postop vs Preop	0.12 ± 0.49	−1.02 ± 0.62	<.001*
3 mo postop vs Preop	0.02 ± 0.35	−1.09 ± 0.41	<.001*
SimK (D)			
1 mo postop vs preop	−0.04 ± 0.33	−0.10 ± 0.30	.462
3 mo postop vs preop	0.01 ± 0.19	−0.04 ± 0.26	.288
TCA (D)			
1 mo postop vs preop	0.17 ± 0.60	−0.76 ± 0.58	<.001*
3 mo postop vs preop	0.09 ± 0.44	−1.01 ± 0.65	<.001*
TCRP (D)			
1 mo postop vs preop	0.01 ± 0.22	−0.03 ± 0.94	.778
3 mo postop vs preop	0.07 ± 0.26	−0.12 ± 0.39	.012

FSAK = femtosecond laser–assisted arcuate keratotomy; SimK = simulated keratometry; TCA = total corneal astigmatism; TCRP = total corneal refractive power; TIOL = toric intraocular lens
*Bonferroni adjustment criterion $P \leq .002$

The reduction in preoperative corneal astigmatism in the FSAK group, although significant, was far smaller than either the target set or the TIA (0.89 ± 0.37 D vs TIA of 1.88 ± 0.33 D) and was less than that obtained by Wendelstein et al. with the same nomogram.[16] This difference can be explained by the higher degree of preoperative corneal astigmatism in the sample included in our study (1.98 ± 0.35 D) when compared with the study by Wendelstein et al. (1.45 ± 0.34 D), resulting in arcuate incisions of greater arcuate length that would take longer to heal and produce less predictable results. Several studies of eyes treated with FSAK also show slight hypocorrections of preoperative keratometric astigmatism when the TIA is greater than 1 D.[12,20,25,26] In all of them, preoperative corneal astigmatism did not exceed 1.45 D, which was lower than that in the sample in our study.

Effectiveness in correcting astigmatism was higher in the TIOL group than that in the FSAK group (Figure 2). Two previous studies, with sample sizes smaller than ours, compared the effectiveness of both techniques in correcting astigmatism.[19,20] As in our study, Yoo et al. did not find statistically significant differences in VA or cylindrical correction between the 2 groups.[20] However, these authors started from a preoperative corneal astigmatism lower than that presented in our study, both in the FSAK group (1.31 ± 0.13 D vs 1.98 ± 0.35 D) and in the TIOL group (1.41 ± 0.12 D vs 2.12 ± 0.34 D). By contrast, Noh et al. reported

Table 4. Vector Analysis Summary.

Surgically induced refractive correction	TIOL, mean ± SD	FSAK, mean ± SD	*P* Value
TIA (D)	2.12 ± 0.34	1.88 ± 0.33	.003
SIA			
1 mo postop	2.30 ± 0.63	1.71 ± 0.58	<.001*
3 mo postop	2.26 ± 0.58	1.78 ± 0.60	.001*
DV (D)			
1 mo postop	0.78 ± 0.86	0.97 ± 0.60	.269
3 mo postop	0.72 ± 0.83	0.92 ± 0.55	.228
AoE (degrees)			
1 mo postop	7.76 ± 12.41	12.77 ± 9.62	.060
3 mo postop	7.57 ± 12.55	11.37 ± 9.19	.140
ME (D)			
1 mo postop	0.17 ± 0.51	−0.14 ± 0.55	.011
3 mo postop	0.13 ± 0.47	−0.04 ± 0.59	.146
CI			
1 mo postop	1.08 ± 0,22	0.92 ± 0.28	.013
3 mo postop	1.06 ± 0.21	0.95 ± 0.30	.068
IS			
1 mo postop	0.34 ± 0,33	0.52 ± 0.30	.022
3 mo postop	0.32 ± 0.33	0.48 ± 0.29	.029

AE = angle of error; CI = correction index; DV = difference vector; FSAK = femtosecond laser–assisted arcuate keratotomy; IS = index of success; ME = magnitude error; SIA = surgically induced astigmatism; TIA = target induced astigmatism; TIOL = toric intraocular lens
*Bonferroni adjustment criterion $P \leq .003$

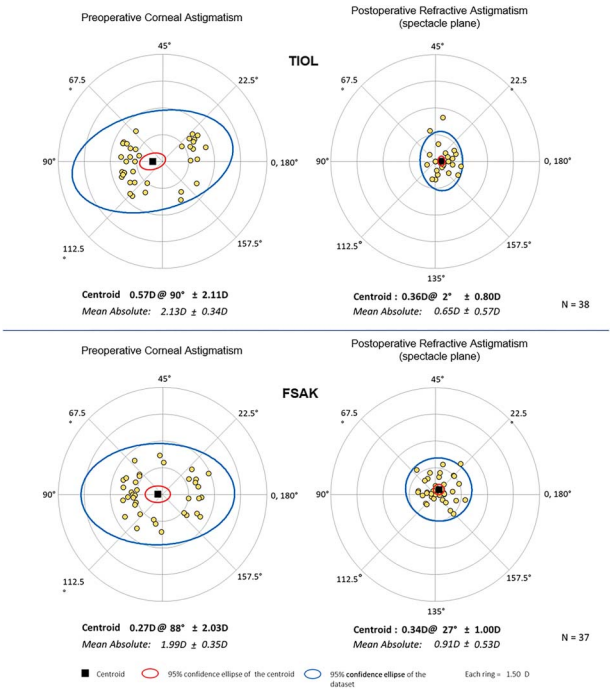

Figure 2. Distribution of preoperative corneal astigmatism and postoperative refractive astigmatism (spectacle plane) in both groups. FSAK = femtosecond laser–assisted arcuate keratotomy; TIOL = toric intraocular lens

statistically significant differences in residual refractive cylinder between both groups at 3 months postoperatively.[19] These authors obtained SIA in their FSAK group with astigmatisms greater than 1.50 D, much lower than their TIA (1.09 ± 0.60 vs 2.01 ± 0.64), whereas, in this study, the SIA of the FSAK group (1.78 ± 0.60) was similar to the TIA (1.88 ± 0.33). Taking into account that the AK incisions made by Noh et al. were not opened, this would explain the greater effect on the SIA of our AK incisions, although there would also be a decrease in the effectiveness of the SIA due to the more extensive healing process.

One possible bias in the results of the residual refractive cylinder would be that there are only steps from 0.50 D to 0.75 D in the cylindrical power of the TIOL, while the FSAKs are based on a linearly scalable nomogram.

The Alpins method can be used to analyze the results of both astigmatic corneal and refractive correction using vector analysis.[27,28] In this study, only the results of the vector analysis performed on astigmatic refractive correction were examined. This analysis showed statistically significant differences in the magnitude of the SIA between the 2 groups, with hypocorrection being observed in the FSAK group (SIA < TIA) and hypercorrection being observed in the TIOL group (SIA > TIA). These findings are corroborated by the values of the correction index at 3 months, with these being less than 1 in the FSAK group (0.95 ± 0.30) and greater than 1 in the TIOL group (1.06 ± 0.21). These results are similar to those obtained by Wang et al. in eyes treated with FSAK and to those obtained by Krall et al. in eyes implanted with TIOLs.[12,29] The index of success gives an astigmatic refractive correction result closer to optimal in eyes with TIOL implantation. This could be due to the greater angle of error in the FSAK group (11.37 ± 9.19 degrees) coupled with a higher DV (0.92 ± 0.55 D), which would reduce the effectiveness of the SIA.

Considering the different types of astigmatism in the initial sample, the ATR astigmatism in the FSAK group presented a higher residual refractive cylinder. This tendency to undercorrection in ATR astigmatism in the FSAK group can be explained by the greater influence of the posterior corneal surface, which would be in agreement with the study by Koch et al.[30] By contrast, the ATR astigmatism in the TIOL group presented the lowest residual refractive cylinder because of the greater effect of the SIA in this group, generating an inversion of the axis in both the WTR and ATR astigmatisms (Table 4).

The use of femtosecond laser technology in cataract surgery has the possibility of making more precise arcuate incisions as it enables control of parameters such as cutting depth, arc length, and optical area diameter, which are influenced by the human factor in manual techniques. Nevertheless, this article demonstrated that TIOL implantation remain a superior choice for correcting moderate astigmatisms because of their stability over time, producing results that are more predictable and less influenced by the biomechanical characteristics of the cornea and its healing.

Ongoing advances in femtosecond laser–assisted cataract surgery, together with the creation and optimization of specific nomograms for this technique, will minimize the uncertainty that incisional surgery to correct astigmatism currently entails.

This study's limitations are its small sample size and short follow-up period. Based on the results published, correction of astigmatism by AK is proposed as a robust alternative to TIOL implantation in cases of mild-to-moderate astigmatism. In some cases, both eyes of the same patient were used, so some bias may exist to the extent that genetic and environmental conditions could produce relationships between 2 eyes of the same patient. However, this situation only occurred in 8 of 75 eyes, so we consider the potential bias to be minimal. It would be beneficial for future studies to analyze long-term stability in corneal and refractive astigmatism and to recruit a larger sample that would make it possible to create subdivisions based on the different types of astigmatism (WTR, ATR, and oblique) to understand the effects of femtosecond laser–assisted arcuate incisions in each case.

WHAT WAS KNOWN

- New nomograms applied to femtosecond laser–assisted arcuate keratotomy (FSAK) to reduce mild-to-moderate astigmatism after cataract surgery have had similar success to toric intraocular lens (TIOL) implantation.
- There are limited published data comparing the outcomes of the 2 techniques for reducing corneal astigmatism.

WHAT THIS PAPER ADDS

- TIOL implantation continues to be the procedure of choice to correct moderate astigmatism after cataract surgery.
- Despite not being as predictable as TIOL implantation, FSAK is a safe technique that should be taken into account in correction of corneal astigmatism.

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Disclosures: *None of the authors has any financial or proprietary interest in any material or method mentioned.*

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