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Comparison of manual and femtosecond astigmatic keratotomy in the treatment of postkeratoplasty astigmatism

Nir Sorkin,[1,2] Michael Mimouni,[1] Gisella Santaella,[1] Mohammad Kreimei,[1] Tanya Trinh,[1] Yelin Yang,[1] Danyal Saeed,[3] Eyal Cohen,[1] David S. Rootman,[1] Clara C. Chan[1] and Allan R. Slomovic[1]

[1]Department of Ophthalmology and Vision Sciences, University of Toronto, Toronto, ON, Canada
[2]Department of Ophthalmology, Tel Aviv Medical Center and Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel
[3]Michael G. DeGroote School of Medicine, McMaster University, Hamilton, ON, Canada

ABSTRACT.
Purpose: **To compare the outcomes of femtosecond astigmatic keratotomy (FSAK) and manual astigmatic keratotomy (AK) in treatment of postkeratoplasty astigmatism.**
Methods: **A retrospective, comparative, pairwise-matched case series including 150 patients who underwent either FSAK (*n* = 75) or manual AK (*n* = 75) for the treatment of astigmatism (>3.00 D) following penetrating keratoplasty or deep anterior lamellar keratoplasty. Pairwise matching for baseline variables (age, visual acuity and astigmatism) was performed.**
Results: **Mean age was 57.5 ± 16.0 years. The FSAK group had significantly better postoperative best-corrected visual acuity (BCVA) (p = 0.010), uncorrected visual acuity (UCVA) (p = 0.049), corneal astigmatism (p = 0.020) and manifest astigmatism (p < 0.001) compared with the manual AK group. Gain of ≥3 lines in BCVA (logMAR) was seen in five eyes (6.7%) and 21 eyes (28.0%) in manual AK and FSAK, respectively (p = 0.005). Alpins vector analysis showed lower (closer to 0) index of success (0.50 ± 0.24 and 0.79 ± 0.48, p < 0.001) and higher (closer to 1) correction index (0.94 ± 0.45 and 0.74 ± 0.55, p = 0.020) in FSAK compared with manual AK. Corneal and manifest astigmatism improved significantly in both groups, while BCVA and UCVA improved significantly in FSAK only.Repeat AK rate was 32% (24 eyes) in manual AK and 4% (three eyes) in FSAK (p < 0.001). Overcorrection-related re-suturing rate was 0% in manual AK and 8% (six eyes) in FSAK (p = 0.037). There was one microperforation (1.3%) in FSAK, and there were no occurrences of graft dehiscence, infectious keratitis or graft rejection.**
Conclusions: **Both manual AK and FSAK were safe and effective in reducing postkeratoplasty astigmatism. FSAK had superior visual and keratometric outcomes compared with manual AK.**

Key words: arcuate keratotomy – astigmatic keratotomy – astigmatism – deep anterior lamellar keratoplasty – femtosecond – femtosecond astigmatic keratotomy – keratoplasty – manual astigmatic keratotomy – manual – penetrating keratoplasty

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Introduction

Astigmatism following corneal transplantation is a common finding, with average postkeratoplasty corneal astigmatism ranging between 4 and 6 dioptres (Busin et al. 1998; Karabatsas et al. 1998; Riddle et al. 1998; Çakir et al. 2018). Lower degrees of astigmatism can be managed successfully with spectacles or soft toric contact lenses. However, higher degrees of astigmatism require either rigid contact lenses or surgical intervention. As corneal astigmatism can greatly affect visual outcomes and patient satisfaction (De Molfetta et al. 1979; Perlman 1981; Williams et al. 1991), as many as 8–20% of postkeratoplasty patients require surgical procedures to correct intolerable astigmatism (Kirkness et al. 1991; Sharif & Casey 1991).

Astigmatic keratotomy (AK), also known as arcuate keratotomy, has been performed for more than a century to correct astigmatism. While it is a robust tool, capable of reducing large amounts of astigmatism, its predictability is lower compared with other astigmatism-correcting procedures (Butrus et al. 2007). Therefore, newer AK techniques have been introduced in an effort to improve the procedure's predictability and safety profile (Ho Wang Yin & Hoffart 2017). The advent of femtosecond laser technology and its incorporation into corneal surgery enables the formation of precise stromal incisions whose depth, length, location and shape can be accurately adjusted. In addition to manual AK performed using a surgical blade, and mechanized AK performed using mechanical keratome, surgeons are able to perform AK incisions using a femtosecond laser. While femtosecond astigmatic keratotomy (FSAK) produces precise AK incisions, it carries additional costs and logistics that are not required with manual AK.

While multiple single-arm studies have found FSAK to be effective in reducing postkeratoplasty astigmatism (Kumar et al. 2010; Fadlallah et al. 2015; Trivizki et al. 2015; Al Sabaani et al. 2016; St. Clair et al. 2016; Hashemian et al. 2017; Chang 2018; anNakhli & Khattak 2019; Elzarga et al. 2019), only two previous publications directly compared outcomes of FSAK with those of manual AK, and found no statistically significant differences in postoperative visual or refractive outcomes between the groups (Bahar et al. 2008; Al-Qurashi et al. 2019). Similar results were found in a prospective comparison of FSAK (10 eyes) and mechanized AK (10 eyes), where a significant difference between the groups was found for manifest astigmatism, but not for any other visual or refractive parameter (Hoffart et al. 2009). The authors concluded that larger comparative series are required to better understand outcome differences of different AK techniques in the management of postkeratoplasty astigmatism.

The purpose of this study was to compare treatment outcomes of FSAK and manual AK in a large group of pairwise-matched eyes with postkeratoplasty astigmatism, incorporating methodology to account for vectorial axis changes as well.

Methods

This retrospective study included patients who underwent either manual AK or FSAK for the treatment of high astigmatism (>3.00 D) following penetrating keratoplasty (PKP) or deep anterior lamellar keratoplasty (DALK) between 2013 and 2017. Cases of significant irregular astigmatism with no discernible steep axis where AK was not performed were excluded from the analysis. The procedures were performed at the Toronto TLC Laser Center and Toronto Western Hospital (Toronto, ON, Canada) by three corneal surgeons (CCC, ARS and DSR). This study received Research Ethics Board approval from the University of Toronto and from the University Health Network, and adhered to the tenets of the Declaration of Helsinki.

Outcome measures included best-corrected visual acuity (BCVA), uncorrected visual acuity (UCVA), corneal astigmatism, manifest astigmatism, keratometry, manifest sphere and need for repeat procedures. Keratometry and corneal astigmatism were obtained using the OPD Scan II ARK 10000 topographer (NIDEK, Tokyo, Japan). Postoperative data were obtained from the latest visit available, ranging from 2 to 6 months following surgery.

All 75 consecutive manual AK eyes (75 patients) were included. Pairwise matching using the van Casteren and Davis Match software was performed to match 75 eyes (75 patients) that underwent FSAK (out of 131 eligible eyes) (Van Casteren & Davis 2007). Matching was performed for baseline variables: age, preoperative UCVA, preoperative BCVA and preoperative corneal astigmatism. When considering postoperative mean BCVA values of 0.44 ± 0.38 logMAR for manual AK and 0.29 ± 0.26 logMAR for FSAK, found in a study by Bahar et al. (2008) the current study had a power of 80% in determining a significant postoperative BCVA difference between the groups, using a sample size of 75 eyes in each group and a p-Value of 0.05.

Data were recorded in Microsoft Excel (2016)™ and analysed using Minitab Software, version 17 (Minitab Inc, State College, PA, USA). Visual acuity values were obtained with a Snellen chart and converted into logMAR. For comparison between preoperative and postoperative continuous variables, the paired *t*-test was used. For comparison of continuous variables between groups, the *t*-test for independent means was used. Categorical variables were compared between groups using the chi-squared test. Astigmatism vector analysis was performed at the corneal plane (vertex of 12 mm) using the Alpins method (Alpins & Goggin 2004). All tests were 2-tailed, and the threshold for statistical significance was defined as a p-value <0.05.

Surgical technique

Complete removal of all graft sutures was required at least 3 months prior to the procedure, with verification of refractive stability. The steep astigmatism axis was determined using corneal topography.

Femtosecond astigmatic keratotomy

Arcuate keratotomy was performed using the iFS IntraLase system (Johnson and Johnson Vision, Jacksonville, FL, USA) under topical anaesthesia (proparacaine 0.5%). Our FSAK technique has been previously described (Sorkin et al. 2020). Briefly, the horizontal and steep axes were marked under the Visx laser (Johnson and Johnson Vision) utilizing the reflection of the circular light on the tear film. The eyelids were prepared with Betadine sponges. Ultrasound pachymetry was performed (Corneo-Gage; Sonogage Inc, Cleveland, OH, USA) to determine graft thickness at the position of the proposed incision. Paired symmetric arcuate incisions were centred around the graft centre and on the topographic location of the steep axis. The incisions were positioned 0.5 mm anterior to the graft–host junction with the incision depth set at 90% of the thinnest measured ultrasound pachymetry. Incision angles (arc length of the incisions) were set according to the following nomogram: 6–8 D of corneal astigmatism was treated with 30- to 45-degree arc length, 8–10 D with 45- to 65-degree arc length, 10–15 D with 70- to 75-degree arc length and greater than 15 D with 90-degree arc length. The laser's limbal suction ring was then applied and the cone positioned so that the fluid meniscus was beyond the graft–host junction. Once the procedure was complete, the suction was released, and the ring was removed.

Manual AK

The eyelids were prepared with Betadine. The patient was placed at the slit lamp, and the steep meridian was marked at the edge of the keratoplasty using a surgical marking pen. Paired incisions were made in the steepest meridian and placed 0.5 mm anterior to the graft–host junction, using a surgical blade, at 75% corneal depth. The arcuate lengths of the cuts were determined by analysing the location and the extent of the steepest meridians

Table 1. Indications for keratoplasty.

	Manual AK (*n* = 75)	FSAK (*n* = 75)	Entire cohort (*n* = 150)
Keratoconus	28 (37.3%)	32 (42.7%)	60 (40.0%)
Herpetic keratitis	11 (14.7%)	5 (6.7%)	16 (10.7%)
Bullous keratopathy	5 (6.7%)	4 (5.3%)	9 (5.6%)
Failed graft	6 (8.0%)	1 (1.3%)	7 (4.7%)
Trauma	3 (4.0%)	3 (4.0%)	6 (4.1%)
Corneal scarring	4 (5.3%)	2 (2.7%)	6 (4.1%)
Stromal dystrophy	5 (6.7%)	1 (1.3%)	6 (4.1%)
Fuchs' dystrophy	2 (2.7%)	3 (4.0%)	5 (3.3%)
Corneal ulcer	1 (1.3%)	3 (4.0%)	4 (2.7%)
Unknown	10 (13.3%)	21 (28.0%)	31 (20.7%)

AK = astigmatic keratotomy, FSAK = femtosecond astigmatic keratotomy.

Table 2. Baseline characteristics of the manual AK and FSAK groups.

	Manual AK (*n* = 75)	FSAK (*n* = 75)	p-Value
Age (years)	58.4 ± 16.1	56.6 ± 15.9	0.500
Gender – Male	38 (50.7%)	41 (54.7%)	0.680
Keratoplasty indication			
Herpetic scarring	11 (14.7%)	5 (6.7%)	0.280
Keratoconus	28 (37.3%)	32 (42.7%)	
Other	36 (48.0%)	38 (50.7%)	
Graft diameter (mm)	7.8 ± 0.3	7.8 ± 0.6	0.405
BCVA (logMAR)	0.57 ± 0.30	0.55 ± 0.27	0.600
UCVA (logMAR)	1.09 ± 0.47	1.16 ± 0.45	0.380
Corneal astigmatism (D)	8.70 ± 3.30	9.40 ± 2.80	0.180
Manifest astigmatism (D)	7.44 ± 3.49	6.81 ± 2.22	0.250
Manifest sphere (D)	−0.08 ± 4.53	−0.12 ± 5.77	0.970
Steep keratometry (D)	51.0 ± 4.1	51.5 ± 3.5	0.400
Flat keratometry (D)	42.1 ± 3.4	42.1 ± 3.2	0.970
AK arc length (degrees)	67.9 ± 16.4	64.1 ± 12.8	0.144

AK = astigmatic keratotomy, BCVA = best-corrected visual acuity, FSAK = femtosecond astigmatic keratotomy, UCVA = uncorrected visual acuity.

in the topographic map (45–90 degrees) (Geggel 2006; Poole & Ficker 2006).

Postoperatively, patients received topical tobramycin and dexamethasone (TobraDex; Alcon, Mississauga, ON, Canada) four times daily for 1 week. Thereafter, they were placed back on their antirejection topical steroid maintenance dose.

Results

Overall, 150 eyes of 150 patients were included (75 eyes in the manual AK group and 75 eyes in the FSAK group). Mean age was 57.5 ± 16.0 years, with 79 male patients (52.7%). Main indications for keratoplasty were keratoconus (40.0%) and herpetic scarring (10.7%) (Table 1). The type of previous keratoplasty in the manual AK and FSAK groups was PKP in 72 of 75 eyes (96%) and 58 of 75 eyes (77%), respectively ($p = 0.002$). All other eyes had DALK. There were no other significant differences between the manual AK and FSAK groups in any of the baseline characteristics (Table 2).

Table 3 compares postoperative outcome parameters of the manual AK group and FSAK group.

Visual acuity

Mean BCVA in the manual AK group was 0.57 ± 0.30 logMAR (Snellen equivalent ~20/75) preoperatively and 0.56 ± 0.31 logMAR (Snellen equivalent ~20/70) postoperatively ($p = 0.170$). Mean BCVA in the FSAK group was 0.55 ± 0.27 logMAR (Snellen equivalent ~20/70) preoperatively and 0.41 ± 0.37 logMAR (Snellen equivalent ~20/50) postoperatively ($p < 0.001$). Postoperative BCVA was significantly better in the FSAK group ($p = 0.010$). Loss of 3 or more lines of logMAR BCVA was seen in four eyes (5.3%) and five eyes (6.7%) in manual AK and FSAK, respectively ($p = 0.905$). Gain of 3 or more logMAR BCVA lines was seen in five eyes (6.7%) and 21 eyes (28.0%) in manual AK and FSAK, respectively ($p = 0.005$).

Mean UCVA in the manual AK group was 1.09 ± 0.47 logMAR (Snellen equivalent ~20/245) preoperatively and 1.06 ± 0.47 logMAR (Snellen equivalent ~20/230) postoperatively ($p = 0.390$). Mean UCVA in the FSAK group was 1.16 ± 0.45 logMAR (Snellen equivalent ~20/290) preoperatively and 0.89 ± 0.51 logMAR (Snellen equivalent ~20/155) postoperatively ($p < 0.001$). Postoperative UCVA was significantly better in the FSAK group ($p = 0.049$).

Astigmatism and spherical equivalent

Corneal astigmatism magnitude decreased from 8.70 ± 3.30 D preoperatively to 6.20 ± 3.90 D postoperatively in the manual AK group ($p < 0.001$), and from 9.40 ± 2.80 D preoperatively to 4.80 ± 3.20 D postoperatively in the FSAK group ($p < 0.001$). Postoperative corneal astigmatism was significantly lower in the FSAK group ($p = 0.020$). Vector analysis of the astigmatic corneal treatment effect is shown in Table 4. Values of surgically induced astigmatism (SIA), difference vector (DV), magnitude of error (MOE), coefficient of adjustment, index of success, correction index, flattening effect and flattening index were all significantly better in the FSAK group.

Manifest astigmatism magnitude decreased from 7.44 ± 3.49 D preoperatively to 5.90 ± 3.60 D postoperatively ($p = 0.003$) in the manual AK group, and from 6.81 ± 2.22 D preoperatively to 3.90 ± 1.60 D postoperatively in the FSAK group ($p < 0.001$). Postoperative manifest astigmatism was significantly lower in the FSAK group ($p < 0.001$).

Manifest sphere decreased from −0.08 ± 4.53 D preoperatively to −1.90 ± 4.90 D postoperatively in the manual AK group ($p = 0.006$), and from −0.12 ± 5.77 D preoperatively to −2.20 ± 5.10 D postoperatively in the FSAK group ($p < 0.001$). Postoperative manifest sphere was not significantly different between the groups ($p < 0.740$). Keratometry values did not show significant changes

Table 3. Postoperative outcome parameters of the manual AK and FSAK groups.

	Manual AK (*n* = 75)	FSAK (*n* = 75)	p-Value
BCVA (logMAR)	0.56 ± 0.31	0.41 ± 0.37	**0.010**
BCVA Gain ≥ 3 lines (logMAR)	5 (6.7%)	21 (28.0%)	**0.005**
UCVA (logMAR)	1.06 ± 0.47	0.89 ± 0.51	**0.049**
Corneal astigmatism (D)	6.20 ± 3.90	4.80 ± 3.20	**0.020**
Manifest astigmatism (D)	5.90 ± 3.60	3.90 ± 1.60	**<0.001**
Manifest sphere (D)	1.90 ± 4.90	2.20 ± 5.10	0.740
Steep keratometry (D)	50.3 ± 4.2	49.7 ± 3.7	0.380
Flat keratometry (D)	44.1 ± 3.9	44.9 ± 3.1	0.220

AK = astigmatic keratotomy, BCVA = best-corrected visual acuity, FSAK = femtosecond astigmatic keratotomy, UCVA = uncorrected visual acuity. Statistically significant p values ($p < 0.05$) are highlighted in bold.

Table 4. Astigmatism results (Alpins method).

	Manual AK	FSAK	p-Value
TIA (D)	9.03 ± 3.72	9.33 ± 2.70	0.590
SIA (D)	5.82 ± 3.67	9.04 ± 5.68	**0.001**
Angle of error (degrees)	0.5 ± 33.9	−2.4 ± 27.9	0.570
Magnitude of error (D)	−3.14 ± 4.22	−0.32 ± 4.57	**<0.001**
Correction index (geometric)	0.74 ± 0.55	0.94 ± 0.45	**0.020**
Coefficient of adjustment	2.53 ± 2.94	1.47 ± 1.29	**0.007**
Difference vector magnitude (D)	6.37 ± 3.56	4.65 ± 2.59	**0.002**
Index of success (geometric)	0.79 ± 0.48	0.50 ± 0.24	**<0.001**
Flattening effect	3.24 ± 5.15	7.40 ± 6.97	**<0.001**
Flattening index	0.38 ± 0.70	0.75 ± 0.64	**0.001**

SIA = surgically induced astigmatism, TIA = target-induced astigmatism. Statistically significant p values ($p < 0.05$) are highlighted in bold.

postoperatively in any of the groups and did not differ significantly between the groups (Table 3).

Repeat procedures and safety

Repeat AK was performed in 24 eyes (32%) in the manual AK group and in three eyes (4%) in the FSAK group ($p < 0.001$), with a mean of 0.47 ± 0.97 procedures per eye in manual AK, and 0.05 ± 0.21 procedures per eye in FSAK (p = 0.001). Wound re-suturing due to over correction was not performed in manual AK and was performed in 6 eyes (8%) in FSAK (p = 0.037). There were no perforations in manual AK and one microperforation (1.3%) in FSAK, which was managed successfully with suturing of the AK incision. There were no occurrences of graft dehiscence, infectious keratitis or graft rejection.

Subanalysis of penetrating keratoplasty eyes

As the vast majority of eyes in the cohort underwent PKP (130 of 150 eyes, 87%), and as the ratio of PKP to DALK differed significantly between the manual AK and FSAK groups (PKP: 72 of 75 eyes [96%], DALK: 58 of 75 eyes [77%], p = 0.002), a subanalysis was performed comparing FSAK and manual AK in PKP eyes only. In the subanalysis, all analysed postoperative parameters including BCVA, gain of >3 BCVA lines, UCVA, corneal astigmatism, manifest astigmatism, index of success and correction index were significantly better in the FSAK group (Table 5).

Discussion

This study compared outcomes of manual AK and FSAK performed in pairwise-matched eyes with postkeratoplasty astigmatism. Although the efficacy and safety of FSAK in the management of postkeratoplasty astigmatism is well established in the literature (Kumar et al. 2010; Fadlallah et al. 2015; Trivizki et al. 2015; Al Sabaani et al. 2016; St. Clair et al. 2016; Hashemian et al. 2017; anNakhli & Khattak 2019; Elzarga et al. 2019), there are little available data comparing it with manual AK techniques (Bahar et al. 2008; Hoffart et al. 2009; Al-Qurashi et al. 2019). To the best of our knowledge, previously published comparative studies did not find any statistically significant advantage of FSAK over manual AK in any visual or keratometric parameter (Bahar et al. 2008; Hoffart et al. 2009; Al-Qurashi et al. 2019).

In the current study, both manual AK and FSAK effectively reduced manifest and corneal astigmatism. However, the astigmatic effect of FSAK was superior, as evident by the arithmetic change in astigmatism magnitude and by the results of vector analysis. Although both procedures had a similar astigmatic target (similar target-induced astigmatism values), the surgical effect of FSAK was significantly larger. This is nicely represented in FSAK's index of success of 0.50, which was significantly smaller than an index of success of 0.79 in manual AK. Although both procedures trended towards undercorrection, FSAK's correction index of 0.94 was significantly closer to 1.00 when compared to a correction index of 0.74 in manual AK. The correction index and index of success of FSAK in the current study are comparable to previously published vector analyses of FSAK outcomes (anNakhli & Khattak 2019; Elzarga et al. 2019). One possible explanation for the low correction index seen in manual AK can be the fact that manual AK incisions were aimed at 75% depth while FSAK incisions were aimed at 90% depth. As the deeper the cut, the larger the effect, this difference in planned incision depth is clinically significant (Price et al. 1995). In addition, manual AK may not be uniform in depth and have shallow parts, especially on its edges.

The higher rate of repeat AK procedures in the manual AK group can also be explained by the reduced correction index. As manual AK patients were more undercorrected, they required more repeat AK procedures to achieve a better astigmatic effect. More undercorrection will also translate into less improvement in visual acuity, and can explain the differences in BCVA and UCVA found between manual AK and FSAK. On the other hand, reduced undercorrection in the FSAK group can lead to more cases of overcorrection. This would explain the higher rate of overcorrection-related

Table 5. Postoperative outcome parameters of manual AK and FSAK in eyes with a PKP graft.

	Manual AK (*n* = 72)	FSAK (*n* = 58)	p-Value
BCVA (logMAR)	0.57 ± 0.31	0.37 ± 0.30	0.001
BCVA Gain ≥3 lines (logMAR)	5 (6.7%)	21 (28.0%)	<0.001
UCVA (logMAR)	1.09 ± 0.47	0.82 ± 0.46	0.049
Corneal astigmatism (D)	6.30 ± 4.00	4.60 ± 2.60	0.008
Manifest astigmatism (D)	5.90 ± 3.70	3.60 ± 1.40	<0.001
SIA (D)	5.90 ± 3.71	8.22 ± 4.46	0.002
Correction index (geometric)	0.74 ± 0.55	0.89 ± 0.40	0.012
Index of success (geometric)	0.80 ± 0.49	0.50 ± 0.24	<0.001

AK = astigmatic keratotomy, BCVA = best-corrected visual acuity, FSAK = femtosecond astigmatic keratotomy, PKP = penetrating keratoplasty, SIA = surgically induced astigmatism, UCVA = uncorrected visual acuity.

wound re-suturing (8%) seen in the FSAK group compared with no such cases in the manual AK group (p = 0.037). Similar rates of suturing for overcorrection (4.8–8.1%) have been previously reported with FSAK (Kumar et al. 2010; Fadlallah et al. 2015). Undercorrection and overcorrection are a result of suboptimal predictability of the AK procedure in general. FSAK after keratoplasty necessitates its own nomogram (in contrast to nomograms produced for virgin corneas), as the fibrotic rim created at the graft–host junction has a different tension than the natural limbus, and also as postkeratoplasty astigmatism magnitudes are higher than those available in nomograms used for virgin corneas. It is our impression that currently available FSAK nomograms are associated with significant overcorrection (St. Clair et al. 2016). Therefore, we are currently using the basic nomogram described in this manuscript, which is based solely on clinical judgement. Efforts are ongoing to try and produce better nomograms that will improve FSAK accuracy. The same issue applies to manual AK. Although manual AK has been in use for over four decades, a standardized universal manual AK nomogram is not yet available. Several publications have described the use of the Hanna nomogram, which was constructed for the mechanical Hanna arcitome, and has been used by groups performing mechanical AK using this device but not by groups performing manual AK (Hanna et al. 1993; Borderie et al. 1999; Hoffart et al. 2007). Manual AK surgical technique in published literature does not include a standardized nomogram (Hjortdal & Ehlers 1998; Geggel 2006; Poole & Ficker 2006; Fares et al. 2013). Therefore, it appears that future research aimed at developing manual AK nomograms can be of significant benefit.

There was one case of microperforation in the FSAK group (1.3%), successfully managed with suturing. The incidence rates of microperforations in postkeratoplasty eyes undergoing FSAK have been reported to be between 3.2% and 8.7% (Fadlallah et al. 2015; Al Sabaani et al. 2016; Hashemian et al. 2017). Although microperforation rate in the current study was low, this is a complication that can have serious potential consequences, and efforts should be made to reduce its risk as much as possible. As FSAK incisions are of precise depth, the cause for perforations in this scenario could be inaccurate pachymetry measurements, with resultant overestimation of corneal thickness. FSAK incisions were programmed for 90% corneal depth, and therefore, there was little room for error. Studies comparing pachymetry modalities such as ultrasound, Scheimpflug and optical coherence tomography in this setting can help improve incision depth accuracy and reduce the incidence of perforations. Until such studies are available, it may be recommended to reduce FSAK incision depth to 80% corneal depth.

This study is limited by its retrospective nature. In addition, data on regularity indices were not available for comparison between the groups. Nevertheless, this is, to the best of our knowledge, the first study to compare pairwise-matched FSAK and manual AK groups. This fact, together with the relatively large sample size, can explain the significant outcome differences found between the two techniques, which have not been described previously. Although manual AK had inferior outcomes, it was safe and effective in significantly reducing corneal and manifest astigmatism. Therefore, we believe that manual AK has a place in clinical practice when considering procedure costs and associated logistics, both of which are reduced in manual AK compared with FSAK.

In conclusion, both manual AK and FSAK were safe and effective in reducing postkeratoplasty astigmatism. FSAK had superior visual and keratometric outcomes compared with manual AK.

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Correspondence:
Nir Sorkin MD
Department of Ophthalmology and Vision Sciences
Toronto Western Hospital
399 Bathurst St
6th Floor East Wing
Reception 1
Toronto
ON M5T 2S8
Canada
Tel: +1-647-860-1871
Fax: +1-416-603-1993
Email: nir.sorkin@gmail.com

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