One-year results and safety of femtosecond arcuate incisions for high post-keratoplasty astigmatism treatment: time to rethink the procedure?

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Abstract

Background/Aims High astigmatism after keratoplasty is the main limiting factor for visual rehabilitation. Among its treatment options the arcuate keratotomy (AK) with the femtosecond laser stands out for its perfection and versatility of the incision making. We designed a study to evaluate the results and safety of femtosecond arcuate keratotomy (femto-AK) in the treatment of high astigmatism after keratoplasty.

Methods A prospective interventional cohort study. We enrolled 17 eyes with high degree of irregular astigmatism, scheduled for Femto-AK. IntraLase FS was used to perform arcuate incisions 1.00 mm inside the graft. Patients' uncorrected visual acuity (UCVA), best spectacle corrected visual acuity (BDCVA), and astigmatic change were recorded and followed up to one year after surgery.

Results Despite overall improvement in corneal cylinder and visual acuity in one-year follow-up, there was a 52.9% complication rate. Cylinder overcorrection occurred in 6 cases (35.3%) that was managed with compressive sutures; microperforation occurred in two cases (11.7%); and endothelial rejection in one case (5.9%).

Conclusion The predictability of astigmatism correction was variable in reducing postkeratoplasty astigmatism and high complication rate was found in our case series. New nomograms and improvements in technique need to be developed in order to reduce the incidence of overcorrections.

Introduction

Currently, success rates of keratoplasty, defined as transparency of the cornea one year postoperative, are above 90% [1]. However, a transparent cornea does not always mean satisfactory visual outcome, being postoperative astigmatism the main responsible factor for an unsatisfying visual rehabilitation [2, 3]. The high astigmatism has a negative impact on quality of life of cornea transplanted patients [4] and may be related to various factors as quality of trepanning, disparities between donor and recipient cornea, irregularities in the incision configuration, recipient underlying disease, suture technique, and postoperative control of astigmatism [5].

In the first year after corneal transplantation, the most widely used method to control the astigmatism is the selective removal of corneal sutures. Despite this, only 27% to 34 % of patients have astigmatism less than or equal to 3.0D in two years [6]. When high astigmatism persists after all sutures are removed, and when the patient does not tolerate hard contact lenses, surgical methods of postoperative astigmatism reduction can be used, including wedge resection [7], compression sutures, intrastromal ring segments, refractive surgery with excimer laser, [8] and arcuate keratotomies (AK) [9].

For mixed or simple myopic astigmatism, AK may represent an interesting option [10]. Manual AK, including freehand techniques [9] or mechanical techniques using devices such as Hanna arcitome [11], is an established method of addressing high degree of post-keratoplasty astigmatism that cannot be managed by spectacle lenses or hard contact lenses. The main principle of AK is based on flattening the steep corneal meridian by placing 1 or 2 incision at the steep axis. This flattens the steep meridian with a reciprocal steepening of the flat meridian 90 degrees away, known as a "coupling effect" [9].

In 2006, femtosecond laser was first used to create PKP incisions (top-hat wound configuration) [12] and to perform femtosecond laser-assisted astigmatic keratotomy [13]. Femtosecond laser arcuate incisions are more precise in arc depth, diameter, length, and curvature [14]. This technique seems to be better than manual keratotomy in terms of safety and fewer higher-order aberrations [15, 16, 17, 18].

This prospective interventional study describes our results in safety and efficacy of femtosecond laser-assisted AK to treat high astigmatism after keratoplasty.

Patients And Methods

Patients

We have included 17 consecutive patients (8 males, 9 females) from May 2014 to July 2015. Institutional ethics committee approval and informed consent for all participants were obtained for this study. Eyes with at least 5.0 of postkeratoplasty astigmatism were included. The time between keratoplasty and AK varied from 1 to 25 years. The keratotomies were performed after at least 2 years of all suture removal. Sixteen patients were submitted to penetrating keratoplasty while one patient was submitted to deep anterior lamellar keratoplasty.

Preoperative evaluation included slit-lamp examination of anterior and posterior segment, refraction, best spectacle-corrected visual acuity (BSCVA) and corneal Scheimpflug tomography (Pentacam HR, Oculus Optikgeräte GMbH).

Inclusion criteria included a clear cornea graft and a corneal topography with a regular, symmetric or asymmetric, astigmatism.

Outcome measures included BSCVA, manifest refraction and Pentacam® tomographic measures. Patients were followed postoperatively at 1 day; 1 week; and 1, 3, 6 and 12 months and so each year or less if necessary. Postoperatively, patients were treated with a topical combination of 0.3% gatifloxacine and 1% prednisolone acetate drops (Zypred, Allergan®), four times a day for 1 week and then were placed on a maintenance dose of a topical steroid according to their individual requirements, as well as lubricant eyedrops.

Surgical technique

All surgeries were performed by the same surgeon (SK), under topical anesthesia (proxymetacaine hydrochloride 0,5%) using a 60KHz Intralase FS system (intralase Corp.). All patients received 0.3% gatifloxacine (Zymar, Allergan®) and 0.5% ketorolac thromethamine (Acular LS, Allergan®) eyedrops every 30 min 2 hours prior surgery.

The laser's limbal suction ring was applied and cone positioned. Applanation was considered adequate if the fluid meniscus was at least beyond the graft-host junction (hard docking).

All surgeries were performed using a single or a paired asymmetric incision centred on the topographic location of the steep meridian, according to Hurmeric and Yoo nomogram [24]. The optical zone ranged from 6.00 to 6.75 mm in diameter and the incision depth was 90% of Scheimpflug pachymetric measurement in 8 cases and 85% in 9 cases (incision depth ranged from 410 to 567um). Lateral cut angles ranged from 60 to 90 degrees and anterior side-cut angle was set at 90 degrees in all cases. The change in astigmatism was assessed by absolute cylinder variation in refraction and by Scheimpflug tomographic measurements.

Statistical Analysis

SPSS software (version 18.0, SPSS, Inc.) were used for statistical analysis. A paired t test was used to compare continuous variables. Data were expressed as means ± SD, and P value of less than 0.05 was considered statistically significant.

Results

Seventeen eyes of 17 patients (8 men, 9 women) were included in the study. The mean age of patients was 40 years. Keratoconus was indication for keratoplasty in 15 cases (88%). The mean interval from keratoplasty to the AK procedure was 8.2 years. Table 1 describes patient´s demography.

Table 1. Preoperative characteristics.

Variable	Result
Age (years)	
Mean ± SD	48.8±14.6
Range	21-75
Gender	
Male, n (%)	8 (47%)
Female, n (%)	9 (53%)
Indication for keratoplasty	
Keratoconus, n (%)	15 (88%)
Bullous keratopathy, n (%)	2 (12%)
Time keratoplasty-AK (years)	
Mean ± SD	8.2±7.7
Range	12-18
Follow-up (mo)	
Mean ± SD	9.1±4.4
Range	3-18

SD, standard deviation; AK, arcuate keratotomy; mo, months.

Topographic cylinder reduced from 8.94D ± 2.27 preoperatively to 6.01D ± 3.44 at 12 months after surgery (P < 0.01). BSCVA improved from 0.39 ± 0.22 preoperatively to 0.55 ± 0.21 (P < 0.001) after surgery. Spherical equivalent did not show statistical significant change after surgery -3.62 ± 3.52 D preoperatively, and -3.19 ± 2.48 D postoperatively (P < 0.05). Table 2 compares preoperative and postoperative data.

Table 2. Preoperative and postoperative measurements (N = 17 eyes).

		1 mo		3 mo		6 mo		1 year	
Parameter	**Preoperative**	**Mean**	***P***	**Mean**	***P***	**Mean**	***P***	**Mean**	***P***
Topographic astigmatism (D)	8.94 ± 2.27	6.01 ± 3.44	<0.01	5.86 ± 2.71	<0.01	5.02 ± 4.76	0.03	4,85 ± 4.41	0.03
Spherical equivalent (D)	-3.62 ± 3.52	-3.19 ± 2.48	<0.01	-3.00 ± 3.45	0.12	-2.85 ± 1.95	0.03	-3.12 ± 2.75	0.21
BSCVA (decimal scale)	0.39 ± 0.22	0.55 ± 0.21	< 0.01	0.60 ± 0.14	<0.01	0.52 ± 0.08	<0.01	0.56 ± 0.07	<0.01

xpressed as mean ± SD .
; are referred to preoperative measurements.
Mo, months; *P,* p value; D, diopters, BSCVA, best spectacle-corrected visual acuity; SD, standard deviation

Overcorrection occurred in 6 cases. In one, there was an initial satisfactory result, but 4 months postoperatively the arcuate incisions opened, and the topographic astigmatism was inverted by 10D (Table 3, patient no. 9). The patient was submitted to compressive sutures with good outcome up to now. In another case stromal oedema has occurred adjacent to one of the keratotomies, inducing a 11D of topographic astigmatism, that was managed with topical steroids and compressive sutures, with improvement over time. In the other four cases, the opened incisions resulted in an inversion of astigmatism in great magnitude and were managed by compressive sutures with good results. Microperforation occurred in two cases during keratectomy; It was managed with therapeutic contact lens without other complications.

Table 3. Description of the cases with any complication.

Gender	Age, yr	Diagnosis	Years after graft	Preoperative			Complication	Management	Final BSCVA
				SE (D)	Topographyc astigmatism (D)	BSCVA			
Female	56	Keratoconus	1.3	impossible	12.5	0.4	Microperfuration	Therapeutic contact lens	0.67
Male	39	Keratoconus	14	Impossible	8	0.5	Perfuration	Suture	0.67
Male	48	Keratoconus	10	+0.25	5.5	0.6	Overcorrection + paraincisional edema	Clinical	0.67
Female	51	Keratoconus	14	-4.50	8	0.4	Opened incision + overcorrection	Suture	0.5
Female	32	Keratoconus	32	-10.50	10	0.25	Opened incision + overcorrection	Suture	0.5
Male	72	Keratoconus	20	impossible	12.8	0.05	Overcorrection	Suture	0.5
Male	37	Keratoconus	11	-4.00	10	0.5	Overcorrection + paraincisional edema	Suture	0.4
Male	51	Bullous keratopathy	1	-6.00	11	0.4	No astigmatism improvement	Topoguided Femtolasik	0.67
Female	45	Keratoconus	2	-3.00	5.9	0.8	Overcorrection	Suture	0.8

Yr, years; SE, spherical equivalent; D, diopters; BSCVA, best spetacle-correted visual acuity.

Discussion

Arcuate incisions are considered an efficient method in the treatment of high astigmatism after keratoplasty. From its conception by Snellen [19] in 1869 to the beginning of its clinical application in the 1970s by Troutman [25], Krachmer [26] and Lindstrom [27], among others, the procedure has shown good results for a difficult-to-treat problem until then. Nevertheless, undesirable complications such as microperforations and overcorrections may occur in some cases.

The advent of femtosecond laser has created an important expectation in the improvement of the technique, due to its greater precision and perfection in the incision making. Since then, some results are being published about the results of the arcuate incisions made with the new technology. Irit Bahar et al. [15] compared the results between manual and femtosecond laser techniques and found no statistically significant difference regarding best-corrected visual acuity, uncorrected visual acuity and mean absolute cylinder. Moreover, there was no difference in overcorrection rate, which occurred in 25% in the cases of the femto-AK group.

In our case series, unexpectedly, we also had a high frequency (35%) overcorrection, 33% of these occurring 6 months after the procedure. Maybe because the incisions are so perfect that the healing process is weaker than when manually performed. One option to try to avoid this is a technique proposed by Clearly et al. [21] by making a 135º beveled incision rather than a perpendicular one. Likewise, the author still recommends more studies with a larger number of patients to adopt the technique.

In fact, overall, the results of the AK procedure, whether mechanized or Femto-AK, show some success in correcting the refractive error, but with varying unpredictable results. In order to have more consistent results, Nubile et al. [16] limited incisions to 80 arc length and had no cases of overcorrection in a 10-case series, indicating that perhaps revision of the traditional nomogram is advised to regard the use of high arc length incisions. St Clair et al. [20] proposed modifying Hanna's nomogram based on regression analysis of a large group of patients from multiple centres. However, this theoretical model still needs to be applied and its results evaluated in a prospective study.

Another possibility to prevent overcorrection overtime due to incision opening is to perform intrastromal femto-AK, which seem to be less effective, but safer. Viswanathan et al. reported significant reduction in high postkeratoplasty astigmatism with femtosecond intrastromal arcuate keratotomies [27].

If, on the one hand, the femtosecond laser for arcuate incisions did not show clinically superior results compared to the manual technique, in the other hand, its superiority with regard to the accuracy and safety of the instrastromal corneal ring (ICRS) implantation is undoubted. In this sense, the use of ICRS proved to be an excellent technique for the correction of high astigmatism after keratoplasty. Coscarelli et al. [22] showed effective corneal cylinder reduction and no cases of visual loss in a series of 59 eyes. In the same way, Arriola-Villalobos et al. [23] published very similar results showing the consistency of the technique.

In conclusion, we have found a high overcorrection rate over time with femtosecond laser arcuate incisions in the treatment of high astigmatism after keratoplasty, many of them needed to be sutured. From our perspective, better nomograms for this technique need to be studied.

Declarations

Contributors:

All authors made substantial contributions to the research. SK was the principal investigator. All authors contributed to the data collection, design, analysis and interpretation of the data, and to the revision of the manuscript.

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