Development of a nomogram for femtosecond laser astigmatic keratotomy for astigmatism after keratoplasty

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PURPOSE: To develop a nomogram for femtosecond laser astigmatic keratotomy (AK) to treat post-keratoplasty astigmatism.

SETTING: Three academic medical centers.

DESIGN: Retrospective interventional case series.

METHODS: A review of post-keratoplasty femtosecond laser AK was performed. Uncorrected (UDVA) and corrected (CDVA) distance visual acuities, manifest refraction, and keratometry were recorded preoperatively and 1, 3, 6, and 12 months postoperatively. The location, length, depth, and diameter of the AK incisions were recorded, and the surgically induced astigmatic correction was related to these variables using regression analysis.

RESULTS: One hundred forty femtosecond laser AK procedures were performed after penetrating keratoplasty (PKP) (n = 129) or deep anterior lamellar keratoplasty (DALK) (n =11), with 89 procedures (80 PKP, 9 DALK) included in the analysis. The mean CDVA improved from 20/59 (0.47 logMAR ± 0.38 [SD]) preoperatively to 20/45 (0.35 ± 0.31 logMAR) postoperatively ($P = .013$) (n = 46). The mean keratometric astigmatism decreased from 8.26 ± 2.90 diopters (D) preoperatively to 3.62 ± 2.59 D postoperatively ($P < .0001$) (n = 89). The mean refractive cylinder decreased from 6.77 ± 2.80 D preoperatively to 2.85 ± 2.57 D postoperatively ($P < .0001$) (n = 69). A nomogram for femtosecond laser AK to treat post-keratoplasty astigmatism was generated using regression analysis.

CONCLUSIONS: Femtosecond laser AK significantly improved UDVA and CDVA and significantly reduced keratometric astigmatism and refractive cylinder after keratoplasty. The nomogram generated should improve the accuracy of post-keratoplasty femtosecond laser AK.

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High corneal astigmatism is a frequently encountered hindrance to visual rehabilitation after cornea transplantation. The degree of corneal astigmatism tolerated after cornea transplantation depends on several factors, including the refractive state of the fellow eye, visual potential, degree of binocularity, contact lens tolerance, and patient expectations.[1] Nonsurgical options for the management of postoperative astigmatism include spectacles, contact lenses, and scleral lenses. However, spectacles might be ineffective if the astigmatism is irregular or of a large magnitude. The success of contact lenses and scleral lenses is dependent on the patient's lifestyle, age, and ability to tolerate the lenses.[2]

After topography-guided selective suture removal, surgical options to reduce astigmatism include, but are not limited to, wound revision, astigmatic keratotomy (AK), astigmatic keratectomy (wedge resection), and photorefractive procedures.[3–8] Arcuate keratotomy, typically performed with freehand techniques or

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mechanized devices such as the Hanna arcitome (Moria), is a generally effective, well-established treatment for astigmatism after corneal transplantation.[5,6,9,10] However, this procedure has poor predictability and a risk for associated complications, such as corneal perforation and wound gape.[4,11,12]

Using a femtosecond laser is an increasingly common means of creating arcuate keratotomies for the treatment of postsurgical and native astigmatism, often at the time of femtosecond laser–assisted cataract surgery.[13–17] The femtosecond laser uses a wavelength in the infrared range to induce a nonthermal photodisruptive ablation based on the generation of a sequence of adjacent cavitation gas bubbles focused in corneal tissue.[13] Femtosecond laser AK provides more precise incision creation than manual or mechanical keratotomy with enhanced reproducibility, safety, and accuracy.[13–19] Femtosecond laser AK has been shown to significantly improve uncorrected distance visual acuity (UDVA) and corrected distance visual acuity (CDVA) as well as significantly reduce astigmatism in patients after corneal transplantation.[13] A retrospective analysis of eyes that had manual AK and femtosecond laser AK[16] found improvement in UDVA and CDVA in both groups; however, only the femtosecond laser AK group achieved a statistically significant improvement in both UDVA and CDVA.

Several nomograms are available for planning manual AK incisions in native corneas, such as the Hanna nomogram[20] and the Lindstrom nomogram.[21] Abbey et al.[22] proposed a femtosecond laser AK nomogram for the treatment of astigmatism in native corneas based on a modified Lindstrom nomogram. Subsequently, Hurmeric and Yoo[A] proposed a modified version of the previous native corneal nomogram to be used for post-keratoplasty astigmatism. The adaptation of a nomogram created for the treatment of astigmatism in native corneas to one for post-keratoplasty corneas assumes that the grafted corneas and native corneas respond in a similar manner to corneas having incisional surgery. However, this assumption is not valid according to Wilkins et al.,[5] who showed that the effect of AK incisions in post-keratoplasty eyes was proportional to the magnitude of the astigmatism, which is not the case in native corneas. Thus, we describe the development of a nomogram for femtosecond laser AK for the management of post-keratoplasty astigmatism that considers a variety of incision-related factors and the degree of preexisting astigmatism.

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PATIENTS AND METHODS

This study followed the tenets of the Declaration of Helsinki. Institutional review board approval was obtained at each participating center.

Patient Identification and Data Collection

This retrospective study was performed at the following 3 centers: Jules Stein Eye Institute, Los Angeles, California, USA; Bascom Palmer Eye Institute, Miami, Florida, USA; and the University of Toronto, Toronto, Ontario, Canada. The charts of all patients who had femtosecond laser AK for the management of post-keratoplasty astigmatism between January 2007 and January 2015 were evaluated for the following information: preoperative UDVA, CDVA, manifest refraction, keratometry, and thinnest corneal pachymetry. In addition, operative parameters, including laser energy and spot separation, as well as the location, arc length, depth, diameter, and angle of each keratotomy incision were recorded. The postoperative UDVA, CDVA, manifest refraction, and keratometry were recorded at 1, 3 and 6 months, and 1 year. Also recorded were postoperative complications and subsequent surgical procedures, including whether the AK incisions were opened. All patients included in the data analysis had all cornea transplant sutures removed at least 100 days before the femtosecond laser AK procedure was performed, and all eyes were followed for a minimum of 1 month after the procedure. Corneal biomechanics are altered in the presence of corneal edema; therefore, eyes in which the thinnest recorded corneal pachymetry was greater than 750 μm were excluded. Data included eyes with previous or combined glaucoma surgery, cataract extraction, or refractive surgery at the time of the corneal transplantation.

Surgical Technique

All AK procedures were performed using the Intralase FS 60 or iFS Advanced femtosecond laser (both Abbott Medical Optics, Inc.). At the Jules Stein Eye Institute and the Bascom Palmer Eye Institute, the arc length of AK incisions was based on preoperative corneal topography using the Hanna nomogram (Table 1).[6] At the University of Toronto, the arc length of the paired incisions, which were centered on the steep axis and placed on the donor side of the cornea, were planned using the following formula: 60-degree paired