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Open Access Journal of Ophthalmology

Biomechanical Impact of Femto-Second Laser Arcuate Keratotomy

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Mini Review

Volume 2 Issue 4

Received Date: November 16, 2017

Published Date: December 22, 2017

Abbreviations: AK: Arcuate Keratotomy; FS: Femto-Second; CH: Corneal Hysteresis; CRF: Corneal Resistance Factor.

Mini Review

It has long been assumed, and since some years is known that refractive surgical treatments have an impact on the biomechanics of the cornea. Therefore, it is even more important to understand the underlying biomechanical mechanism of such procedures. One such surgical technique, exploiting biomechanical effects to treat corneal astigmatism, is femto-second laser arcuate keratotomy (AK). Manual AK incisions were being used for years in clinical practice, but were abandoned by many because of too poor outcome predictability. Now with the femto-second (FS) laser getting more and more popular, the technique sees a comeback in clinics. FS Laser manufacturers such as Alcon, Bausch+Lomb, Johnson+Johnson Vision, or Ziemer are already providing the ability to cut arcuates into corneal tissue.

In this context, it is interesting to note, that two recent (2016) consecutive publications by the same authors of the Moorfields Eye Hospital in London focused on efficacy, predictability, sensitivity, and the effect of multiple parameters in the femto-second laser intrastromal arcuate keratotomy. Printed one after another, in the same issue of the Journal of Cataract and Refractive Surgery (Issue 42, 2016), the first study by Alexander C Day, et al. describes the effects and results of intrastromal femto-second astigmatic keratotomy (AK) [1]. Due to the minimal data about the efficacy of intrastromal AK, it aims to determine the astigmatic changes happening in this intervention.196 eyes were used, and the operation was planned with nomograms. The corneas all underwent an astigmatic correction additionally to a cataract surgery. They then were analyzed with three vectors of the Alpins method: the target induced astigmatism (set at 0, to facilitate calculations), surgically induced astigmatism, and the difference vector. Additional parameters were the correction index, the coefficient of adjustment, the magnitude and angle of error, and the index of success. The results are summarized in Table 1.

Vector analysis parameter values (N = 196 eyes)		
Parameter	**Mean (SD)**	**Range**
Target induced astigmatism [D]	1.21±0.42	0.75, 2.64
Surgically induced astigmatism [D]	0.74±0.40	0.00, 2.86
Difference vector [D]	0.74±0.38	0.00, 2.25

Table 1: Target- and surgically induced astigmatism for the group of 196 eyes in the study on intrastromal arcuate keratotomy by the Moorfields Eye Hospital

As can be seen in the graph below, this method can indeed reduce astigmatism. A closer look at the results, however, shows that most cases were under-corrected. This was expected by the authors, as the nomogram targets an outcome of 0.7D, to avoid over-correction. Still, there were some cases with over-correction, but no correlation with age, sex or arc length was noticed. The coupling ratio between steep and flat axis was 0.56, showing that the opposite (flat) meridian underwent a

change in corneal power of 56%. Overall, the authors found that intrastromal femto-second laser AK can reduce astigmatism, and that the between-eye variance in the astigmatism vector must be further analyzed see Figure 1.

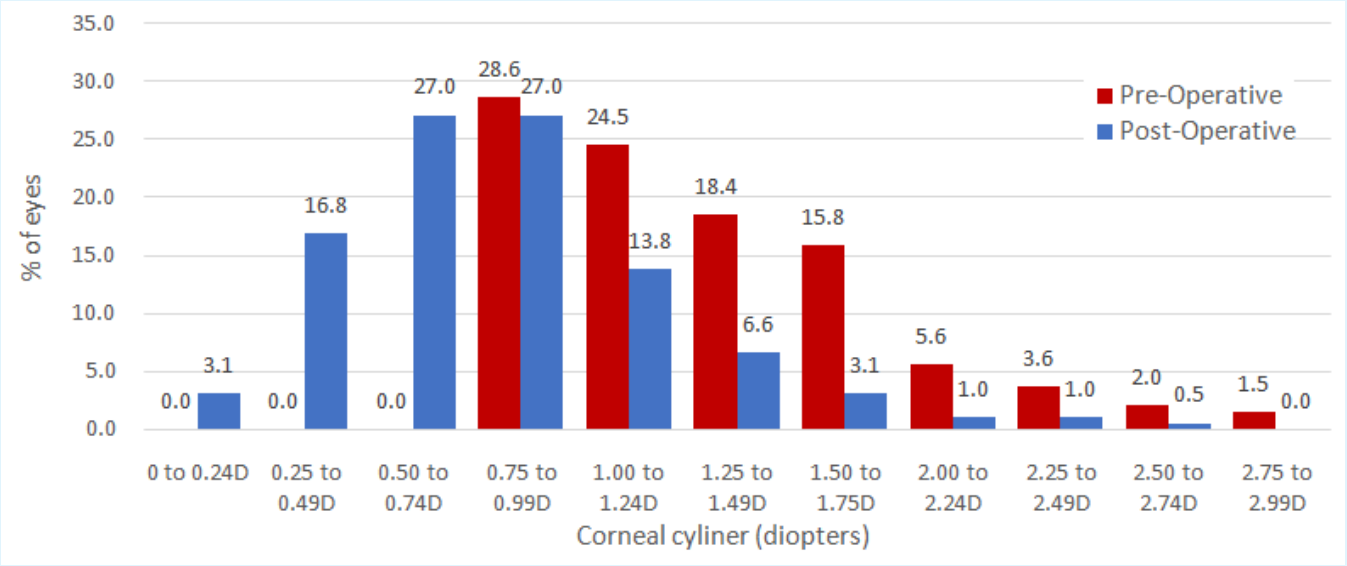

Figure 1: Nomogram comparison of pre- to post-operative Cylinder values for femto-second intrastromal arcuate keratotomy surgery including 196 eyes at the Moorfields Eye Hospital in London.

Referencing to their first findings, the authors state in their second study that it is known that intrastromal keratotomy reduces astigmatism. However, the exact correlation between the arc length of the AK and the astigmatic correction is not clear. With their second study, Alexander C Day, et al. intends to change this, and additionally want to analyze the effects of corneal biomechanical parameters on the efficacy of the operation [2]. The selected preoperative parameters were axial length, anterior chamber depth, central corneal thickness, corneal hysteresis, corneal resistance factor and some more, as can be seen in Table 2.

Multiple variable regression model of dependent variable SIA induced by femto-second AK			
Variable	**B Value**	**B 95% CI**	***P* Value**
Femto-second arc length [°]	0.005	0.001, 0.008	0.006
Preoperative cylinder [D]	0.347	0.220, 0.474	<0.001
Age [years]	0.005	0.000, 0.009	0.044
Astigmatism type (oblique/WTR/ATR)	-0.067	-0.131, -0.004	0.038
Corneal hysteresis	-0.063	-0.099, -0.027	0.001
Corneal resistance fractor	0.044	0.080, 0.800	0.018

Table 2: Multi-variat regression modeling of surgical outcome of 319 eyes, receiving intrastromal arcuate keratotomy surgery, operated with a femto-second surgical laser.

The study included 319 eyes which underwent an astigmatism reduction in addition to the normal cataract surgery. Results primarily showed that long and deep incisions as well as high preoperative cylinder correlate with higher astigmatic correction. Regression analysis indicated that increasing patient age was associated with the SIA magnitude. In a second step, the authors considered biomechanical parameters, and correlated them to astigmatic effects.Results showed that surgically induced astigmatism is meridian-dependent and its magnitude is greater when corneal hysteresis (CH) is lower, but its corneal resistance factor (CRF) is higher. It also appeared that WTR (with the rule) astigmatism induces a 0.13 higher SIA than ATR (against the rule). Finally, the authors state that out of all parameters they looked at, only preoperative corneal cylinder magnitude,

AK depth, and the steep astigmatism meridian were independent predictors for surgically induced astigmatism. Moreover, the correlation between incision length and the induced astigmatic correction was found to be poor.

It is interesting to see, that a surgical technique abandoned by many, sees a revival thanks to femto-second laser technology. Even though clinical results are promising, it appears that there is room for improvement, and that more studies and improved surgery planning technologies are needed.

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