Research Article

Femtosecond laser-assisted arcuate keratotomy in correction of corneal astigmatism

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Abstract

**Background:** Astigmatism is a major challenge for surgeons. Many measures have been studied to manage astigmatism starting from simple measures such as; contact Lenses, Spectacles. Femtosecond LASER-assisted incisions decrease the risk of infection and associated pain. The arcuate relaxing incision (Arcuate keratotomy) provides a fast visual rehabilitation, economic, easy, and a relatively safe procedure for the management of astigmatism.

**Subjects and Methods:** This prospective study included 40 eyes of patients with different degrees of astigmatism. None of the patients had a history of previous ocular surgery or diseases that would affect the corneal refraction.

Incisions will be done at 65% to 75% depth, and arc lengths of 60 to 90.

**Results:** The mean Preoperative BCVA (LogMAR) was 0.56 improved to 0.35. The mean BCVA change (Postoperative - Preoperative) (LogMAR) showed an improvement of 0.21 (LogMAR) “gain of two lines”. The mean Preoperative topographic astigmatism was 4.28 improved to 0.78. The mean Preoperative refractive astigmatism was 3.73 Diopter improved to 0.88.

**Conclusion and Recommendations:** AK is a simple and safe technique to manage astigmatism which involves the creation of relaxing incisions in the corneal stroma. AK have considerable technical limitations, including difficulty in the creation of uniform incisions and a lack of reproducibility and predictability. Recent rise in popularity of the femtosecond laser has led to its application in a variety of corneal procedures. It has proven to be a safe, effective and highly accurate instrument and continues to be studied for other operations because of its ability to produce precise incisions.

Introduction

Astigmatism is a major challenge for surgeons. Many measures have been studied to manage astigmatism starting from simple measures such as; contact Lenses, Spectacles. Femtosecond LASER-assisted incisions for treating astigmatism is one of recent and favorable methods, the advantage here is preserving the epithelium, and this decreases the risk of infection and associated pain. Arcuate Incisions. The arcuate relaxing incision (Arcuate keratotomy) provides a fast visual rehabilitation, economic, easy, and a relatively safe procedure for the management of astigmatism. It is defined as...
creating one or more arc shaped incision in the cornea, it can be constructed using the blade, arcuate Keratome or Femtolaser. Moreover; it can be combined with Excimer LASER, stress sutures, and during cataract surgery.

**Principle**

Its main principle is flattening of the steep meridian, and that will also steepen the opposite unincised meridian that is 90 degrees away, which is known as the coupling ratio, the coupling ratio can be 1; where the flattening of the steep meridian and the steepening of the opposite meridian is equal and that will not change the spherical equivalent, However if the coupling ratio is more than one; that will result in more flattening of the incised meridian than the steepening of the un-incised opposite meridian leading to more flattening of the cornea and the spherical equivalent will be a hyperopic shift. And vice versa for the coupling ratio that are less than one; that will result in more steepening effect of the incised meridian than the effect of the un-incised opposite meridian and it will result in a myopic shift of the spherical equivalent.

**Figure 1:** Change in the curvature of the principal Figure corneal meridians induced by arcuate keratotomy.

$K_{\text{steep}}$ is the power of the steep preoperative meridian. $K_{\text{flat}}$ is the power of the flat preoperative meridian. After astigmatic keratotomy, the power of the incised meridian is $K_{\text{steep}} - F$, where $F$ is flattening of the incised meridian. The power of the opposite, unincised meridian is $K_{\text{flat}} + S$, where $S$ is steepening of the unincised meridian. This is based on Gauss' Law, which states that: "For every change in curvature in one meridian there is an equal and opposite change 90 degrees away." It is often demonstrated by squeezing a balloon that will result in steepening one meridian and flattening the opposite other.

However, another law applies to the living cornea after an incision, "the law of the modified living elastic dome" (the law of the incised cornea) is as follows: "The change in curvature 90 degrees away from a corneal incision is proportional to the change in the primary meridian reduced by the increase in circumference.

Adding tissues to a dome flattens the dome due to the increase in its radius of curvature and ultimately decrease its refractive power, and vice versa. Corneal incisions act like adding tissue hence it will result in increasing the radius of curvature.

**Material and Method**

This study is a prospective and retrospective cohort study. We analyzed 40 consecutive eyes of patients intervened. Forty consecutive eyes fulfilled the inclusion criteria were obtained from November 2016 to December 2017.

**Purpose:** To study arcuate incisions outcome made by femtosecond laser in the management of astigmatism.

**Design:** Interventional case series.

**Methods:** This study will comprise 40 eyes that had an arcuate incision for correction of astigmatism. Informed consent obtained from all the patients enrolled.

**Inclusion Criteria**

- Patient were adults (more than 18 years old).
- Patients were of any sex.
- None of the patients had a history of previous ocular surgery or diseases that would affect the corneal refraction.

**Exclusion Criteria**

- High, irregular astigmatism that prevented proper estimation of the refraction and improvement of visual acuity.
- Dry eye, untreated lid margin disease.
- History of previous corneal surgery or diseases.
Any active infectious disease or history of herpetic disease in the eye.
Visually Significant Cataract.
Pregnancy.
Collagen disease.

**Informed Consent**
The patients signed consent for intervention, including advantages and disadvantages, risks of possible complications and periodical follow-up.

**Preoperative Evaluation**
Data collection included demographic information, and corneal topography using Oculus Pentacam®. All the patients were completely examined preoperatively including:
- Refraction
- Slit-lamp examination.
- IOP assessment.
- Fundus examination.
- Corneal topography, using the Oculus Pentacam ®.

**Operative Procedure**
All patients with astigmatism were offered an arcuate relaxing incision, the 6 O’clock position is marked while the patient is upright and looking straight ahead with both eyes open to avoid cyclotorsion, all eyes had at least 2 relaxing incision using a Femtosecond laser assisted keratotomy incisions done at 65% to 75% depth, and arc lengths of 60 to 90 degree arc of the thinnest point at the steepest hemi-meridian guided by the corneal topography, after surgery, topical antibiotic and steroids were prescribed. An example of pre-operative and post-operative pentacams are shown in figure 3,4.

**Figure 2: Catalys femtosecond laser**

**Figure 3 A pre-operative pentacam photo showing corneal astigmatism**

**Figure 4 A post-operative pentacam photo showing improving of the astigmatism.**
Figure 5 Arcuate incision at the steep meridian “A demonstration photo”.

Postoperative Follow Up
Postoperative follow up examinations were performed on the first day post operatively, at week 1, at months 1, 2, 3 and Included:
- Refraction.
- Slit-lamp examination.
- IOP assessment.
- Fundus examination.
- Corneal topography, using the Oculus Pentacam ®.
- The vector analysis was calculated using the Alpins method for vector analysis.

Measurement of the best-corrected visual acuities (BCVA).

Figure 6: Our own software for astigmatic analysis.

Statistical Analysis
At the end of this study, data were statistically described in terms of mean ± standard deviation (± SD), median, correlation and percentages when appropriate. All statistical calculations were made using computer programs IBM® SPSS® Statistics Version 22. P-values less than 0.05 were considered significant.

Results
Best Corrected Visual Acuity (LogMAR)
In LogMAR, Each letter has a score value of 0.02 log units. Since there are 5 letters per line, the total score for a line on the LogMAR chart represents a change of 0.1 log units. The mean Preoperative BCVA (LogMAR) was 0.56 improved to 0.35. The mean BCVA change (Postoperative-Preoperative) (LogMAR) showed an improvement of 0.21 (LogMAR) “gain of two lines”. The results were statistically significant (p-value = 0.03).

Topographic Astigmatism
The topographic astigmatism was calculated using Pentacam (Oculus Inc., Lynnwood, Washington, USA) in the preoperative and postoperative visits. Since we are mainly treating corneal astigmatism so this is the most accurate index of the effect of the surgery as it directly measures the effect of the treatment in the cornea. The mean Preoperative topographic astigmatism was 4.28 improved to 0.78. The mean topographic astigmatism change (Postoperative-Preoperative) showed an improvement of 3.5. The results were statistically significant (p-value = 0.01).

Refractive Astigmatism
The mean Preoperative refractive astigmatism was 3.73 Diopter improved to 0.88. The mean refractive astigmatism change (Postoperative-Preoperative) showed an improvement of 2.85. The results were statistically significant (p-value = 0.03).

Spherical Equivalent
The mean spherical equivalent was -2.08 Diopeters (D) changed to -0.08.
The mean spherical equivalent change (Postoperative - Preoperative) showed a change of -2.00 Diopters. The results were statistically significant (p-value = 0.02).

Discussion

Improvement in the Visual Acuity
Our Study showed an improvement of 0.22 (LogMAR) “gain of two lines”. The Results were statistically significant (p-value = 0.03).

Loriaut et al. studied the arcuate incision using the Femtosecond laser in 20 patients and their results showed an improvement in vision from 0.5 to 0.3 (p-value = 0.49).

Improvement in the Topographic Astigmatism
The mean topographic astigmatism change showed an improvement of 3.5. The results were statistically significant (p-value = 0.01).

The mean Preoperative topographic astigmatism was 4.28 improved to 0.78 (81.77 %).

In Loriaut et al. Femtosecond laser study, the mean topographic astigmatism decreased from (9.45 D) to (4.64 D) (P = 0.001), they showed a 50% improvement, which was below our study and almost the same as Kubaloglu et al. study.

Improvement in the Refractive Astigmatism
In our study, the mean Preoperative refractive astigmatism was 3.73 Diopter improved to 0.88.

In our study, the mean refractive astigmatism change (Postoperative - Preoperative) showed an improvement of 2.85 (76.4%). The results were statistically significant (p-value = 0.03).

In Loriaut et al. Femtosecond laser study, The mean Preoperative refractive astigmatism decreased by 3.79 D. However, they didn’t report the mean Preoperative astigmatism.

Improvement in the Spherical equivalent
In our study, the mean spherical equivalent was -2.08 Diopter changed to -0.08.

In our study, the mean spherical equivalent change (Postoperative - Preoperative) showed a change of -2.00 Diopter. The results were statistically significant (p-value = 0.02).

However, In Kubaloglu et al. Study although they didn’t calculate the change, but their results show a hyperopic shift so that their coupling ratio was more than one.

In Loriaut et al. 2015 Femtosecond laser study, The mean spherical equivalent was -4.34 D changed to -4.44 D, showing a myopic shif.

Conclusion
The assessment of the surgical treatment of astigmatism using the Alpins method is considered an accurate and effective method for the proper evaluation of astigmatism, as it deals with astigmatism not just in the dioptic power of the cylinder, but it also takes the cylinder axis into consideration, hence it deals with astigmatism as a vector, then using the mathematical or graphical vectors summations, besides Alpins Indices, it can show the effectiveness of the surgical treatment.

Moreover the editorial staffs of the Journal of Refractive Surgery, the Journal of Cataract and Refractive Surgery and the cornea journal have proposed a standard for reporting astigmatism for any astigmatism published study and they acknowledged the Alpins method for a better and a more detailed reporting of astigmatism; especially in incisional surgery just like our study.

The arcuate relaxing incision is considered an effective and safe procedure in reducing the astigmatism and improving the best corrected visual acuity. In our study; there was a mild overcorrection, and mild rotation of treatment (Torque).

Mechanical incisions made leading to a) variation in achieving the actual 90% depth we sought b) variation in the verticality of the incisions (ie: not always possible to know that the incisions were placed perfectly perpendicular to the surface of the cornea c) Variation of the length of incisions variable

A Moorefields study showed that the higher the astigmatism, the greater the effect of the same number and length of relaxing incisions. A Relative low number of cases for analysis, and with this much variability, it is difficult to draw conclusions.
References


https://books.google.com.eg/books?id=93s6aes5ob0C.