Epi- On versus Epi- Off Techniques of Corneal Collagen Cross Linking for Treatment of Keratoconus

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Abstract

Aim of the Work: The aim of this study is to evaluate and compare the epi-on versus the epi-off techniques of corneal collagen cross linking as regards their safety and efficacy for treatment of mild to moderate degree keratoconus.

Design: Prospective, non randomized study.

Patients and Methods: Thirty eyes in 15 patients (9 males and 6 females) with bilateral mild to moderate degree keratoconus were included in this study. Their mean age ± SD was 26.2 ± 3.9 years. Diagnosis of keratoconus was based on clinical evaluation as well as pentacam examination. All patients were subjected to corneal collagen cross linking. According to the technique used, eyes were classified into 2 groups:

Group I: Included 15 eyes in 15 patients, where cross linking was performed after removal of the corneal epithelium (Epi-off).
Group II: included the other 15 eyes of the same patients, where cross linking was performed with intact epithelium (Epi-on). Comparison between the two groups as regards visual outcome, keratometric readings, least corneal thickness, refraction outcome and corneal haze was done.

Results: No intra operative complications were reported in our study. Re-epithelialization in eyes of group I was reported within a week except three eyes were re- epithelialization was reported after 10,14and 21 days.
There was a statistically significance improvement in best corrected visual acuity in both groups (0.36 before versus 0.60 six months after surgery) but the difference between both groups was not significant.
As regards refraction, there was reduction in spherical error 6 months after surgery in both groups (-6.14D before,-5.22D 6 months after surgery) as well as cylindrical error (4.87D before 3.79 D 6 month after surgery).
Differences between both groups were statistically not significant.
There was increase in the least corneal thickness after surgery (448.6 microns before surgery versus 451.9 microns 6 months after surgery) but statistically the difference was not significant (P=0.75) and the difference between both groups was also not significant.
Changes in keratometric readings were statistically not significant, and the difference between both groups was also not significant.
Corneal haze was observed one month post operatively in four eyes in group one versus 3 eyes in group II. Persistent haze at the end of follow up was reported in three eyes in group I versus two eyes in group II.
The incidence of haze as well as its density was higher in group I than group II with statistical significant difference.

Conclusion: Both epi-on and epi-off techniques of corneal collagen cross linking are safe and effective in stabilization or even improvement of mild to moderate degree keratoconus as regards best corrected visual acuity, refraction, keratometric readings, and least corneal thickness. The epi-on technique is easier and more tolerable by the patient with less postoperative corneal haze.

Key words: Keratoconus- collagen cross linking- Epi-on, Epi-off - corneal haze.

Introduction

Keratoconus is a bilateral, non symmetric, non inflammatory progressive corneal degeneration that frequently manifests in young adults as progressive steepening attributed to biochemical stromal collagen weakening[1]. Prevalence of Keratoconus is about 1: 2000 [2]. The increased number of patients undergoing screening for laser refractive surgery suggests the prevalence may be higher [3].

Patients with keratoconus usually complain of blurred vision secondary to myopia and uncorrected astigmatism. They may also complain of ghost images, monocular diplopia or polyopia[4].

Clinic diagnosis of keratoconus is based early on the history of multiple inadequate spectacle corrections as well as oblique astigmatism and myopia on eye refraction.

On progression of keratoconus, we may observe one or more of the following; Vogt's striae, Fleischer's ring, stromal scarring, Munson's sign and acute corneal hydrops[5].

Keratometry may reveal distortion of mires and central or inferior steepening. Orbascan system depends on the computer assisted video keratoscope that uses the placido disc principle. It is efficient in detecting subtle topographic changes present in early keratoconus and for documentation of their progression by serial topographic analysis[6].

Pentacam uses pachymetry, elevation data of the anterior and posterior corneal surfaces as well as indices of the anterior surface for accurate diagnosis of keratoconus[7].

Many surgical / non surgical interventions such as spectacles, contact lenses, and penetrating keratoplasty[8], lamellar keratoplasty [9] and intra corneal ring segment implantation[1].

Corneal collagen cross linking was introduced by **Wollensak et al., (2003)** [10]. It is based on the combined use of the photosensitized riboflavin and ultraviolet rays of 370 nm. Corneal cross linking is the only available treatment directed at the underlying pathology in keratoconic cornea, which is stromal biomechanical and structural instability, leading to progressive ectasia. Corneal collagen cross linking induces covalent inter-and intra-fibrillar collagen cross-links creating an increase in biomechanical rigidity of the human cornea by about 300%[11].

To evaluate refractive and topographic results of transepithelial cross linking, **Ertan et al, 2009**[12] reported a retrospective study on 25 eyes in 15 patients. They reported that cross linking improved BSVA by 0.36 Snellen's lines. The decrease of spherical, cylindrical, mean K reading and steepest K value were 0.5 D, 0.15 D, 0.35 D and 0.76 D respectively 3 months after corneal collagen cross linking.

Patients and Methods

This prospective study was held between September, 2011 and September, 2012 at Al Zahraa University Hospital and the Eye Subspecialty Center. It included 30 eyes in 15 patients, 9 males (60.0%) and 6 females (40.0%) who had bilateral mild to moderate degree keratoconus. Their mean age ± SD was 26.2 ± 3.9 years. (Range: 20- 36 years).

Inclusion criteria included:

-    Mild to moderate degree keratoconus (K readings up to 52.0 diopters)

-    Clear cornea

-    Least corneal thickness is more than 400 microns.

Exclusion criteria included:

-    Corneal scaring.

-    Other ocular pathology affecting visual acuity.

-    Pregnancy.

-    Systemic collagen or autoimmune diseases.

-    Least corneal thickness less than 400 microns.

-    K readings more than 52.0D (Advanced keratoconus).

All patients were subjected to the following:

- Best corrected visual acuity using chart projector. Data were reported according to the decimal scale.
- Slit lamp extermination for the anterior segment.
- Cycloplegic refraction using 1% tropicamide eye drops.
- Intraocular pressure measurement using slit lamp mounted applanation tonometer.
- Fundus examination using the indirect ophthalmoscope.
- Pentacam examination (using ALLEGRO machine) to prove the diagnosis of keratoconus, to estimate K1, and K2 readings and to detect the least corneal thickness.

All patients received prophylactic 0.3% tobramycin eye drops 3 times daily for one week before surgery.

A formed consent was signed by the patient prior to surgery and both eyes were operated in the same session.

Eyes were divided into 2 groups according to the technique of cross linking used. One eye in each patient was subjected to cross linking using the Epi-off technique *(Group I)*, while the other eye of each patient was subjected to the Epi-on technique *(Group II)*.

Technique of Epi-off corneal collagen cross linking for group I:

- Benoxinate hydrochloride eye drops (0.4 %) were applied 3 times with one minute interval just before surgery as well as when the patient feels discomfort during the procedure.
- Sterilization around the eye using 10% providine-Iodine solution.
- Application of a wire speculum.
- Central 8 mm of the corneal epithelium was removed using a micro sponge soaked with 70% alcohol for one minute. Care was taken to keep the epithelium outside the central 8 mm unaffected.
- Profuse irrigation by saline.
- Removal of the central 8 mm of corneal epithelium using a dry micro-sponge.

- Two drops of 0.1% riboflavin in 20% dextran (Medio Cross D) was applied to the cornea every 5 minutes for 30 minutes.
- The anterior chamber was examined for evidence of the presence of a yellow coloration in its contents using the cobalt blue light, if absent we continued the application of riboflavin to the cornea until the yellow coloration of the anterior chamber is established.
- The eye was then positioned under the cross linkage system (Opto X Link or UV-XTM) according to the following parameters:
o Time : 30 minutes
o Spot size: 8 mm
o Distance between the cornea and the cross linking system: 45 millimeters
o Irradiation power: 3.0 mw/ cm^2.
- The cross linking is turned on.
- Two drops of riboflavin were continued to be applied on the cornea every 5 minutes during the irradiation time (30 minutes)
- Cross linking machine was automatically switched off after 30 minutes.
- Tobramycin eye drops (0.3%) and 0.1% dexamethasone eye drops were applied to the eye followed by application of a bandage contact lens.
- Eye speculum was then removed.

Technique of epi-on corneal collagen cross linking for group II:

The same steps of the epi-off technique were applied to the other eye of each patient but without removal of corneal epithelium and no bandage contact lenses were used.

Postoperative care

Tobramycin 0.3% together with dexamethasone 0.1% eye drops were prescribed 4 times/ day for 7 days.

Sodium hyaluronate 2.0mg/ml eye drops were prescribed 4 times/ day for 30 days.

Oral sodium diclofenac 100 mg tablets were prescribed once daily after meal for 7 days.

Patients were instructed to come for follow up visits after one day, 2 days, one week, one

month, 3 months and 6 months after surgery. Postoperative examination was done. Further follow up visits were requested according to the need.

In each follow up visit, slit lamp examination was done to detect re- epithelialization of the cornea, keratitis or stromal haze.

Table 1, shows the postoperative examination at the the follow up visits.

Post operative haze was graded as follows:
Grade 0: Clear cornea.

Grade 1: Barely perceptible seen only by tangential illumination.

Grade 2: Trace haze of minimal density seen with difficulty using direct illumination.

Grade 3: Moderate haze, easily visible with direct slit illumination.

Grade 4: Marked haze that partially obscures anterior chamber observation or iris details.

Grade 5: Severe haze that obscures anterior chamber or iris details.

Contact lenses were removed on complete re-epithelialization in eyes of group I.

Results

No intraoperative complications were reported in our study. Surgeries for eyes in group II (the Epi-On technique) were easier and more tolerable by the patient. Re-epithelialization in eyes of group I was reported within a week postoperatively except in 3 eyes where re-epithelialization was reported after 10, 14 and 21 days.

A. Best corrected visual acuity (BCVA):
Mean best corrected visual acuity as reported by the decimal fraction ± SD in both groups before surgery was 0.36±0.11 (Range: 0.20-0.50).

In group I it was 0.40 ±0.14 (Range: 0.20-0.50). In group II it was 0.32±0.09 (Range: 0.25-0.40). One week postoperatively in both groups it was 0.35±0.16 (Range: 0.10-0.60).

In group I it was 0.37 ±0.12 (Range: 0.15-0.50).

In group II it was 0.33± 0.10 (Range: 0.10-0.60).

One month postoperatively in both groups it was 0.44±0.14 (Range: 0.25-0.60).

In group I it was 0.47±0.11 (Range: 0.30-0.60). In group II it was 0.41± 0.12 (Range: 0.25-0.60).

Three months postoperatively in both groups it was 0.60±0.15 (Range: 0.30-0.90).

In group I it was 0.63±0.08 (Range: 0.40-0.80). In group II it was 0.57± 0.11 (Range: 0.30-0.99). Six months postoperatively in both groups it was 0.61±0.17 (Range: 0.30-0.90).

In group I it was 0.65± 0.10 (Range: 0.50-0.90).

In group II it was 0.57±0.12 (Range: 0.30-0.8). The difference between both groups was statistically not significant (P = 0.082).

Table 2 and figure 1, show the best corrected visual acuity ± SD before surgery and in the follow up visits in both groups.

B. Refraction:
i. Spherical error:
Mean spherical error ± SD in both groups before surgery was-6.14 ±0.03 D (Range: -2.50 : -12.00 D),

In group I it was -7.02 ±2.82 D (Range: -3.25: -12.00 D).

In group II it was -5.26±2.97 D (Range: -2.50: -11.25 D).

One week postoperatively in both groups it was-6.50± 2.42 D(Range: -2.00- -9.50 D).

In group I it was -6.76 ± 2.16 D (Range: -2.75 : -9.50 D).

In group II it was -5.28 ±2.22 D (Range: -2.00 : -10.50 D).

One month postoperatively in both groups it was -5.81±2.61 D (Range: -1.25 : -10.00 D).

In group I it was -6.44 ±2.04 D (Range: -2.50 : -8.75 D).

In group II it was -5.18 ±2.70 D (Range:-1.25 : -10.00 D).

Three months postoperatively in both groups it was -5.20 ± 3.05 D (Range: -0.50 : -9.00 D).

In group I it was -5.88 ±2.02 D (Range: -1.50 : -8.25 D).

In group II it was -4.52 ±2.78 D (Range: -0.50 : -9.06 D).

Six months postoperatively in both groups it was -5.22±2.90 D (Range: -0.50 : -9.25 D).

In group I it was -5.90 ±1.82 D (Range: -1.50 : -8.00 D).

In group II it was -4.54- ±2.65 D (Range: -0.50: -9.25 D).

The statistical difference between spherical error before and 6 months after surgery was significant (P = 0.026). The difference between both groups was statistically not significant (P = 0.061).

Table 3 and figure 2, show the mean spherical error of refraction ± SD before surgery and in the follow up visits in both groups.

ii. Cylindrical error:

Mean cylindrical error of refection ± SD in both groups before surgery was 4.87 ± 2.16 D (Range: 0.75- 8.00 D).

In group I it was 4.67 ± 2.09 D (Range: 0.75-7.00 D).

In group II it was 4.98 ± 2.12 D (Range: 1.25-8.00 D).

One week postoperatively in both groups it was 3.92 ± 2.02 D (Range: 0.50-7.25 D).

In group I it was 3.98 ±1.94 D (Range: 0.50-7.00 D).

In group II it was 3.86 ±2.07 D (Range: 0.75-7.25 D).

One month postoperatively in both groups it was 3.81±1.96 (Range: 0.00-7.50).

In group I it was 3.86±1.89 D (Range: 0.00-7.50 D).

In group II it was 3.76 ±2.03 D (Range: 0.75-7.50 D).

Three months postoperatively in both groups it was 0.80±1.88 (Range: 0.00-7.00).

In group I it was 3.84 ±1.92 D (Range: 0.00-6.00 D).

In group II it was 3.76 ±1.66 D (Range: 0.50-7.00 D).

Six months postoperatively in both groups it was 3.79 ±2.04 D (Range: 0.00-7.00 D).

In group I it was 3.84 ±1.95 D (Range: 0.00-6.00 D).

In group II it was 3.74±1.73 D (Range: 0.25-7.00 D).

The statistical difference between cylindrical error before and 6 months after surgery was significant (P = 0.04). The difference between both groups was not significant (P= 0.14).

Table 4 and figure 3 show the mean cylindrical error of refraction + before surgery and in the follow up visits in both groups.

C. Least corneal thickness

Mean least corneal thickness ± SD in both groups before surgery was 448.6±21.1 microns (Range: 418-492 microns).

In group I it was 439.2 ±23.6 microns (Range: 426-490 microns).

In group II it was 458.0 ±20.8 microns (Range: 418-492 microns).

At the end follow up visit (6 months postoperatively) in both groups it was 451.9±19.40 microns (Range: 424-498 microns).

In group I it was 442.7±20.4 microns (Range: 430-498 microns).

In group II it was 461.1 ±21.1 microns (Range: 424-492 microns).

There is insignificant statistical difference between mean least corneal thickness before and 6 months after surgery (P = 0.75), and the difference between both groups was also not significant (P= 0.24).

Table 5 and figure 4, show the mean least corneal thickness + SD before surgery and 6 months postoperatively.

D. K- Readings

Mean K1 and K2 ± SD in all eyes before surgery ± SD was 46.37 ± 2.0 D (Range: 42.1 – 51.9 D).

In group I it was 46.2 ± 1.9 D (Range: 42.2 – 51.7 D).

In group II it was 46.5 ± 1.8 D (Range: 42.1 – 51.9 D).

Six months postoperatively) in all eyes it was 46.4 ± 1.9 D (Range: 42.0 – 50.8 D).

In group I it was 46.3 ± 1.6 D (Range: 42.1 – 50.8 D).

In group II it was 46.5 ± 1.8 D (Range: 42.0 – 50.5 D).

Changes in keratometric readings were statistically insignificant (P = 0.37), and the difference between both groups was also insignificant (P= 0.72).

Table 6 and figure 5, show the mean K readings + SD before surgery and in the follow up visits in both groups.

E. Corneal haze:

Group I:

Corneal haze was observed in 4 eyes at one month postoperatively (26.7%). It was affecting about 4 to 7 mm of the central cornea. Depth of haze as estimated by the slit lamp examination was affecting about the anterior half of the stroma.

Grade of haze was: Grade 2: 2 eyes
                     Grade 3: one eye
                     Grade 4: one eye

Dexamethasone eye drops were prescribed 3 times / day for 3 weeks.

On follow of at 3 months postoperatively, the extent of corneal haze was the same (4-7 mm) of the central cornea. The depth was also the same (about 50% of the stroma). The grade was:

                     Grade 1: one eye.
                     Grade 2: one eye
                     Grade 3: two eyes

Six months postoperatively the depth and extension were not affected, while the grade was:

                     Grade 1: one eye
                     Grade 2: 0
                     Grade 3: Two eyes

Group II:

Corneal haze was observed in 3 eyes (20.0%) at one month postoperatively. As in cases of group I, corneal haze also affected about 4 -7 mm of central cornea and was manifested in the anterior 1/2 of the corneal stroma.

Grade of haze was   Grade I: one eye
                     Grade 2: 0
                     Grade 3: Two eyes

Patients as in group I received also dexamethasone eye drops 3 times /day for 3 weeks.

On follow up 3 months postoperatively the depth and extension of haze were not affected while the grade was: Grade 1: 0
                     Grade 2: one eye
                     Grade 3: one eye

Six months postoperatively, there was no change in depth, extension or grade of haze.

Discussion

In our study, there was decrease in BCVA at one week postoperatively, followed by gradual increase between month 1 and month 6 in both groups. The differences between preoperative BCVA and BCVA at 6 months in both groups, group I and group II were statistically significant. The difference between improvement of BCVA in group I and group II was statistically not significant.

In our study, there was no decrease in BCVA in any of our cases at 6 months follow up.

Rikbov et al., (2011)[13] in a study that included 87 eyes, reported improvement of BCVA from 0.41 ± 0.12 logMAR to 0.52 ± 0.01 logMAR at 6 months after corneal collagen cross linking.

Agrawal, (2009)[14] studied 68 eyes with mild to moderate progressive keratoconus. He reported that, BCVA improved at least one line in 54% of cases and remained stable in 28%.

Arbelaez et al., (2009)[15] reported a mean increase by 1.65 lines of BCVA after corneal collagen cross linking.

In our study, there was reduction in spherical error of refraction in both groups, in group I and in group II during the follow up visits. It decreased by 0.92 D, 1.12 D, and 0.72 D in both groups, group I and group II respectively at 6 months follow up. The difference between spherical error of refraction preoperatively and at the end of the follow up period in both groups, group I and group II were statistically significant. The difference between group I and group II was statistically not significant.

As regards cylindrical error of refraction, there was gradual reduction is both groups, group I and group II after surgery. It decreased by 1.08 D, 0.92 D, and 1.24 D in both groups, group I and group II respectively, at 6 months follow up. The difference between cylindrical error of refraction preoperatively and at the end of the follow up period in both groups, group I and group II were statistically significant. The difference between group I and group II was statistically not significant.

Agrawal, (2009)[14] in his study, that included 68 eyes reported that astigmatism decreased by a mean of 1.2 diopters in 47% of eyes and remained stable (within ±0.50 diopter) in 42% of eyes.

In our study, there was decrease in mean K value (keratometric reading) after corneal collagen cross linking. The differences in mean K value preoperatively and after 6 months in both groups, in group I and in group II were statistically significant. The difference between the decrease in K value in group I and group II was statistically not significant.

Rikbov et al., (2011)[13] reported that corneal refractive power decreased from 50.62 ± 1.94 D to 49.41 ± 1.69 D at 12 months postoperatively.

Agrawal (2009), (14) reported a decrease in mean K value by 2.73 D in 66% of eyes and remained stable (within ± 0.50 D) in 22% of eyes. He reported also that the maximum K value decreased by a mean of 2.47 D in 54% of eyes and remained stable on 38% of eyes.

Arbelaez et al, (2009)[15] reported a prospective study that included 20 eyes with keratoconus treated with corneal collagen cross linking. They reported that the average keratometry reading was 1.36 D (P = 0.0004) and 1.4 D of the apex (P = 0.001) Manifest refraction showed a mean reduction of 1.26 D (P = 0.033) for spherical error and 1.25 D (p = 0.0003) for manifest cylinder.

In our study we did not report any eye with persistent corneal edema postoperatively.

In our study, the least corneal thickness was more than 400 microns. *Raiskup et al, (2011)*[16] did their study on thin corneas that were less than 400 microns and were treated by a hypo-osmolar riboflavin solution after its de-epithelialization. Mean least corneal thickness was 382.3 ± 41.9 microns, after corneal collagen cross linking it increased to 491.8 ± 46.7 microns. Before surgery the mean K value was 65.6 ± 11.2 diopters and at 1 year post operatively it was 64.9 ± 11.0 diopters. Best corrected VA before treatment was 0.63 ± 0.37 log MAR. At one year post operatively it was 0.59 ± 0.42.

As regards corneal haze, in our study it was reported in 7 eyes out of 30 (23.3%). In group I, it was reported in 4 eyes (20.0%), the mean grade of haze was 0.73. There was decrease in the grade of haze during the follow up period to be 0.47 at six months post operatively.

In group II, corneal haze was reported in 3 eyes (20.0%), at one month postoperatively. The mean grade was 0.47. Six months postoperatively corneal haze was reported in 2 eyes only (13.3%) and the mean grade of haze was 0.33.

The depth of corneal haze involved about 50% of the anterior stroma, while the extension was about 4 to 7 mm of the central cornea in both groups. During the follow up visits there was no change in depth or extension of haze.

Mazzotta et al, (2007)[17] reported corneal haze in 5 out of 44 eyes (11.4%) at 6 months follow up. *Raiskup et al, (2009)*[18] reported corneal haze in 9% of eyes at one year after corneal collagen cross linking. Grade of corneal haze as reported by *Koller et al, (2009)*[19] was 0.18 at 6 months postoperatively. The difference in grade of haze between our study and *Koller et al, (2009)*[19] may be attributed to the difference in the study size or to different grading systems of haze in the two studies.

Carr et al, (1995)[20] reported that haze involved approximately 60% depth of corneal stroma after cross linking.

Our results were in agreement with *Greanstein et al, (2010)* [21] who reported the peak of corneal haze at 1 month and plateaued between 1 month and 3 months then began to clear between 3 months and 6 months.

Torun and Turan, (2012)[22] reported a case of post corneal collagen cross linking microbial keratitis. They attributed this to epithelial debridement and bandage contact lenses used after corneal collagen cross linking. In our study, we did not report any case with microbial keratitis in both groups.

Conclusion

Both epi-on and epi-off techniques of corneal collagen cross linking are safe and effective in stabilization or even improvement of mild to moderate degree keratoconus as regards best corrected visual acuity, refraction, keratometric readings, and least corneal thickness. The epi-on technique is easier and more tolerable by the patient with less postoperative corneal haze.

Recommendations

A longer follow up period is recommended to evaluate the stability of keratometric readings and visual outcome of both technique as well as their possible late complications. A larger study sample is also recommended to obtain more accurate results.

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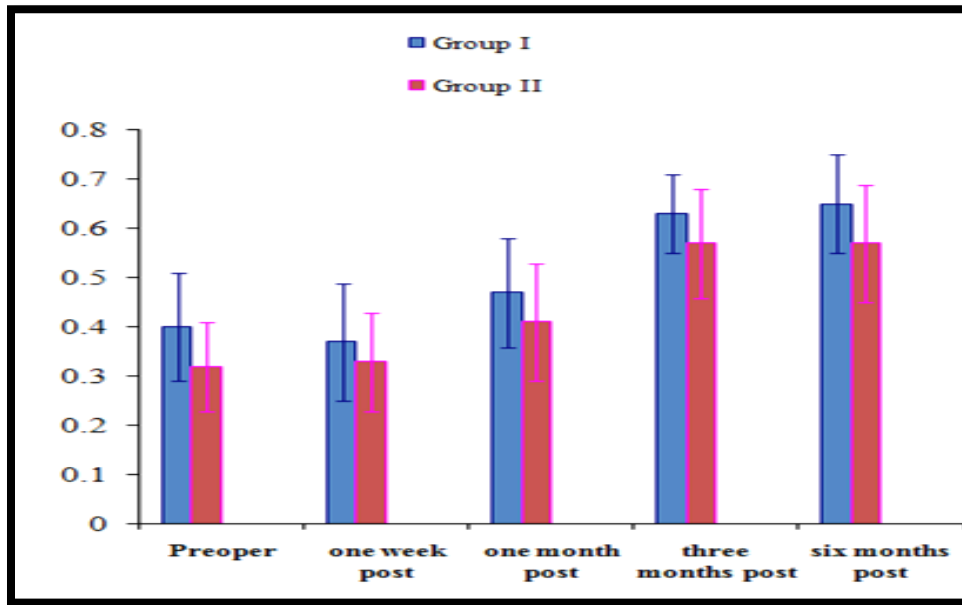
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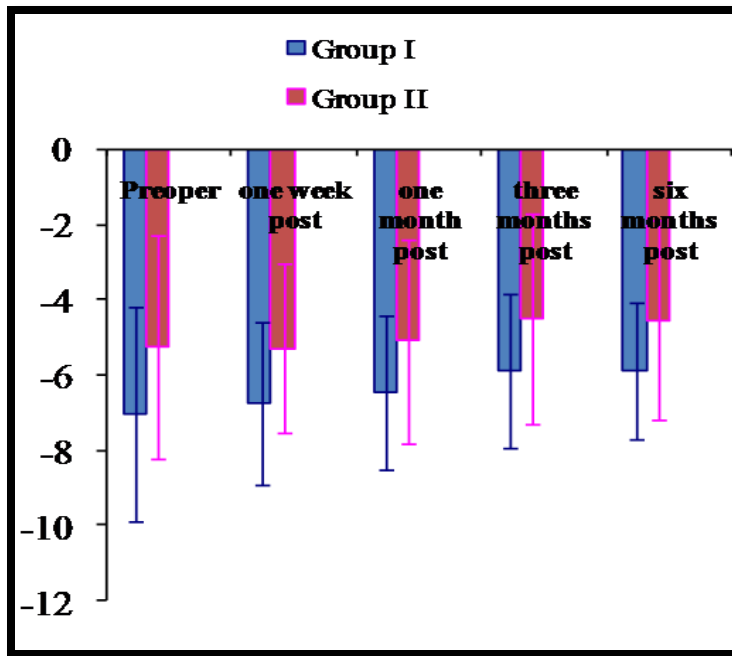**Table (1): Postoperative examination at the follow up visits:**

	1 day	2 days	1 week	1 month	3 months	6 months
Best corrected visual acuity			√	√	√	√
Cycloplegic refraction			√	√	√	√
Slit lamp examination	√	√	√	√	√	√
Pentacam examination						√

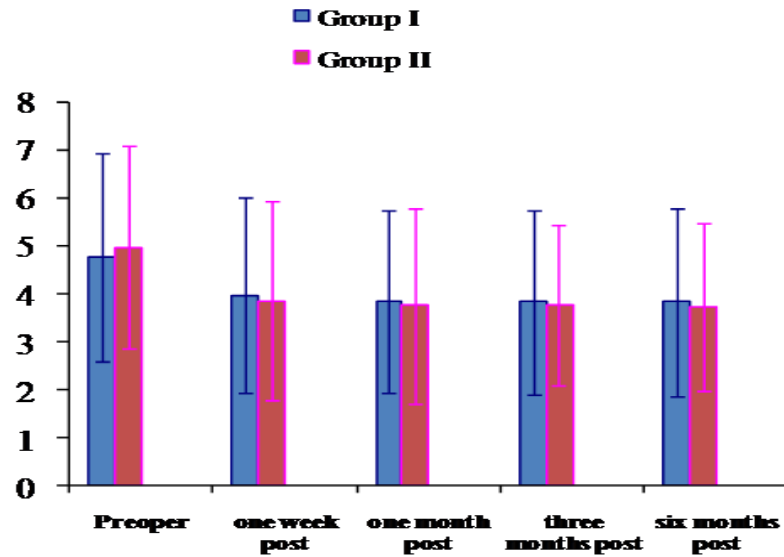**Table (2): Best corrected visual acuity $\pm$ SD before surgery and in follow up visits in both groups.**

	Mean best corrected visual acuity ± SD	
Preoperatively Both groups Group I Group II	0.36 0.40 0.32	+0.11 +0.14 +0.09
One weak postop. Both groups Group I Group II	0.35 0.37 0.33	+0.16 +0.12 +0.10
One month postop. Both group Group I Group II	0.44 0.47 0.41	+ 0.14 + 0.11 + 0.12
Three months postop Both group Group I Group II	0.60 0.63 0.57	+0.15 +0.08 +0.11
Six months postop Both group Group I Group II	0.61 0.65 0.57	+0.17 +0.1 +0.12

Figure (1) Best corrected visual acuity + SD before surgery and in follow up visits in both groups

Table (3): Mean spherical error refraction + SD before surgery and in follow up visits in both groups

	Mean spherical error Refraction ± SD	
Preoperatively Both groups Group I Group II	 -6.14 -7.02 -5.26	 +3.02 +2.84 +2.97
One weak postoperatively. Both groups Group I Group II	 -6.02 -6.76 -5.28	 +2.42 +2.16 +2.22
One month postoperatively. Both group Group I Group II	 -5.81 -6.44 -5.18	 +2.16 +2.04 +2.70
Three months postoperatively. Both group Group I Group II	 -5.20 -5.88 -4.52	 +3.08 +2.02 +2.78
Six months postoperatively. Both group Group I Group II	 -5.22 -5.90 -4.54	 +2.90 +1.82 +2.65

Figure (2): Mean spherical error Refraction + SD before surgery and in follow up visits in both groups

Table (4): Mean cylindrical error of refraction + before surgery and in follow up visits in both groups

	Mean Cylindrical error of refraction + SD	
Preoperatively		
Both groups	4.87	+2.16
Group I	4.76	+2,09
Group II	4.96	+2.12
One weak postoperatively		
Both groups	3.92	+2.02
Group I	3.98	+1.94
Group II	3.86	+2.07
One month postoperatively		
Both group	3.81	+1.96
Group I	3.86	+1.89
Group II	3.76	+2.03
Three months postoperatively		
Both group	3.80	+1.88
Group I	3.84	+1.92
Group II	3.76	+1.66
Six months postoperatively		
Both group	3.79	+2.04
Group I	3.84	+1.95
Group II	3.74	+1.73

Figure (3): Mean cylindrical error of refraction ± SD before surgery and in follow up visits in both groups.

Table (5): Mean least corneal thickness + SD before surgery and 6 months postoperatively.

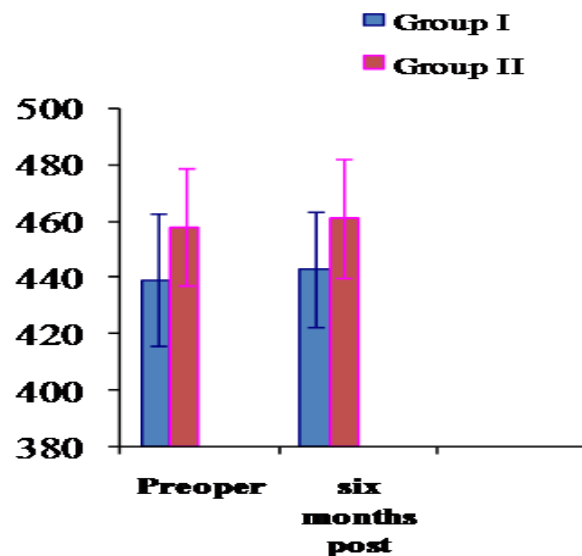|	Mean last corneal thickness + SD	
Preoperatively Both groups Group I Group II	448.6 439.2 458.0	+21.1 +23.1 +20.8
Six months postop Both groups Group I Group II	451.9 442.7 461.1	+19.4 +20.4 +21.1

Figure (4): Mean least corneal thickness ± SD before surgery and 6 months postoperatively

Table (6): Mean K readings ± SD before surgery and in follow up visits in both groups.

	Mean K Readings ± SD	
Preoperatively		
Both groups K1	43.93	±1.9
K2	48.8	±2.1
Group I K1	43.84	±1.6
K2	48.6	±2.2
Group II K1	44.02	±1.5
K2	49.0	±2.3
Six months postop		
Both groups K1	44.51	±1.8
K2	48.3	±2.1
Group I K1	44.36	±1.4
K2	48.2	±2.0
Group II K1	44.6	±1.6
K2	48.4	±2.1

Figure (5): Mean K readings before surgery and in follow up visits in both groups