The Egyptian Journal of Hospital Medicine (April 2023) Vol. 91, Page 4204-4209

# Management of Post-Penetrating Keratoplasty Astigmatism by Photorefractive Keratectomy

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## ABSTRACT

**Background:** Astigmatism after keratoplasty continues to be a difficult case for corneal refractive surgeons. Astigmatism is a barrier to visual recovery after a successful corneal transplant, even though graft viability is the primary concern in keratoplasty.

**Aim and objectives:** The aim of the study was to assess the management of postoperative penetrating keratoplasty astigmatism by photorefractive keratectomy.

**Subject and methods:** Study was done between March 2021 and March 2022 at Al-Nahar eye center (Assiut). 30 eyes of 30 patient underwent PTK-PRK (phototherapeutic keratectomy and photorefractive keratectomy), all were done by the same surgeon.

**Results:** The BCVA (Best Corrected Visual Acuity) of the studied eyes ranged from 0.01 to 0.2 with a median value of 0.1 and IQR between (0.1 and 0.2) preoperatively, which was significantly improved after 1 month to have a median value of 0.5 and IQR between (0.4 and 0.58, P=0.003) and kept improving significantly after 2 and 3 months by comparison to preoperative to have a median of 0.7 with IQR (0.7: 0.8) after 2 months and all eyes had a BCVA of 0.8 after 3 months (P<0.001).

**Conclusion:** Clear graft penetrating keratoplasty (PK) improves eyesight. Significant postoperative astigmatism, however, may impair visual acuity to some degree. After keratoconus, patients with astigmatism have more than one treatment option available.

**Keywords:** Topography-guided photorefractive keratectomy, Post keratoplasty astigmatism, Irregular astigmatism, Laser refractive surgery, Keratoplasty**.**

## INTRODUCTION

For patients who have undergone penetrating keratoplasty, postoperative astigmatism, which can be anywhere between 15 and 20 diopters (D) and result in severe anisometropia, is the main barrier to adequate visual rehabilitation (PKP)[(1)].

Too much astigmatism can be caused by a number of things, such as preexisting corneal thinning, eccentric trephination of the host, vascularization, preoperative keratoconus, big grafts, and astigmatism of the donor eye, and the length, depth, tension, and arrangement of corneal sutures[(2)].

Sadly, utilising glasses for vision rehabilitation often yields unsatisfactory visual results[(3)].

Contact lenses are the go-to in cases like these, but they may be tricky to install. In addition, contact lenses have been shown to enhance the likelihood of transplant rejection by inducing peripheral neovascularization[(4)].

The need for surgical intervention in vision rehabilitation arises when conventional optical approaches fail to provide satisfactory results. Astigmatism after PKP may be surgically corrected in a number of ways. They include: relaxing incisions, wedge resection, astigmatic keratotomy, and selective suture removal[(5)].

Myopia and astigmatism after PKP have been reported to respond well to laser refractive surgeries including photorefractive keratectomy (PRK) and laser in situ keratomileusis (LASIK)[(6)].

Nevertheless, most of the investigations are part of much smaller series with brief follow-ups[(7)].

## THE AIM OF THE STUDY

Discuss the efficacy of photorefractive keratectomy to improve visual acuity by correction of astigmatism after penterating keratoplasty procedure.

## PATIENTS AND METHODS

This study was done between March 2021 and March 2022 at Al-Nahar eye center (Assiut). 30 eyes of 30 patient underwent PTK-PRK (phototherapeutic keratectomy and photorefractive keratectomy), all were done by same surgeon.

**Inclusion criteria:**

Patient 2 years after PKP, PKP after complete suture removal, astigmatism up to ± 6 diopter, myopia or hypermetropia up to ± 2, age of the patient 21-35 year, no ocular surface disorder, normal IOP, no dryness, BCVA up to 0.8.

**Exclusion criteria:** Ocular surface disorder as dry eye, high astigmatism more than ± 6 diopter, myopia or hypermetropia more than ± 2 diopter and systemic disease as DM and autoimmune disease.

Complete ocular examination was done. Pentacam and Z-wave Aberrometry were used.

**Operative details:**

After explaining the procedure's purpose and potential hazards, we got all patients' informed permission. Patients were included in the trial if their visual acuity improved with phoropter correction,



Received: 29/10/2022
Accepted: 01/01/2023

although we did not need them to be correctable to 20/20.

It was usual for contact lenses to increase visual acuity by one or two lines compared to glasses because of an uneven astigmatism component[8].

A total of 30 patients participated in the analysis. There was no one among these individuals who could use contacts or who could wear glasses with a high cylindric correction.

Patients were given the option of pursuing other surgical procedures. The Food and Drug Administration and the University of Southern California's Institutional Review Board have both given their blessing to the protocol that guided this exploratory treatment. Slit-lamp microscopy and preoperative photographs were taken to record any issues before surgery. Refraction, keratometry, ultrasound pachymetry, and computer-assisted corneal topography were all conducted pre- and postoperatively by a seasoned professional.

Contact lens overrefraction or, if needed, the potential acuity meter was used to determine the patient's theoretical visual acuity (PAM, Mentor O and O Inc., Norwell, Massachusetts, USA).

Patients had excimer laser surgery after a circular protractor was aligned with a landmark visible under the slit lamp and put on the globe at the corneoscleral limbus.

Cylindrical ablations were set to be performed by the computer when the preoperative cylindric inaccuracy was 80% or more, with the corneal plane taken into account. An attempted 66% correction was programmed for one patient with 6 diopters of post-K astigmatism, while a 50% correction was tried for two others.

An intentional alteration in refractive index was input into the computer as a "negative cylinder" (For instance, a piano set at -6.00 x 180 will cause a flattening of 6 diopters along the vertical axis.).

The computer instructs the blades to be aligned perpendicular to the refractive cylinder's axis, which is expressed in negative cylinder form, in order to produce the necessary corneal flatness along the chosen (steeper) meridian. Patients were administered tobramycin sulphate (0.3%) and dexamethasone sodium phosphate (0.1%) combination ointment after surgery, and they were maintained in a semi-pressure dressing until reepithelialization was complete. During two weeks, they received prednisone acetate 1% four times daily. Next, for four weeks, they had it three times daily. Finally, for another four weeks, they received it twice daily. The same masked observer performed refraction, keratometry, ultrasonic pachymetry, and computer-assisted topography after two weeks, one month, two months, three months following surgery.

**Ethical Approval: The Al-Nahar Eye Center's Ethics Board authorised the research, and patients were provided with all the information they need concerning the experiment. Each research participant provided his signed permission after receiving full information. The Declaration of Helsinki, the International Medical Association's code of ethics for research involving people, guided the conduct of this study.**

**Statistical analysis:** The statistical evaluation made use of SPSS version 28. (IBM Co., Armonk, NY, USA). The mean and standard deviation (SD) were used to present the quantitative parametric data. Friedman's test was used to analyse measurement differences across time periods, using non-parametric quantitative data presented as the median and interquartile range (IQR), Wilcoxon signed-rank tests also used to compare each group with each other. To represent qualitative features, frequency and percentage were utilised. We utilised Spearman's rank correlation coefficient to roughly estimate the strength of relationship between two non-parametric quantitative variables. In this investigation, a two-tailed P value of less than 0.05 was considered statistically significant.

## RESULTS

The demographic data of the studied 20 participants are shown in table 1.

**Table 1: Demographic data of the studied participants**

| | | **Study participants (n=30)** |
|---|---|---|
| **Age (years)** | Mean ± SD | 28.6 ± 3.7 |
| | Range | 21 – 35 |
| **Sex** | Male | 12 (40%) |
| | Female | 18 (60%) |

Data are presented as frequency (%) unless otherwise mentioned

As shown in **Error! Not a valid bookmark self-reference.**, by studying the relation between postoperative measurements, we found that K1 and K2 were significantly decreased after 3 months as compared to 1 month, while were comparable between 1 and 2 months and between 2- and 3-months measurements. Regarding astigmatism degree, it changed insignificantly after 1 month while the improvement was significant after 2 and 3 months than preoperative measurement. By studying the relation between postoperative measurements, we found that astigmatism was significantly improved after 2 and 3 months as compared to 1 month but was comparable between 2- and 3-months measurements.

**Table 2: Keratometry and astigmatism degree of the studied eyes (n=30)**

| | | Pre | 1 month | 2 months | 3 months |
|---|---|---|---|---|---|
| **K1 (Diopter)** | Median (IQR) | 42 (41.5: 43) | 36 (35: 37) | 35.5 (34.63: 36.38) | 35 (34: 35.88) |
| | Min-Max | 41.5: 43.5 | 34: 43 | 33: 43 | 33.5: 43 |
| | P1<0.001*, P2 <0.001*, P3 <0.001*, P4=0.134, P5= 0.002*, P6= 0.099 | | | | |
| **K2 (Diopter)** | Median (IQR) | 47 (46.75: 48) | 40.13 (39.19: 41.94) | 40 (39: 41.19) | 40 (38.44: 41) |
| | Min-Max | 45.25: 48.25 | 35.5: 45.5 | 35: 44.5 | 34: 45 |
| | P1<0.001*, P2 <0.001*, P3 <0.001*, P4=0.089, P5= 0.001*, P6= 0.121 | | | | |
| **Astigmatism (Diopter)** | Median (IQR) | -3.5 (-5: 2) | 0.5 (-0.25 - 1) | 1 (0.75 - 1) | 1 (1 - 1) |
| | Min-Max | -6: 5 | -0.5: 1 | -0.5: 1 | 0.5: 1 |
| | P1= 0.803, P2= 0.032*, P3= 0.004*, P4=0.016*, P5=0.002*, P6=0.453 | | | | |

IQR: Interquartile range, P1: Comparison between preoperative and 1-month measurements, P2: Comparison between preoperative and 2-months measurements, P3: Comparison between preoperative and 3-months measurements, P4: Comparison between 1- and 2-months measurements, P5: Comparison between 1- and 3-months measurements, P6: Comparison between 2- and 3-months measurements, *: Statistically significant, K1: flat keratometry, K2: steep keratometry

By comparing between postoperative measurements of mean spherical equivalent, it was significantly improved after 2 and 3 months as compared to 1-month measurement while was comparable between 2- and 3-months measurements (Table 3).

**Table 3: Pre- and postoperative evaluation of median of SE of the studied eyes (n=30)**

| | | Pre | 1 month | 2 months | 3 months |
|---|---|---|---|---|---|
| **Median of SE (Diopter)** | Median (IQR) | -4 (-5: -3.625) | 1.5 (-1.88 - 1.75) | 0.5 (-3.5 - 1) | -1.38 (-3 - 0.94) |
| | Min-Max | -6: 4 | -4: 2.25 | -5: 2 | -5: 1 |
| **P1<0.001*, P2 <0.001*, P3=0.011*, P4=0.011*, P5= <0.001*,** P6= 0.368 | | | | | |

P1: Comparison between preoperative and 1-month measurements, P2: Comparison between preoperative and 2-months measurements, P3: Comparison between preoperative and 3-months measurements, P4: Comparison between 1- and 2-months measurements, P5: Comparison between 1- and 3-months measurements, P6: Comparison between 2- and 3-months measurements, *: Statistically significant, SE: Spherical equivalent, IQR: Interquartile range.

By comparing between postoperative spherical errors, they were significantly changed after 2 and 3 months as compared to 1-month measurement but were comparable between 2- and 3-months measurements as shown in **Error! Not a valid bookmark self-reference.**

**Table 4: Pre- and postoperative evaluation of spherical errors of the studied eyes (n=30)**

| | | Pre | 1 month | 2 months | 3 months |
|---|---|---|---|---|---|
| **Spherical errors (Diopter)** | Median (IQR) | -1.5 (-1.75: 1.44) | -0.7 (-1.5: 0.94) | 0.75 (-0.5 - 1.19) | 0.75 (0.25: 1) |
| | Min-Max | -2: 2 | -1.75: 2.25 | -2.25: 2.25 | -1.5: 2.25 |
| P1= 0.653, **P2= 0.046***, **P3= 0.024*, P4=0.014*, P5=0.007*,** P6= 0.803 | | | | | |

IQR: Interquartile range, P1: Comparison between preoperative and 1-month measurements, P2: Comparison between preoperative and 2-months measurements, P3: Comparison between preoperative and 3-months measurements, P4: Comparison between 1- and 2-months measurements, P5: Comparison between 1- and 3-months measurements, P6: Comparison between 2- and 3-months measurements, *: Statistically significant,

The BCVA of the studied eyes was significantly improved after 1 month and kept improving significantly after 2 and 3 months by comparison to preoperative value (table 5).

**Table 5: Pre and post operative evaluation of BCVA of the studied eyes (n=30)**

| | | Pre | 1 month | 2 months | 3 months |
|---|---|---|---|---|---|
| **BCVA** | Median (IQR) | 0.1 (0.1: 0.2) | 0.5 (0.4: 0.58) | 0.7 (0.7: 0.8) | 0.8 |
| | Min-Max | 0.01: 0.2 | 0.3: 0.6 | 0.6: 0.8 | 0.8 |
| **P1=0.003*, P2 <0.001*, P3 <0.001*, P4<0.001*, P5<0.001*,** P6=0.11 | | | | | |

BCVA: Best corrected visual acuity, IQR: Interquartile range, P1: Comparison between preoperative and 1-month measurements, P2: Comparison between preoperative and 2-months measurements, P3: Comparison between preoperative and 3-months measurements, P4: Comparison between 1- and 2-months measurements, P5: Comparison between 1- and 3-months measurements, P6: Comparison between 2- and 3-months measurements, *: Statistically significant.

As shown in **Error! Not a valid bookmark self-reference.**, there was a statistically significant positive correlation between astigmatism degree and mean spherical equivalent preoperatively, while there was a significant negative correlation between astigmatism and BCVA. On the other hand, there was no correlation between astigmatism and spherical errors preoperatively.

**Table 6: Correlation between astigmatism and different eye measurements preoperatively (n=30 eyes)**

| | Astigmatism (Diopter) | |
|---|---|---|
| | rs | P |
| **Mean spherical equivalent (Diopter)** | 0.482 | 0.007* |
| **Spherical errors (Diopter)** | 0.052 | 0.784 |
| **BCVA** | -0.527 | 0.003* |

rs: Spearman's correlation coefficient, *: Statistically significant.

As shown in **Error! Not a valid bookmark self-reference.**, there was a statistically significant negative correlation between astigmatism and BCVA 1 month postoperatively.

**Table 7: Correlation between astigmatism and different eye measurements 1 month postoperatively (n=30 eyes)**

| | Astigmatism (D) | |
|---|---|---|
| | rs | P |
| **Mean spherical equivalent (Diopter)** | -0.136 | 0.474 |
| **Spherical errors (Diopter)** | 0.05 | 0.793 |
| **BCVA** | -0.362 | 0.049* |

rs: Spearman's correlation coefficient, *: Statistically significant as P value<0.05.

As shown in Table 8, there was no statistically significant correlation between astigmatism and (mean spherical equivalent, spherical errors and BCVA) 2 months postoperatively.

**Table 8: Correlation between astigmatism and different eye measurements 2 months postoperatively (n=30 eyes)**

| | Astigmatism (diopters) | |
|---|---|---|
| | rs | P |
| **Mean spherical equivalent (Diopter)** | 0.064 | 0.737 |
| **Spherical errors (Diopter)** | 0.214 | 0.257 |
| **BCVA** | -0.001 | 0.998 |

rs: Spearman's rank correlation coefficient

## DISCUSSION

Myopia and astigmatism after PKP have been reported to respond well to photorefractive keratectomy (PRK) and laser in situ keratomileusis (LASIK) [(4)].

There was a total of 30 people (12 men and 18 females) in this research, and their ages varied from 23 to 35, with a mean of 28.6 ± 3.7.

A study by **Bilgihan *et al*.** [(9)] demonstrated that PRK was successfully used to treat post-PKP myopia and astigmatism in 16 eyes (8 right and 8 left) among 16 individuals. The 9 women and 7 men had a mean age of 28.4 6.8 years (SD).

Twenty-five right eyes and twenty-nine left eyes received PRK for post keratoplasty astigmatism, as reported by **Bizrah *et al*.** [(10)]. To eliminate potential for bias in the screening process, all 54 eyes were examined rather than just the eyes of 50 patients. There were 17 female patients and 33 male patients in all. Ages ranged from 23 to 79, with a mean of 32 (± 12.4 years).

In this study we demonstrated that the preoperative flat keratometry value (K1) ranged from 41.5 to 43.5 D with a median of 42 D, which decreased significantly after 1, 2 and 3 months to have medians of 36, 35.5 and 35 D respectively (P<0.001). Similarly in steep keratometry (K2), the preoperative value ranged from 45.25 to 48.25 D with a median of 47 D, which was significantly decreased after 1, 2 and 3 months to have medians of 40.13, 40 and 40 diopters respectively (P<0.001). By studying the relation between postoperative measurements, we found that K1 and K2 were significantly decreased after 3 months as compared to 1 month (P=0.002, 0.001 for K1 and K2 respectively) while were comparable between 1 and 2 months and between 2- and 3-months measurements.

Mean K central values were obtained for all 54 eyes before surgery and 52 eyes thereafter in a study by **Bizrah *et al*.** [(10)]. Fifty-three eyes had their preoperative and postoperative keratometric astigmatism values recorded; while 52 eyes had theirs recorded at the final follow-up. K central went from 45.51 0.30 D before surgery to 44.13 0.39 D at the most recent checkup.

In this study we found that regarding astigmatism degree, it ranged from -6 to 5 D with a median of -3.5 D preoperatively which changed insignificantly after 1 month to have a median of 0.5 D while the improvement was significant after 2 and 3 months than preoperative measurement with a median of 1 diopter (P=0.032, 0.004 respectively). By studying the relation between postoperative measurements, we found that astigmatism was significantly improved after 2 and 3 months as compared to 1 month (P=0.016, 0.002 respectively) but was comparable between 2- and 3-months measurements.

Data from **de Oteyza *et al*. [11]** shows that the average refractive astigmatism decreased from 11.47± 3.57 to 4.79 ± 3.32 diopters (D) during the pre- and postoperative periods, respectively (p <0.001).

The keratometric astigmatism value dropped from 5.24 ± 0.36 D before surgery to 2.98± 0.34 D at the last follow-up, as determined by **Bizrah *et al*. [10]**. K central and keratometric astigmatism were found to be significantly different from preoperative values using a paired samples t test (P<0.0001 and P<0.0001, respectively).

Astigmatism was reduced from 4.57± 2.05 D preoperatively (topographic) to 1.58± 1.25 D postoperatively (refractive) in the 2014 research by **Wade *et al*. [12]**, with 76.2% of eyes falling within 1 D of anticipated manifest astigmatism at the last visit (mean follow-up of 14.7 months).

In the current research, the mean spherical equivalent of the studied eyes ranged from -6 to 4 diopter with a median value of -4 and IQR between (-5 and -3.625) diopter preoperatively, which had a significant improvement after1 month to have a median value of 1.5 and IQR between (-1.88 and 1.75, P<0.001) and kept changing significantly after 2 and 3 months by comparison to preoperative with medians of 0.5 and -1.38 respectively with IQRs (-3.5: 1) and (-3: 0.94) respectively and with P<0.001 and 0.011 respectively.

The average spherical equivalent before surgery was found to be−3.10 ± 4.15 D, whereas the average spherical equivalent after surgery was determined to be 1−1.55 ± 3.41 D (p = 0.002).

Results by **Bilgihan *et al*. [9]** were comparable to those found in earlier research, showing a decrease in spherical equivalent refraction of 24% and refractive astigmatism of 42%. This data suggests that PRK is superior to PKP for correcting postoperative spherical myopia and astigmatism.

In this study we illustrated that the spherical error of the studied eyes ranged from -2 to 2 D with a median value of -1.5 D and IQR between (-1.75 and 1.44) D preoperatively, changed insignificantly after 1 month to -0.7 D with IQR between (-1.5 and 0.94) D and kept changing significantly after 2 and 3 months by comparison to preoperative with a median of 0.75 D, IQRs of (-0.5: 1.19) and (0.25: 1) D respectively (P= 0.046 and 0.024 respectively).

By creating a lamellar corneal flap, **Dada *et al*. [13]** found that post-penetrating keratoplasty astigmatism might be reduced by 5 diopters in a young patient.

Lamellar keratotomy's impact on post-K astigmatism was the subject of a separate investigation by **Busin *et al*. [14]**. On average, they detected a flattening of 1 D in the spherical equivalent and a flattening of 1.5 D in the refractive cylinder across nine eyes from nine individuals.

In this study we illustrated that the BCVA of the studied eyes ranged from 0.01 to 0.2 with a median value of 0.1 and IQR between (0.1 and 0.2) preoperatively, which was significantly improved after 1 month to have a median value of 0.5 and IQR between (0.4 and 0.58) with P=0.003 and kept improving significantly after 2 and 3 months by comparison to preoperative to have a median of 0.7 with IQR (0.7: 0.8) after 2 months and all eyes had a BCVA of 0.8 after 3 months (P<0.001).

According to **Keskinbora [15]** throughout the first and final month of follow-up, the accomplished correction consistently under-estimated the desired correction. Four years after treatment, 80.8% of patients with astigmatism between -6.00 and -10.00 diopters who had multizone PRK achieved 20/40 vision or better.

In this study, a positive link between astigmatism degree and preoperative mean spherical equivalent was found (rs= 0.482, P=0.007), whereas a negative correlation between astigmatism and best-corrected visual acuity was found (rs= -0.527, P=0.003).

As **Wolffsohn *et al*. [16]** shown, a cylinder power of 1.00 D is associated with a significant increase in the incidence of visual impairment, suggesting that this value may be a reasonable astigmatism threshold. The drop in BCVA and rise in BCVI seen in hyperopic, emmetropic, and myopic eyes with astigmatism 1.00 D suggests that greater levels of cylinder generate optical distortions that are not totally correctable by the typical correction of both sphere and cylinder.

## CONCLUSION

According with other research, our results show that PRK may significantly enhance refraction, topographic keratometry readings, and visual acuity.

## DECLARATIONS

**Consent for publication:** I attest that all authors have agreed to submit the work.
**Availability of data and material:** Available
**Competing interests:** None
**Funding:** No fund
**Conflicts of interest:** no conflicts of interest.

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