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Characteristics of Astigmatism after MyoRing Implantation

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ABSTRACT

Considering the rising number of MyoRing implantation procedures in keratoconic corneas and the refractive outcomes associated with this treatment modality, this study aimed to evaluate and compare the magnitude and axis orientation of total and corneal astigmatism between before and after MyoRing implantation in 34 eyes of 28 patients with keratoconus (KCN) (mean age: 29.41 ± 7.0 years). The inclusion criterion was a reliable diagnosis of clinical KCN based on corneal biomicroscopic and tomographic findings. The mean total astigmatism of ocular refraction decreased significantly from -4.27 ± 3.15 D (before MyoRing implantation) to -2.18 ± 1.63 D (after MyoRing implantation) ($P < 0.001$). The mean astigmatism in the anterior and posterior surface of the cornea decreased significantly by 1.16 D ($P = 0.001$) and 0.24 D ($P = 0.009$), respectively, after MyoRing implantation. Before MyoRing implantation, the axis orientation of total ocular astigmatism for with-the-rule, oblique, and against-the-rule astigmatism was 21%, 42%, and 37%, respectively; at 6 months after MyoRing implantation, it was 18%, 24%, and 58%, respectively. Before MyoRing implantation, the axis orientation for with-the-rule, against-the-rule, and oblique astigmatism of the anterior surface of the cornea was 59%, 24%, and 17%, respectively; at 6 months after MyoRing implantation, it was 52%, 24%, and 24%, respectively. Before MyoRing implantation, the axis orientation of with-the-rule, oblique, and against-the-rule astigmatism of the posterior surface of the cornea was 68%, 29%, and 3%, respectively; at 6 months after MyoRing implantation, it was 67%, 12%, and 12%, respectively. MyoRing implantation significantly decreased the amount of total, anterior, and posterior corneal astigmatism.

KEY WORDS

Astigmatism; MyoRing; Keratoconus; Cornea; Refractive Error

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INTRODUCTION

Keratoconus (KCN) is a bilateral, asymmetric, and progressive corneal degenerative disease characterized by localized corneal thinning and bulging commonly occurring in the inferotemporal or central cornea [1, 2]. The clinical manifestations of this ectatic corneal disorder include high myopia, irregular astigmatism, and

decreased visual acuity due to changes in the corneal microstructure [3, 4]. The prevalence of KCN in the general population is 1:375 [5]. The strategy for KCN treatment mainly depends on the severity of the condition. In low and moderate stages of KCN, spectacles and/or contact lenses are used for improvement of the visual acuity [1, 6]. In advanced stages, penetrating keratoplasty and deep anterior lamellar keratoplasty were the most commonly used methods in the past years [7]. However, keratoplasty has many problems including the cost of surgery, the need for long-term postoperative follow-up, decreased visual acuity, graft rejection, corneal infection, and suture problems [8]. For these reasons, alternative effective treatment options have been developed. One such option is the implantation of intracorneal rings, which differ from intrastromal rings. Examples of currently used intracorneal rings are the intracorneal ring segments [9] and full-ring (continuous) flexible intracorneal implants (MyoRing; DIOPTEX GmbH, Linz, Austria) [10, 11]. Ibrahim and Elmor reported that intracorneal ring segment implantation might be beneficial in keratoconic corneas [9]. Indeed, Jabbarvand et al. showed that continuous intracorneal rings can improve visual acuity and reduce refractive errors [10]. In another study, Jadidi et al. showed that MyoRing is effective in KCN and high myopia [11]. In patients with KCN, corneal parameters such as corneal astigmatism are different from those of the normal cornea. MyoRing implantation can induce refractive changes in the cornea. Therefore, it would be important to study the effect of MyoRing implantation on the total, anterior, and posterior corneal astigmatism in these patients. Considering the rising number of MyoRing implantation procedures in keratoconic corneas and the refractive outcomes of this treatment modality, this retrospective observational study aimed to investigate and compare the characteristics of astigmatic refractive error before and after MyoRing implantation in eyes with KCN.

MATERIALS AND METHODS

The present study was conducted at Farabi Eye Hospital in Tehran from 2013 to 2015. The Institutional Review Board and the Ethics Committee of Shahid Beheshti University of Medical Sciences approved the study and ensured its protocol followed the tenets of the Declaration of Helsinki. In this retrospective observational study, we collected data from the medical records of patients with strict diagnosis of KCN who had MyoRing implantation surgery. All the cases had been examined before the surgery by a single experienced ophthalmologist (M.KH). The inclusion criteria of the study were as follows: patients whose medical records contained comprehensive ophthalmic examination data; patients with a clear central cornea; patients with a minimum corneal thickness of not less than 360 microns preoperatively; and patients who refrained from using contact lenses for at least 3 weeks before surgery. The exclusion criteria were as follows: patients with incomplete medical records; patients with corneal scar and/or opacity, which could affect the measurements taken before and/or after MyoRing implantation; and patients with systemic and/or ophthalmic diseases (such as glaucoma, cataract, and previous corneal surgery). Consequently, patients with KCN with acquired or congenital anterior segment disorders as well as acquired or congenital posterior segment disorders were excluded. Based on the inclusion and exclusion criteria, 34 eyes of 28 patients with KCN were included in the study. The data extracted from the medical records included the results of visual acuity, cycloplegic refraction (Topcon KR-1, Tokyo, Japan), slit lamp biomicroscopy, and Scheimpflug-based tomography (Pentacam HR, Oculus Optikgeräte GmbH, Wetzlar, Germany) of KCN eyes. The data also included the axis and amount of total, anterior, and posterior corneal astigmatism measured by the Pentacam HR. All refractive and corneal measurements were performed by a single experienced optometrist (M.G) between 8:00 AM and 12:00 AM. All corneal imaging was performed in a consistent manner based on the manufacturers' user guides. The manufacturers' representatives routinely calibrated the Pentacam HR every 6 months. The mechanism of the Pentacam HR has been described previously. The Pentacam HR system rates the quality of the imaging study, and only good-quality corneal measurements are included in the analysis. The corneal measurements used in this study had acceptable quality. All the cases were operated by a single refractive surgeon (M.KH). MyoRing implantation was performed according to the published protocol and procedure [11].

The axis orientation of total astigmatism as well as anterior and posterior corneal astigmatism were noted and analyzed. Total and corneal astigmatisms were classified as with-the-rule (WTR), against-the-rule (ATR), and oblique astigmatism. When the steep meridian of the astigmatism was within 60–120 degrees, we classified the orientation of the astigmatism as WTR. When the steep meridian was within 0–30 degrees or 150–180 degrees, we classified the orientation of the astigmatism as ATR. The astigmatism was considered as oblique if the axis orientation was neither WTR nor ATR. With regard to the negative dioptric power of the posterior surface of the cornea, we classified the axis

orientation of the posterior surface of the cornea differently from that of the anterior surface of the cornea. When the steep meridian of the posterior surface of the cornea was within 0–30 degrees or 150–180 degrees, the axis orientation of the posterior corneal astigmatism was recorded as WTR. Posterior corneal astigmatism with the steep meridian within 60–120 degrees was classified as ATR astigmatism. The axis orientation of the astigmatism of the posterior corneal surface was considered oblique if the axis orientation was neither WTR nor ATR. In the present study, we measured the safety and safety index of the procedure. According to the published literature, the safety of the surgery has been defined as the percentage of eyes that lose more than 2 lines of uncorrected distance visual acuity (UDVA) expressed in Snellen units [10]. Statistical analysis was performed using SPSS version 22 for Windows (IBM Inc., Chicago, IL, USA). The normal distribution of the parameters was assessed using the Kolmogorov–Smirnov test. The paired-sample t-test was used to compare normally distributed variables, and the Wilcoxon signed rank test was used to compare non-parametric variables. P-values less than 0.05 were considered statistically significant.

RESULTS

This study included 34 eyes of 28 patients with a confirmed clinical diagnosis of KCN. There were 15 (54%) male patients and 13 (46%) female patients. The mean age of the patients was 29.41 ± 7.0 years (range: 17 to 46 years) and a 6-month follow-up was performed for all cases. Six months after MyoRing implantation, the mean best-corrected visual acuity [in logarithm of the minimum angle of resolution (LogMAR) units] improved significantly from 0.30 ± 0.22 to 0.20 ± 0.20 (P = 0.006). The safety of the MyoRing implantation surgery was 100% because no eye lost corrected distance visual acuity (CDVA) or UDVA expressed in Snellen notation. The mean ± standard deviation (SD) of spherical refractive error before and after MyoRing implantation was -4.66 ± 3.77 D and -1.48 ± 3.72 D, respectively, which represented a significant decrease (-3.18 D, P < 0.001). The results of the total ocular astigmatism as well as the astigmatism of the anterior and posterior surface of the cornea before and 6 months after MyoRing implantation are presented in Table 1.

The frequency results of the axis orientation of total and corneal astigmatism before and after MyoRing implantation are presented in Table 2.

Table 1: Total and Corneal Astigmatism before and after MyoRing Implantation

Time of examination	Minimum	Maximum	Mean (D)	SD (D)
TA				
Before surgery	-1.00	-17.00	-4.27	3.15
After surgery	+1.75	-6.00	-2.18	1.63
ACA				
Before surgery	-6.40	-8.60	-3.65	1.90
After surgery	-3.20	-6.70	-2.49	1.75
PCA				
Before surgery	-1.10	-3.20	-0.95	0.55
After surgery	-0.2	-1.50	-0.71	0.35

D: Diopter; SD: Standard Deviation; TA: Total Astigmatism; ACA: Anterior Corneal Astigmatism; PCA: Posterior Corneal Astigmatism

Table 2: Frequency of Axis Orientation of Total and Corneal Astigmatism before and after MyoRing Implantation

Time of examination	Axis type		
	WTR	Oblique	ATR
TA			
Preoperative astigmatism	21% (7)	42% (15)	37% (12)
Postoperative astigmatism	18% (6)	24% (8)	58% (20)
ACA			
Preoperative astigmatism	59% (20)	24% (8)	17% (6)
Postoperative astigmatism	52% (18)	24% (8)	24% (8)
PCA			
Preoperative astigmatism	68% (23)	29% (10)	3% (1)
Postoperative astigmatism	67% (26)	12% (4)	12% (4)

WTR: With-the-Rule; ATR: Against-the-Rule; TA: Total Astigmatism; ACA: Anterior Corneal Astigmatism; PCA: Posterior Corneal Astigmatism

There was no change in the frequency of oblique axis of the anterior corneal surface from before to after MyoRing implantation. Notably, the greatest change in the frequency of axis orientation in the posterior surface of the cornea was related to oblique astigmatism (a decrease of 17%). The mean differences and a comparison between the results of the total ocular astigmatism as well as the astigmatism of anterior and posterior surface of the cornea before and after MyoRing implantation are presented in Table 3.

Table 3: Mean Differences and Comparison between Total Ocular Astigmatism as well as Anterior and Posterior Corneal Astigmatism before and after MyoRing Implantation

Parameter	Mean preoperative astigmatism	Mean postoperative astigmatism	Mean differences of preoperative and postoperative astigmatism	*P-value
TA (D)	-4.27	-2.18	-2.08 ± 0.94	< 0.001
ACA (D)	-3.65	-2.49	-1.16 ± 0.59	0.001
PCA (D)	-0.95	-0.71	-0.24 ± 0.12	0.009

D: Diopter; TA: Total Astigmatism; ACA: Anterior Corneal Astigmatism; PCA: Posterior Corneal Astigmatism; *Paired t-Test

The rate of total corneal astigmatism after MyoRing implantation decreased significantly (2.08 D, P < 0.001). The mean astigmatism of the anterior and posterior surface of the cornea also decreased significantly (1.16 D, P = 0.001 and 0.24 D, P = 0.009, respectively).

DISCUSSION

The present study showed that, compared with preoperative measurements, total ocular astigmatism was decreased by 2.08 D after MyoRing implantation. A comparison of the data between before and 6 months after MyoRing implantation revealed that anterior and posterior astigmatism were decreased by 1.16 D and 0.24 D, respectively. The results of this study indicated that all cylindrical indices were improved after MyoRing implantation. A few studies investigated the outcomes of MyoRing implantation, namely an improvement in refractive error. However, those studies differ from the present study mainly in two aspects. First, the reported values of astigmatism improvement after MyoRing implantation are different from ours. Second, none of the previous studies investigated the changes in posterior corneal astigmatism after MyoRing implantation. In a study by Jabbarvand et al., the dioptric power of the anterior corneal surface was decreased by 6.9 D, which was three times higher than that of the current study [10]. It should be mentioned that Jabbarvand et al. investigated the anterior surface of the cornea whereas in the present study, we showed a mean difference of -0.24 D posterior corneal astigmatism.

In a study by Alio et al, a significant reduction in spherical and cylindrical levels (by 4.62 D and 4.47 D, respectively) was observed after MyoRing implantation [12]. In the present study, the spherical and cylindrical refractive error was decreased by 3.18 D and 2.08 D, respectively. Although the amount of spherical and cylindrical refractive error changes in the present study was lower than that of the previous study, the values of spherical and cylindrical improvement obtained in this and the previous study were much higher than those of studies on intrastromal corneal ring segments for the treatment of KCN [13, 14] Therefore, MyoRing implantation seems to have a stronger potential for spherical and cylindrical correction in patients with KCN compared to intrastromal corneal ring segments. This may be due to the fact that MyoRing implants have a significantly greater arc-shortening effect [10, 15]. Janani et al. investigated the outcomes of MyoRing implantation after 3 years of follow-up. The authors showed an improvement in CDVA, UDVA, and spherical and cylindrical refractive error after long-term follow-up. The total ocular cylindrical refractive error was improved by -2.98 D, which was similar to our result. Although Janani et al. studied various parameters before and after MyoRing implantation, they did not evaluate the posterior surface of the cornea in terms of posterior corneal astigmatism [16].

In the present study, the mean posterior corneal astigmatism before surgery was approximately -0.9 D as measured using the Pentacam HR. In another study using a dual Scheimpflug analyzer (Galilei), the posterior corneal astigmatism was approximately -0.30 ± 0.15 D (range: -0.01 to -1.10 D) in healthy subjects [17]. The reason for this difference might be related to the study samples. Indeed, Koch et al. [17] did not study eyes with KCN. In the present study, the anterior and posterior corneal astigmatism was WTR in 59% and 68% of patients with KCN before MyoRing implantation, respectively (Table 2). However, in the study by Koch et al., the anterior and posterior corneal astigmatism was WTR in

50.9% and 86.8% of the healthy subjects. These data show significant differences in axis orientation of anterior and posterior corneal astigmatism between healthy and KCN cases [17]. Kamiya et al. studied the anterior and posterior astigmatism in KCN eyes using the Pentacam HR. The authors reported that the anterior and posterior corneal astigmatism was -3.9 D and -0.9 D, respectively [18]. In another study in Iran, the average amounts of anterior, posterior, and total corneal astigmatism were 4.08 ± 2.21 diopters (D), 0.86 ± 0.46 D, and 3.50 ± 1.94 D, respectively [19], which was close to the preoperative values of KCN eyes in the present study.

Our results showed that the amount of astigmatism in the anterior and posterior corneal surfaces in patients with KCN was -3.65 D and -0.95 D, respectively. The similarity between the two studies can be explained by the fact that both studied patients with KCN and used the same device, the Pentacam HR. Notably, Kamiya et al. did not investigate the anterior and posterior corneal astigmatism after MyoRing implantation. One limitation of this study was its retrospective design and the inclusion of s small sample size. In summary, the present study provides valuable data on posterior corneal astigmatism before and after MyoRing implantation in KCN eyes. According to the results of the present study, it can be concluded that MyoRing implantation significantly improved the amount of total ocular astigmatism and spherical refractive error as well as anterior and posterior corneal astigmatism, which improved the visual acuity of patients with KCN.

DISCLOSURE

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