

Corneal asphericity changes after implantation of intracorneal ring segment (kerarings) in the treatment of Keratoconus

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Abstract

Purpose: To evaluate changes in visual outcome, refractive error and corneal asphericity after implantation of intracorneal ring segments (ICRS) (keraring) for the treatment of keratoconus

Setting: Memorial institute for ophthalmic research, Egypt

Methods: This study was conducted on 23 eyes of 17 patients with keratoconus. ICRS was implanted intrastromally in the cornea as a treatment for keratoconus. One or two rings with thicknesses ranging from 150 μm to 300 μm and arc lengths ranging from 160° to 210° were implanted. Uncorrected visual acuity (UCVA), best corrected visual acuity (BCVA) and refractive error (sphere, cylinder) changes were assessed. Keratometric values (k_1, k_2, k_{max}) and corneal asphericity values anterior and posterior respectively (Q_{ant} and Q_{post}) were obtained from Pentacam .

Results: There was clinically significant improvement regarding UCVA from 0.1 ± 0.04 to 0.31 ± 0.17 and improvement in BCVA was from 0.37 ± 0.15 to 0.46 ± 0.1 . The spherical and cylindrical errors significantly decreased postoperatively ($p < 0.001$). k_2 showed a highly significant decrease ($p = 0.001$) while k_1 showed a significant reduction ($p = 0.022$) and k_{max} showed non-significant changes postoperatively with $p = 0.469$. Q_{anterior} shows significant decrease from -1.29 ± 0.55 to -0.78 ± 0.77 ($p < 0.001$) while $Q_{\text{posterior}}$ shows non-significant change ($p = 0.692$).

Conclusion: ICRS implantation for the treatment of keratoconus changes the anterior corneal asphericity by approximating the Q value to the ideal Q value (-0.46) and improves the UCVA and BCVA of patients in addition to decreasing the refractive sphere and cylinder values.

Key words: intracorneal ring segment, ICRS, Kerarings, keratoconus

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Introduction

Keratoconus is a bilateral ,noninflammatory , progressive ectatic disease of the cornea that mostly starts at puberty and progresses until the middle of the 3rd decade.¹ it results in progressive corneal protrusion which causes decreased visual acuity and optical quality .² A wide range of therapeutic choices are available including contact lenses ,corneal collagen crosslinking (CXL),intracorneal ring segments (ICRS),photorefractive keratectomy (PRK) , IOLs ,lamellar keratoplasty and PKP^{3,4}

Intracorneal ring segments have been used in cases of clear cornea and contact lens intolerance with successful results .⁵ However in some cases visual satisfaction was not guaranteed despite reaching nearly emmetropia ⁶. This could be explained by the insufficiency of lower order aberrations of the eye (on which ICRS implantation is based) to explore patient quality of vision.⁷

As the Corneal asphericity is the main source of spherical aberration of the eye , The corneal asphericity coefficient (Q value) that would decrease the spherical aberration to the minimum was calculated as -0.46.⁸ Although the spherical aberration and adverse visual effect change in different curvatures in spite of the same Q value .Therefore changes in the Q value together with keratometric changes should be evaluated .⁷ICRS can modify the corneal shape to a more physiologic aspheric shape.⁹ Therefore, in our study we aimed to evaluate the effect of ICRS implantation on corneal asphericity and visual outcome .

Materials and methods

Design:

Retrospective case series study

Setting:

Memorial institute for ophthalmic research, Giza ,Egypt

Approval:

The Study was reviewed and approved by the general organization for teaching hospitals and institutes (GOTHI) ethical committee.

Patients:

The study included 23 eyes of 17 patients with progressive moderate keratoconus with the following inclusion criteria : steepest K reading from 48 to 52D, Corneal thickness >400 µm at Kerarings implantation site , Best corrected visual acuity (BCVA) of 0.1 or better and age 16-40 years .UCVA and BCVA were measured using Snellen chart. The exclusion criteria were the presence of Corneal opacities reading >60 D, Corneal thickness <400 µm at the Kerarings implantation site , or Other ocular diseases and surgeries .Patients who failed to attend follow up visits were excluded .

Methods:

Femtosecond laser device (iFS, Advanced Femtosecond laser, Abbott Laboratories Inc. Abbott Park, Illinois, USA) was used to perform the intrastromal tunnels with an amount energy of 2.00 µJ. One or two ring segments were chosen according to KeraRing¹⁰ 2009 nomogram which is based on visual, refractive and topographic parameters and implantation

were done at the depth of 70%-80% of stromal thickness at the implantation site. Inner diameter of intrastromal tunnel for the ICRS was 5 mm, outer diameter was 5.9. The thicknesses of ICRS were in range from 150 μm to 300 μm and arc lengths were in the 160° and 210°. Selections of the rings and implantation parameters, as well as surgical implantation were performed by the same surgeon at Memorial Institute for ophthalmic research.

A complete ophthalmologic examination was performed preoperatively and postoperatively. The aimed data were documented preoperatively and postoperatively including Uncorrected visual acuity (UCVA), Best corrected visual acuity (BCVA), Topographic values of the cornea [K1, K2, K max] measured by Pentacam (Oculus Optikgeräte GmbH, Wetzlar, Germany), Corneal pachymetry and Corneal asphericity by (Q1 and Q2) were also obtained from Pentacam.

Data analysis was performed using IBM computer with the use of SPSS (statistical program for social science version 21) in the following manner: Quantitative variables description as mean, SD, median and interquartile range (IQR), and Qualitative variables description as number and percentage. Student's t-test for paired data was used to compare preoperative and postoperative data; $P \leq 0.05$ significant, $P < 0.01$ highly significant.

Results

This study was performed on 23 eyes of 17 patients 9 were females and 8 were males. The age mean \pm SD was 24.0 ± 6.9 . kerarings were implanted in all of them uneventfully; one ring segment was implanted in 47.80% of them while two segments were implanted in 52.20% of them.

The visual acuity:

There was a statistically significant improvement in UCVA with p value < 0.001 where the mean \pm SD change from 0.1 ± 0.04 to 0.31 ± 0.17 . BCVA mean also shows improvement from 0.37 ± 0.15 to 0.46 ± 0.1 with P value 0.001. The changes in the refraction of the sphere and cylinder also show highly significant reduction where the sphere mean \pm SD reduces from -3.54 ± 3 to -1.17 ± 1.87 and the cylinder mean \pm SD reduces from -5.39 ± 1.19 to -1.95 ± 2.01 as shown in (Table 1)(Figure 1).

TABLE 1. Changes After Kerarings Insertion

	UCVA	Sphere	Cylinder	Axis	CDVA
Preoperative					
Mean ±SD	0.1±0.04	-3.54±3	-5.39±1.19	88.7±41.78	0.37±0.15
Median(IQR)	0.1(0.1:0.15)	-3(-5:0)	-6(-6:-4.5)	90(55:110)	0.3(0.3:0.5)
Postoperative					
Mean ±SD	0.31±0.17	-1.17±1.87	-1.95±2.01	60.24±69.85	0.46±0.1
Median(IQR)	0.3(0.2:0.4)	0(-3:0)	-2(-3:0)	15(0:115)	0.5(0.4:0.5)
P value	<0.001*	<0.001*	<0.001*	<0.001*	0.001*
	HS	HS	HS	HS	HS

*Significant change compared with baseline measurements

IQR (interquartile range);HS (highly significant)

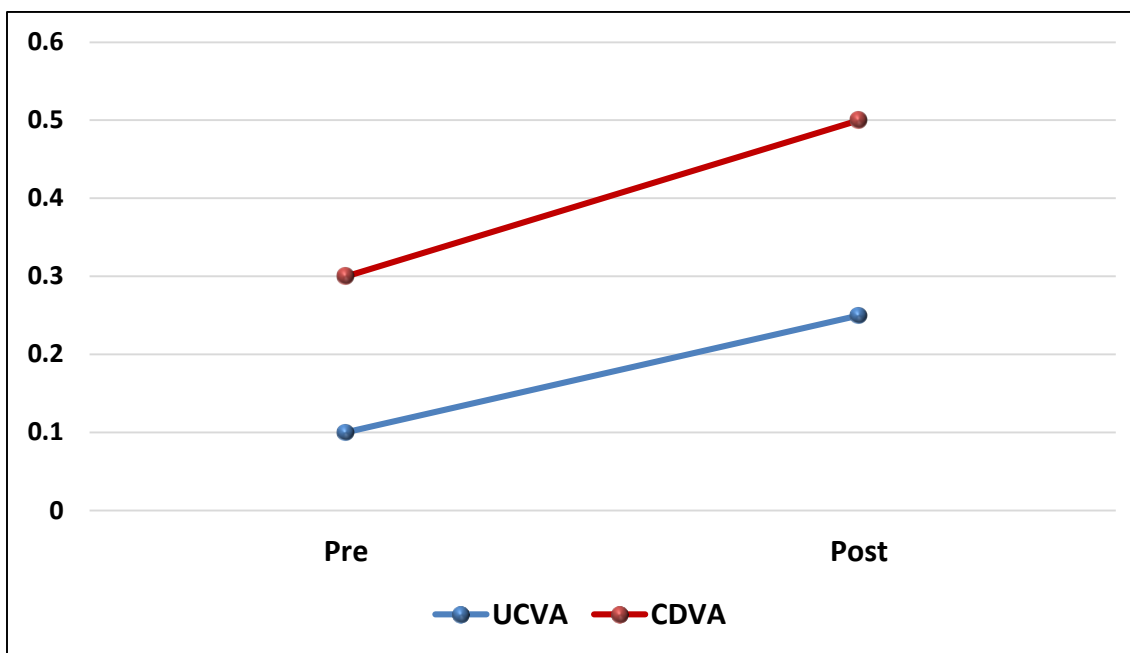


Figure 1: Line chart showing mean UCVA and CDVA improvement after kerarings implantation

The keratmetric values:

They were also recorded and shows significant changes regarding K2 in which the mean changes from 55.36D±4.55 to 52.16D±5.47 with p <0.001 and the astigmatism changes from 5.53D±2.34 to 3.82D±2.39 with p=0.001 however the K1 shows significant change from 49.57D±3.51 to 48.34D±4.31 with p=0.022 and Kmax shows non-significant changes from 62.74±7.73 to 62±5.7 with p= 0.469 as shown in (Table 2)(Figure 2) .

TABLE 2 .Keratometric changes after Kerarings Insertion

	K1	K2	K max	Astigmatism
Preoperative				
Mean± SD	49.57±3.51	55.36±4.55	62.74±7.73	5.53±2.34
Median (IQR)	49.5(46.3:52.7)	56.2(51.4:59)	62.6(55.6:68.1)	5.8(4.6:6.5)
Postoperative				
Mean± SD	48.34±4.31	52.16±5.47	62±5.7	3.82±2.39
Median(IQR)	48.6(44:52.2)	53.6(47.7:55.7)	62.7(56.7:67.7)	3.7(2.1:5)
P value	0.022	<0.001*	0.469	0.001*
	S	HS	NS	HS

*Significant change compared with baseline measurements..

IQR, interquartile range; NS, not significant; S, highly significant.

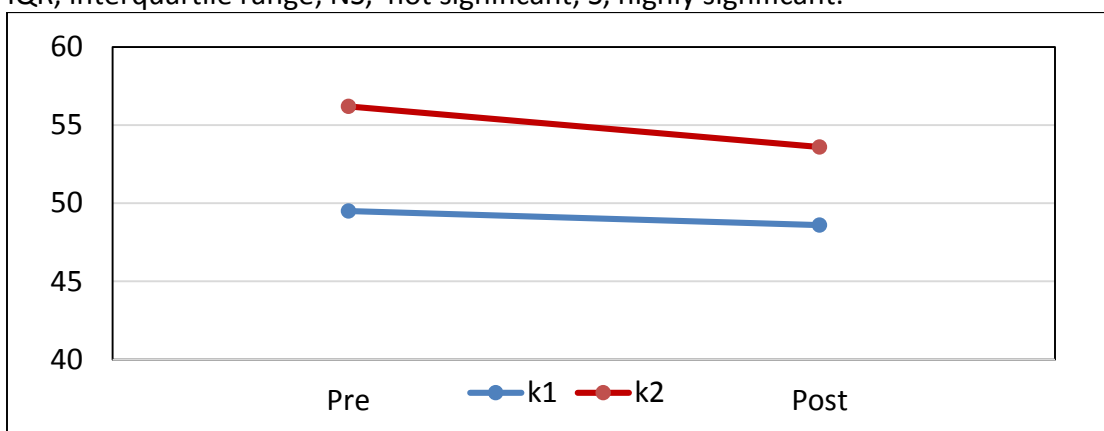


Figure 2: Line chart showing mean K1 and K2 changes after kerarings implantation

The corneal asphericity:

The asphericity indicated by the Q1 value (Q anterior) shows highly significant reduction from -1.27 ± 0.55 to -0.78 ± 0.77 which is much closer to the ideal Q value ,while the posterior Q shows non-significant change as it change from -1.29 ± 0.56 to -1.33 ± 0.52 . (Table 3)(Figure 3).

TABLE 3 .Q value changes after Kerarings Insertion

	Q anterior	Q posterior
Preoperative		
Mean± SD	-1.27±0.55	-1.29±0.56
Median (IQR)	-1.1(-1.6:-0.77)	-1.2(-1.6:-0.77)
Postoperative		
Mean± SD	-0.78±0.77	-1.33±0.52
Median(IQR)	-0.9(-1.4:-0.31)	-1.3(-1.6:-0.99)
P value	<0.001	0.692
	HS	NS

*Significant change compared with baseline measurements.

IQR, interquartile range; NS, not significant; HS, highly significant.

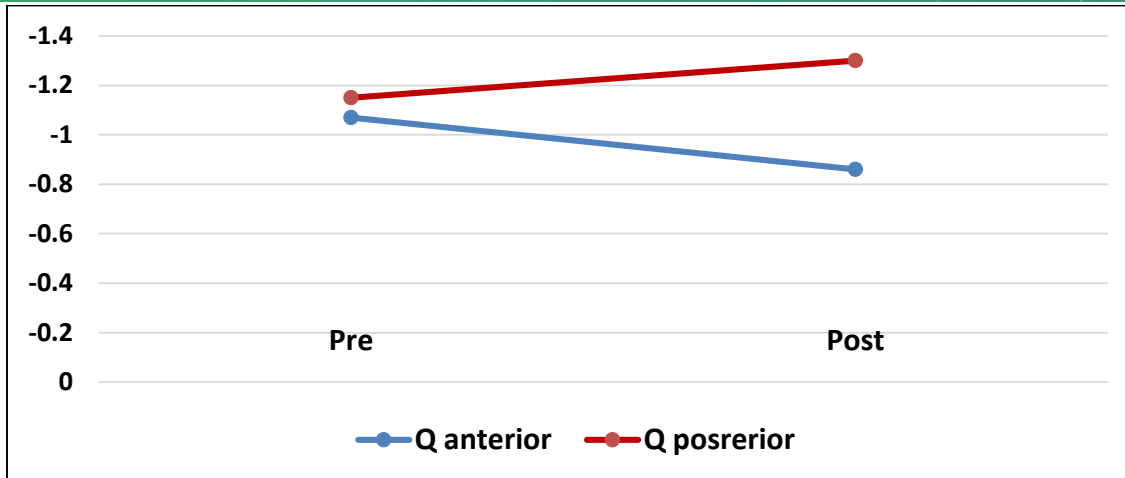


Figure 3: Line chart showing mean Q1 and Q2 changes after kerating implantation

Discussion

In our study we found that kerarings for the treatment of moderate keratoconus in 23 eyes was an effective treatment for improvement of the visual outcome of the patients. According to our results, we found significant improvement in the UCVA and BCVA with a significant reduction in the refractive error with regard to spherical and cylindrical errors. We studied the changes in the Q value (anterior and posterior) after implantation of ICRS obtained from Pentacam .The mean Q anterior was -1.27 ± 0.55 and changed to -0.78 ± 0.77 with P value < 0.001 indicating highly significant changes approximating the Q value more towards the ideal Q value $(-0.46)^8$ decreasing the spherical aberrations of the eyes. The keratometric values (K1,K2, Kmax)were also measured pre and postoperatively and showed highly significant reduction of K2 while k1shows less reduction with significant change while kmax reduction was no significant.

Torquetti L et al. conducted a retrospective study of on135 keratoconic eyes and found a significant reduction in the anterior corneal asphericity in keratoconus patients by Ferrara ICRS implantation and found that this reduction increases with increasing thickness of the implanted segment (or pair of segments).⁹

Torquetti L ,et al. on another retrospective case series study done on 50 eyes of 40 keratoconic patients and found the improvement in mean

UCVA was from 0.82 to 0.31 (<0.001); the improvement in the mean BCVA was from 0.42 to 0.05 (<0.0001), the changes in the mean spherical refraction was from -3.06 ± 3.80 D to -0.80 ± 2.5 D (<0.0001) and the reduction in the mean refraction astigmatism was from -4.51 ± 2.08 D to -2.26 ± 1.18 D (<0.0001). They found statistically significant changes from preoperative to postoperative, in parameters of the anterior and posterior surface of the cornea except the elevation posterior at the apex of the cornea and posterior asphericity which showed non-significant changes.¹¹

Canan A.et.al.^{7,12} In a similar study on 42 keratoconic eyes, the UDVA and BCVA improved significantly and also found a significant reduction in refractive spherical equivalent, cylinder and SimK avg postoperatively ($P<0.001$). The mean postoperative Q changed from -1.06 ± 0.48 to -0.57 ± 0.58 ($P<0.001$). They found that the changes in mean postoperative Q were insignificant ($P=0.92$). In this study the postoperative changes in UDVA and CDVA were not correlated with the postoperative changes in SE and cylinder ($P>0.05$ for all); but were correlated with the preoperative SimKavg and Qant values ($P<0.001$ for all).⁷

Saif et al.¹³ found a statistically highly significant reduction in keratometric readings postoperatively. The flattest keratometric reading (K1) improved from 46.42 ± 3.08 D preoperatively to 43.25 ± 3.45 D postoperatively, which is highly significant ($P<0.01$). The steepest keratometric reading (K2) improved from 49.96 ± 3.29 D preoperatively to 46.04 ± 3.15 D postoperatively, which is highly significant ($P>0.01$). The total HOA root mean square improved from 1.55 ± 0.54 preoperatively to 1.26 ± 0.38 postoperatively, with a statistically significant difference ($P<0.05$). Primary coma improved from 1.27 ± 0.54 preoperatively to 0.87 ± 0.27 postoperatively, which is highly significant ($P>0.01$). In addition, astigmatism root mean square changed from 2.42 ± 1.52 preoperatively to 1.98 ± 1.31 postoperatively. Trifoil and quadrifoil showed nonsignificant changes ($P>0.05$).

Cristina Peris-Martínez et al.¹⁴ found statistically significant reduction of sphere ($p=0.043$), a significant improvement of UCVA associated ($p=0.019$), a significant reduction of anterior corneal power measurements ($p \leq 0.014$), steepest posterior keratometric reading ($p=0.006$) were observed at 1 month postoperatively, with no significant changes afterwards ($p \geq 0.133$). No significant changes were observed in manifest cylinder

($p \geq 0.175$), BCVA ($p \geq 0.174$), flattest posterior keratometric measurement ($p \geq 0.282$), volumetric measurements ($p \geq 0.051$), and corneal biomechanical parameters ($p \geq 0.068$). Vector analysis revealed an initial trend to overcorrection of astigmatism, with a trend to undercorrection at the end of follow-up and a significant variability in the outcome achieved in each patient.

Roach et al¹⁵ found that mean UCVA and BCVA improved with a significant spherical equivalent improvement ($p < 0.05$), with no differences between the 320-degree intrastromal corneal ring segment groups. All corneal tomographic parameters improved significantly ($p < 0.05$) between the preoperative and postoperative intervals, with a significant better performance when they used spherical equivalent for the 320-degree intrastromal corneal ring segment thickness selection.

Conclusion

We can conclude that ICRS implantation for treatment of keratoconus changes the anterior corneal asphericity approximating the Q value to the ideal Q value (-0.46) and improves the UCVA and the BCVA of patients besides decreasing the refractive sphere and cylinder values.

Financial disclosure

I have no financial interest to disclose

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