Predictability, Stability and Safety of MyoRing Implantation in Keratoconic Eyes During One Year Follow-Up

Sahar Mojaled Nobari, BSc[1] • *Consuelo Villena, PhD*[2] • *Khosrow Jadidi, MD*[3]

Abstract

***Purpose*:** To assess the stability of visual and refractive outcomes that was compared between three and 12 months after MyoRing implantation in moderate and severe keratoconus

***Methods*:** This study included 54 eyes of 50 patients (27 males and 23 females) with stage II and III keratoconus who underwent MyoRing (Dioptex GmbH) implantation. Clinical outcomes including uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), manifest refraction, spherical equivalent (SE) and mean keratometry (k)- readings were compared preoperatively and postoperatively (follow-up times were at 1, 3, 6 and 12 months postoperation).

***Results*:** The mean age was 28.48±6.3. The mean UDVA (logMAR) and the mean CDVA (logMAR) improved significantly from 1.20±0.24 to 0.20±0.09 and from 0.58±0.22 to 0.14±0.06, respectively ($p<0.001$). Both SE and the maximum keratometry (k)-reading decreased significantly by six diopters ($p<0.001$). There was no significant difference in visual and refractive outcomes between three and 12 months postoperatively. Twelve months after MyoRig implantation the predictability was 47 eyes (87%) within ±1.00 D and 31 eyes (57%) within ±0.50 D of emmetropia.

***Conclusion*:** MyoRing implantation in keratoconic patients improves SE, UDVA and CDVA significantly. Additionally, the improvement in UDVA was remarkable (approximately 10 lines). The procedure was safe and effective in treatment of patients with moderate and severe keratoconus. The visual and refractive outcomes remained stable between three and 12 months postoperatively.

***Keywords*:** Keratoconus, Intrastromal Corneal Ring Implantation, MyoRing

Iranian Journal of Ophthalmology 2014;26(3):136-43 © 2014 by the Iranian Society of Ophthalmology

1. PhD Candidate of Optometry, Master in Optometry and Vision, Department of Optics II (Optometry and Vision), Complutense University, Madrid, Spain
2. Professor of Optometry, Department of Optics II (Optometry and Vision), Complutense University, Madrid, Spain
3. Associate Professor of Ophthalmology, Baghiyatallah University of Medical Sciences, Tehran, Iran

Received: September 27, 2014
Accepted: December 11, 2014

Correspondence to: *Khosrow Jadidi, MD*
Associate Professor of Ophthalmology, Baghiyatallah University of Medical Sciences, Tehran, Iran, Email: khosrow.jadidi@yahoo.com

Financial disclosure: No financial support was received for this submission.
Conflict of interest: None of the authors has conflict of interest with the submission.

Introduction

Keratoconus is a progressive, non-inflammatory ectatic disorder which leads to corneal thinning and gradual biomechanical instability of the cornea. The corneal thinning induces irregular astigmatism and progressive myopia. This condition decreases the visual quality in keratoconic patients.[1,2]

Keratoconus appears to be a multifactorial disease caused by a combination of several genes abnormalities, environmental factors (including atopy, eye rubbing, contact lens use, oxidative damage) and ultrastractural alteration of the collagen matrix. However, the exact etiology of this disorder remains to be unknown.[3]

To treat keratoconic patients, non-surgical methods including spectacles and hard contact lenses are used. However, surgical procedures should be applied if these optical tools could not restore the vision or patients could not tolerate the hard contact lens.

The main surgical therapeutic option for more advanced cases is lamellar or penetrating keratoplasty.[4,5] In spite of its acceptable results, collagen cross-linking (CXL) and intracorneal ring segments (ICRS) have provided an alternative to manage keratoconus as less invasive procedures.[6-13]

Also, the use of full-ring implants has been proposed as a potential solution for the treatment of corneal irregularity in keratoconic patients.[14-16] MyoRing is a full-ring intracorneal implant (DIOPTEX GmbH) which be inserted into the cornea by means of a new surgical technique called “Corneal Intrastromal Implantation System” (CISIS).

Previous studies on MyorRing implantation have reported that MyoRing is an effective and safe method to correct high myopia and keratoconous.[14-19] However, to our knowledge, few studies have investigated the stability of visual and refractive outcomes after MyoRing implantation during 12 month follow-up. To address this issue, we conducted this retrospective study.

Methods

Study population and assessment

This retrospective cohort study included 54 keratoconic eyes of 50 patients who underwent MyoRing intra-corneal implantation (created by the pocketMaker microkeratome; Dioptex GmbH) at Bina Eye Hospital, Tehran, Iran, between November 2010 and July 2011. All participants were selected from the pool of outpatients with keratoconus.

Keratoconus diagnosis was based on slit-lamp examination and corneal topography. The characteristics of keratoconus were observed in all patients: corneal topography revealing an asymmetric bowtie pattern with or without skewed axes and at least one keratoconus sign on slit-lamp examination, such as stromal thinning, conical protrusion of the cornea at the apex, Vogt Striae or Fleischer ring. The severity of keratoconus was graded according to the Amsler–Krumiech classification.[20]

MyoRing is a flexible, full-ring intracorneal implant (Dioptex GmbH) which is available in a diameter range of 5 to 6 mm and thickness range of 200 to 400 µm in 20 µm increments. The width of the ring body is 0.50 mm. The implant is made of polymethyl metacrylate (PMMA). The anterior surface is convex and the posterior surface concave, with a radius of curvature of 8.00 mm.[14]

The appropriate MyoRing dimensions (diameter and thickness) were selected according to the MyoRing nomogram that was derived from theoretical calculation based on a biomechanical corneal model which was developed by Albert Daxer on the basis of experimental data.[21-23] This nomogram takes into account the corneal thickness at its thinnest point and the mean central keratometry (K) -reading.[15]

In all eyes, ophthalmic examinations included uncorrected distance visual acuity (UDVA), manifest refraction with corrected distance visual acuity (CDVA), corneal topography (Orbscan II, Baush & Lomb), Goldmann applanation tonometry, slit-lamp biomicroscopy and fundus examination. Lines of improvement in acuity were calculated in logarithmic scales according to logMAR notation. Patients were followed at 1, 3, 6 and 12 months after surgery.

Inclusion criteria were age older than 19 years, contact lens intolerance, clear central corneas, proof of keratoconus evolution and minimal corneal thickness $\geq$350 µm. Exclusion criteria were patients with stage I and IV keratoconus, hydrops, corneal opacity, corneal dystrophy, herpetic keratitis, previous ocular surgery (including CXL), pregnancy,

autoimmune or other systemic diseases. All patients were fully informed about the details and possible risks of the procedure.

Safety, efficacy, and predictability of refractive correction

The safety of the procedure was defined as the percentage of eyes losing more than two lines of Snellen CDVA. The safety index is equal to the ratio of mean postoperative CDVA to mean preoperative CDVA. The efficacy was defined as the percentage of the eyes achieving a UDVA of $^{20}/_{40}$ or better postoperatively. The efficacy index is equal to the ratio of mean postoperative UDVA to mean preoperative CDVA.[24,25]

The predictability of refractive correction was the percentage of eyes with ±1 D and ±0.50 D of emmetropia at 12 months postoperatively.[26]

Surgical technique

All surgeries were performed by the same surgeon (KHJ). The system for preparing the tissue and inserting MyoRing into the cornea is called CISIS. The surgical technique is characterized by a two-step procedure:

Step 1: Creation of a closed corneal pocket of 9 mm in diameter and 300 µm in depth by means of PocketMaker microkeratom. The equipment consists of a suction ring, a transparent disposable applanator which defines the cutting depth (A 300 µm applanator can be ordered from the company), and a micro-vibrating diamond blade with its tip following a circular curve of 9 mm in diameter without passing through the cornea along this path.

Step 2: MyoRing implantation into the pocket: using an implantation forceps in one dimension, the MyoRing (360º and deformable ring) is inserted into the corneal pocket via a small incision tunnel which is located in the temporal periphery of the cornea. Once placed into the pocket, the MyoRing inflates to its original preoperative shape. The surgical technique is described in more detail elsewhere.[17]

The surgery was performed under topical anesthesia. Postoperatively, patients were prescribed to use chloramphenicol and bethamethasone drops four times daily. Chloramphenicol was interrupted one week after surgery whereas bethamethasone was tapered off during 4-6 weeks.

Statistical analysis

Statistical analysis was performed using SPSS version 16 for Windows (version 16; SPSS Inc., Chicago, IL, USA). All visual acuity measurements were converted from Snellen notation to logMAR. The normality of distribution was checked for all variables. Continuous variables are expressed as mean±SD [range].

Differences between pre and postoperative refractive and visual outcomes were tested using paired *t*-test. The results were compared between preoperative and postoperative examination. In addition, the results of 3rd and 12th months of postoperative follow-up were compared. The threshold of statistical significance was a p value less than 0.05.

Results

This study evaluated 54 eyes of 50 patients (27 males and 23 female). The mean age was 28.48±6.3 years old [range 20 to 45]. There were 40 eyes (74.1%) with stage II and 14 eyes (25.9%) with stage III keratoconus. No significant difference was noted between sex groups (p=0.571).

The clinical outcome of MyoRing implantation was compared at 3 and 12 months postoperatively which was not observed significant difference between identical values. Table 1 shows the visual and refractive outcomes during 12 months follow-up.

Visual outcome, efficacy and safety

The mean UDVA (logMAR) was 1.20±0.2 [range 0.50 to 1.30] preoperatively and 0.3±0.1 [range 0.10 to 0.50] and 0.2±0.1 [range 0.00 to 0.40] at 3rd and 12th months, respectively (both p<0.001). There was a statistically improvement in mean UDVA from three months to 12 months postoperatively (p=0.016; Figure 1 demonstrates the changes in UDVA during the 12 months follow-up).

Preoperatively, 50 out of 54 eyes (92%) had an uncorrected visual acuity (UCVA) of $^{20}/_{200}$ or worse, whereas 53 eyes (97%) had a UCVA of $^{20}/_{40}$ or better 12 months after surgery.

At 12 months (N=54 eyes) the UDVA was $^{20}/_{50}$ in one eye, $^{20}/_{40}$ in 17 eyes, $^{20}/_{32}$ in 26 eyes, $^{20}/_{25}$ in 7 eyes and $^{20}/_{20}$ in 4 eyes. The improvement in mean UDVA was approximately 10 lines after 12 months. The efficacy index was 1.96 at 12 months.

The mean CDVA (logMAR) in all operated eyes improved significantly from 0.6±0.2 [range 0.30 to 1.20] preoperatively to 0.2±0.1 [range 0.00 to 0.40] and 0.1±0.1 [range 0.00 to 0.20] at 3 and 12 months postoperatively (both p<0.001).

The mean CDVA improved statistically at 12 months when compared to three months postoperatively (p=0.017). At 12 months, the CDVA was $^{20}/_{32}$ in 32 eyes, $^{20}/_{25}$ in 18 eyes and $^{20}/_{20}$ in four eyes. Also, 12 months after surgery, the improvement in mean CDVA was approximately four lines. The procedure was safe because no patient lost more than two lines of snellen CDVA. The safety index was 2.5 at 12 months.

Refractive and keratometry outcomes

The mean sphere of manifest refraction improved significantly from -4.6±3.7 D (range, -12.00 to +3.00 D) preoperatively to 0.7±1.0 D (range, -3.50 to +2.00 D) and 0.7±1.0 D (range, -3.50 to +2.50 D) at 3 and 12 months postoperatively, respectively (both p<0.001).

The mean preoperative cylinder significantly decreased from -5.2±1.0 D (range, -3.00 to -7.00 D) to -1.8±0.7 D (-1.00 to -3.50 D) and -1.5±0.7 D (range, -0.50 to -3.50 D) at 3 and 12 months postoperatively, respectively (both p<0.001).

The mean preoperative SE was -6.1±3.5 D (range, -14.00 to +1.50 D), which improved to -0.2±0.7 (range, -4.50 to +1.50 D) and -0.1±0.7 (range, -4.00 to +1.00 D) at 3 and 12 month postoperatively, respectively (both p<0.001). We found that there was not statistically significant difference in sphere (p=0.267), cylinder (p=0.471) and SE (p=0.525) between three and 12 months postoperatively. Figure 2 shows the changes in SE during the 12 months follow-up.

In terms of refractive predictability, 47 eyes (87%) were within ±1.00 D and 31 eyes (57.4%) were within ±0.50 D of emmetropia.

The steep keratometric value (k_{max}) decreased significantly from 52.97±3.54 D (range, 48 to 60 D) preoperatively to 47.10±2.37 at 12 months postoperatively (range, 43.50 to 51 D) (p<0.001). Table 2 summarizes mean keratometric values preoperatively and 12 months postoperatively. The mean central corneal thickness (CCT) was 439.62±35.42 preoperatively and 436.21±28.43 at 12 months postoperatively with no statistically significant change (p=0.22).

The patients were divided in two groups based on the MyoRing diameter (group 1 included 30 eyes with 5 mm diameter and group 2 included 24 eyes with 6 mm diameter. No significant difference was noted between identical values of the two groups. The mean UDVA was 0.2±0.09 in group 1 and 0.22±0.89 in group 2, which was not statistically significant difference between two groups (p=0.71). The mean CDVA was 0.15±0.06 in group 1 and 0.16±0.07 in group 2 with no statistically significant difference (p=0.56). Also no significant difference was noted in spherical equivalent (SE), sphere and cylinder of manifest refraction between two groups. The mean postoperative data are shown in table 3.

Table 1. Mean preoperative and postoperative visual and refractive outcomes during one year follow-up period

Parameters	Preop	Postop				p value		
		1 Month	3 Month	6 Month	1 Year	Preop vs 3 Month	3 Month vs 1 Year	Preop vs 1 Year
UDVA (logMAR)	1.2±0.2	0.3±0.2	0.3±0.1	0.2±0.1	0.2±0.1	<0.001	0.016	<0.001
CDVA (logMAR)	0.6±0.2	0.2±0.1	0.2±0.1	0.2±0.1	0.1±0.1	<0.001	0.017	<0.001
Sphere (D)	-4.6±3.7	0.8±1.1	0.7±1.0	0.6±1.0	0.6±1.0	<0.001	0.267	<0.001
Cylinder (D)	-5.2±1.0	-2.0±1.1	-1.8±0.7	-1.5±1.0	-1.5±0.7	<0.001	0.471	<0.001
SE (D)	-6.1±3.5	-0.2±1.0	-0.2±0.7	-0.2±0.9	-0.1±0.9	<0.001	0.525	<0.001

UDVA: Uncorrected distance visual acuity, CDVA: Corrected distance visual acuity, SE: Spherical equivalent, D: Diopters, Postop: Postoperative, Preop: Preoperative

Table 2. Mean of the keratometric (K) values before and 12 months postoperative as well as the amount of reduction

	Preoperative	Postoperative	Pre-Post‡	p value
K_{max} (D)	52.97±3.54	47.10±2.37	5.87	<0.001
K_{min} (D)	47.49±3.04	44.95±2.52	2.54	<0.001
$K_{average}$ (D)	50.19±3.10	45.75±2.37	4.44	<0.001

D: Diopters, K_{max}: Maximum K value in diopters, K_{min}: Minimum K value in diopters, K_{mean}: Average K value in diopters, ‡: Difference between preop and postop K

Table 3. Postoperative data based on the MyoRing diameter (5 mm and 6 mm)

Parameter	Ring diameter	Mean±SD	p-value
SE (D)	5 6	0.04±1.00 0.24±0.69	0.66
UDVA (logMAR)	5 6	0.20±0.09 0.22±0.89	0.79
CDVA (logMAR)	5 6	0.15±0.06 0.16±0.07	0.56
Sphere (D)	5 6	0.77±1.09 0.53±0.75	0.84
Cylinder (D)	5 6	-1.47±0.64 -1.56±0.61	0.94

SE: Spherical equivalent, UDVA: Uncorrected distance visual acuity, CDVA: Corrected distance visual acuity, D: Diopeter

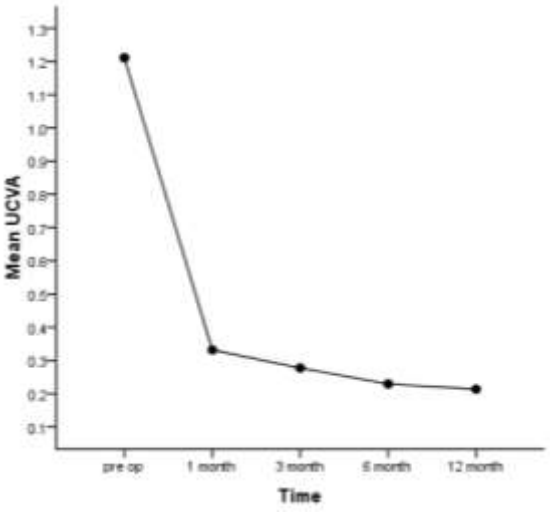

Figure 1. Changes in uncorrected visual acuity during the 12 months follow-up

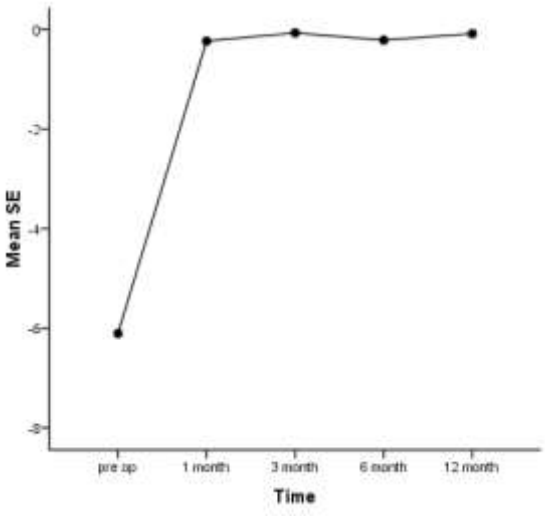

Figure 2. Changes in spherical equivalent during the 12 months follow-up

Discussion

The MyoRing intracorneal implantation has been used to manage high myopia and keratoconus. The technique to place MyoRing in the pocket by means of a mechanical dissector is called CISIS. The mechanism of action for CISIS is volume added in the periphery which leads to a new biomechanical equilibrium of the cornea, thereby flattening its center.[15,17]

The results of this study showed an overall 10 lines increase in the mean UDVA at 12 months postoperatively. Additionally, it revealed that the results of visual and

refractive outcomes between 3rd and 12th months follow-up were stable.

According to previous studies of MyoRing implantation, CISIS appears to be safe and effective in decreasing myopia, corneal steepness and decentration of the corneal apex.[14-18] Our results in accordance with those studies demonstrated that CISIS was an effective procedure for keratoconus correction.

In contrast to Jabarvand et al[19] who reported that males had better outcomes in comparison to females, no significant difference was noted between sex groups in our study.

In the current study, there was a significant improvement in the mean UDVA from $^{20}/_{320}$ to $^{20}/_{32}$ (approximately 10 lines) 12 months after surgery. Furthermore, CDVA improved from $^{20}/_{80}$ to $^{20}/_{32}$ (approximately four lines). These levels of improvement in UDVA and CDVA are consistent with the results of a study by Daxer et al.[16] On the other hand, in contrast to other MyoRing studies and previous reports of ICRS, our results showed a greater improvement in mean UDVA.[7-14,18,19] Alio et al reported that in 12 keratoconic eyes with MyoRing implantation, the mean UDVA increased from 1.36 logMAR to 0.61 logMAR.[18] Jabarvand et al showed a mean change of six lines in a sample of 95 keratoconic eyes.[19] Mahmood et al reported that the mean gain in UDVA was seven lines in six keratoconic eyes.[14]

In a study by Shabayek et al, the mean change of UDVA was approximately six lines in 21 keratoconic eyes implanted with KeraRing ICRS.[10] Colin et al reported that the mean improvement in mean UDVA was almost five lines after Intacs implantation in 100 keratoconic eyes.[9]

In this study, following MayoRing implantation, the mean spherical and cylindrical components of manifest refraction decreased by 5.30 and 3.70 D, respectively. In agreement with other MyoRing studies, our results showed a greater improvement in sphere in comparison with the cylindrical component of the manifest refraction. This finding could be due to the specific circular shape of MyoRing. Consequently, it has a greater effect on the corneal power than ICRS, which impacts strongly the spherical component of refraction. It has been proven that intrastromal corneal ring segments act by an arc-shortening effect on the corneal lamellae and flatten the cornea.[27] MyoRing as a result of its continues design has a greater flattening effect and this is probably the reason why the UDVA improvement after MyoRing implantation is so impressive even though the improvement in the cylinder is less than sphere.

Previous MyoRing studies have assessed the efficacy and safety of MyoRing implantation for myopia and keratoconus correction.[14,16,18] The safety and efficacy index in this study confirmed the safety and efficiency of this procedure.

Although there was a statistically significant difference in both UDVA and CDVA between three and 12 months after surgery, this difference was approximately equal to one line which is not clinically important.

In this study, there were 5.20, 3.50 and 6.00 D reduction in the mean sphere, manifest cylinder, and SE three months after surgery respectively. Also, 12 months after surgery the mean sphere, manifest cylinder and SE reduced by 5.30, 3.30 and 6.00 D, respectively. These results are in accordance with the findings of other MyoRing studies although the reduction in refractive outcomes in this study were more than those reported in previous studies on ICRS; for example, in a study by Shabayek et al, the mean decrease in sphere, cylinder, and SE was 0.96, 2,67 and 2.23 D after KeraRing implantation, respectively.[10]

In a study by Colin et al, the cylinder and SE decreased by 1.31 and 3.13 D following Intacs implantation, respectively.[9]

Taking into account the results of this study, it seems that both visual and refractive outcomes were stabilized in the 3rd months after surgery. This result is possibly due to biomechanical changes after MyoRing implantation. It has been demonstrated that addition of the extra material at the corneal mid-periphery induces the displacement of the local anterior surface forward to this area and flattening of the central portion of the anterior cornea caused by the morphologic structure of the corneal lamellae.[21]

Regarding corneal topography, the maximum keratometry reading (K_{max}) decreased approximately by 6.00 D. This flattening was consistent with the results of

the study by Daxer et al[16] whereas Alio et al and Jabarvand et al reported a reduction of 8 and 9 D, respectively.[18,19]

According to the MyoRing nomogram, more advanced keratoconus cases need to be treated with a thicker implant and reduced diameter. In our sample, a significant number of eyes had grade II (moderate) keratoconus whereas most of the eyes had grade III and IV keratoconus in studies performed by Alio et al[18] and Jabarvand et al.[19] Therefore, we suppose that the greater flattening effect observed in these studies is probably due to the use of thicker implants and reduced diameter which are factors proven to be related to a more significant flattening.[21]

Alio et al[18] reported significant thickening of the CCT after MyoRing implantation while there were no significant changes postoperatively in our study with a larger sample size, which consistent with the results of a study by Jabarvand et al.[19]

Although there was no complication in any case during the surgery or follow-up, one limitation of this study was the non-homogeneous number of patients in each stage of keratoconus; thus, it would be interesting to carry out further long term, prospective, comparative studies to assess this procedure in different stages of keratoconus.

Conclusion

In conclusion, MyoRing leads to an impressive reduction of spherical and cylinder components of manifest refraction by flattening the central cornea. MyoRing implantation was a safe and effective procedure for the management of moderate and severe keratoconus.

CISIS significantly improved both UDVA and CDVA although the improvement of UDVA was more impressive. Moreover, the improvement in UDVA after MyoRing implantation was more than those reported after ICRS implantation in keratoconic patients. However, additional comparative studies should be performed to compare MyoRing and ICRS.

The stability of visual and refractive outcomes between three and 12 months postoperatively indicates that MyoRing could affect keratoconus progression; however, further prospective, randomized studies are recommended to establish the role of MyoRing in controlling the progression of keratoconus.

References

1. Rabinowitz YS. Keratoconus. Surv Ophthalmol 1998;42(4):279-319.
2. Krachmer JH, Feder RS, Belin MW. Keratoconus and related noninflammatory corneal thinning disorders. Surv Ophthalmol 1984;28(4):293-322.
3. Gordon-Shaag A, Millodot M, Shneor E. The epidemiology and etiology of keratoconus. Int J Keratoco Ectatic Corneal Dis 2012;1(1):7-15.
4. Shimmura S, Tsubota K. Deep anterior lamellar keratoplasty. Curr Opin Ophthalmol 2006;17(4):349-55.
5. Troutman RC, Lawless MA. Penetrating keratoplasty for keratoconus. Cornea 1987;6(4):298-305.
6. Spoerl E, Huhle M, Seiler T. Induction of cross-links in corneal tissue. Exp Eye Res 1998;66(1):97-103.
7. Siganos D, Ferrara P, Chatzinikolas K, Besssis N, Papastergiou G. Ferrara intrastromal corneal rings for the correction of keratoconus. J Cataract Refract Surg 2002;28(11):1947-51.
8. Colin J, Cochener B, Savary G, Malet F, Holmes-Higgin D. INTACS inserts for treating keratoconus; one year results. Ophthalmology 2001;108(8):1409-14.
9. Colin J, Malet FJ. Intacs for the correction of keratoconus: two year follow-up. J Cataract Refract Surg 2007;33(1):69-74.
10. Shabayek MH, Alió JL. Intrastromal corneal ring segment implantation by femtosecond laser for keratoconus correction. Ophthalmology 2007;114(9):1643-52.
11. Alió JL, Shabayek MH. Intracorneal asymmetrical rings for keratoconus: where should the thicker segment be implanted? J Refract Surg 2006;22(3):307-9.
12. Alió JL, Shabayek MH, Artola A. Intracorneal ring segments for keratoconus correction: long-term follow-up. J Cataract Refract Surg 2006;32(6):978-85.
13. Burris TE, Ayer CT, Evensen DA, Davenport JM. Effects of intrastromal corneal ring size and thickness on corneal flattening in human eyes. Refract Corneal Surg 1991;7(1):46-50.
14. Mahmood H, Venkateswaran RS, Daxer A. Implantation of a complete corneal ring in an intrastromal pocket for keratoconus. J Refract Surg 2011;27(1):63-8.
15. Daxer A. Adjustable intracorneal ring in a lamellar pocket for keratoconus. J Refract Surg 2010;26(30:217-21.
16. Daxer A, Mahmoud H, Venkateswaran RS. Intracorneal continuous ring implantation for keratoconus: one-year follow-up. J Cataract Refract Surg 2010;36(8):1296-302.
17. Daxer A. Corneal intrastromal implantation surgery for the treatment of moderate and high myopia. J Cataract Refract Surg 2008;34(2):194-8.

18. Alió JL, Piñero DP, Daxer A. Clinical outcomes after complete ring implantation in corneal ectasia using the femtosecond technology: a pilot study. Ophthalmology 2011;118(7):1282-90.
19. Jabbarvand M, Salamatrad A, Hashemian H, Khodaparast M. Continuous corneal intrasromal ring implantation for treatment of keratoconus in an Iranian population. Am J Ophthalmol 2013;155(5):837-42.
20. Amsler M. [Early diagnosis and microsymptome]. Ophthalmologica 1965;149(5):438-46.
21. Patel S, Marshall J, Fitzke FW, 3rd. Model for deriving the optical performance of the myopic eye corrected with an intracorneal ring. J Refract Surg 1995;11(4):284-52.
22. Daxer A, Fratzl P. Collagen fibril orientation in the human corneal stroma and its implication in keratoconus. Invest Ophthalmol Vis Sci 1997;38(1):121-9.
23. Daxer A, Misof K, Grabner B, Ettl A, Fratzl P. Collagen fibrils in the human corneal stroma: structure and aging. Invest Ophthalmol Vis Sci 1998;39(3):644-8.
24. Fratzl P, Daxer A. Structural transformation of collagen fibrils in corneal stroma during drying. An x-ray scattering study. Biophys J 1993;64(4):1210-4.
25. Koch DD, Kohnen T, Obstbaum SA, Rosen ES. Format for reporting refractive surgical data. J Cataract Refract Surg 1998;24(3):285-7.
26. Shetty R, Kurian M, Anand D, Mhaske P, Narayana KM, Shetty BK. Intacs in advanced keratoconus. Cornea 2008;27(9):1022-9.
27. Güell JL, Morral M, Salinas C, Elies D, Gris O, Manero F. Intrastromal corneal ring segments to correct low myopia in eyes with irregular or abnormal topography including forme fruste keratoconus: 4-year follow-up. J Cataract Refract Surg 2010;36(7):1149-55.