ABSTRACT

Purpose: To evaluate the long-term results of Ferrara rings intracorneal ring segments for the treatment of keratoconus.

Setting: Private medical center, Ophthalmology Department, Hadassah Optimal Medical Center, Haifa, Israel. The National Center for the Treatment of Keratoconus Haifa, Israel.

Materials and methods: Retrospective review of data for patients implanted with Ferrara intrastromal rings segment for the treatment of keratoconus in patients with more than 6 years follow-up.

Results: A statistically significant improvement was documented in uncorrected visual acuity, best spectacle corrected visual acuity and reduction of myopia, astigmatism and keratometry readings. No sight threatening immediate or late complications were noticed.

Conclusion: Ferrara intrastromal corneal rings segment are safe and effective method for the treatment of keratoconus for the long-term.

Keywords: Keratoconus, Ferrara rings, Intrastromal, Cornea rings, Ectasia, Corneal thickness, Corneal topography.

INTRODUCTION

Keratoconus is an ectatic corneal disease characterized by noninflammatory progressive thinning of unknown origin in which the cornea assumes a conical shape. Keratoconus causes irregular astigmatism that cannot be fully corrected with spectacles and contact lenses are often needed. Patients which are contact lenses intolerants become candidates to penetrating keratoplasty which is increasingly being replaced by deep anterior lamellar keratoplasty (DALK).

Intracorneal ring segments (ICRS) are indicated for ectatic corneal diseases. They reduce corneal steepening, reduce irregular astigmatism and improve the visual acuity (VA). ICRS delays/eliminates the need for lamellar or penetrating keratoplasty.1-3 Long-term results in patients with keratoconus and post-lasik ectasia have been reported with significant success.4,5 The changes in corneal structure induced by implantation of ICRS can be roughly predicted by the Barraquer’s thickness law; that is when material is added to the periphery of the cornea or an equal amount of material is removed from the central area, a flattening effect is achieved. The corrective result varies in direct proportion to the thickness of the implanted segment and is in inverse proportion to its diameter. The thicker the segment and smaller its diameter the higher the resulted correction.6,7

The Ferrara ring segments are PMMA Perspex CQ acrylic segments of variable thickness of 0.15, 0.20, 0.25 and 0.30 mm. The segment cross-section is triangular, and its base is a fixed 0.60 mm diameter. The segments have 90, 120°, 160° or 210° of arc.7

Preliminary investigations have demonstrated that ICRS are effective for the treatment of astigmatism and myopic astigmatism, with preservation of best spectacle corrected visual acuity (BSCVA) over time and negligible endothelial cell damage.6-12 Satisfactory results have been reported when 210° Ferrara segments are used.13 Moreover, Ferrara rings are effective in improving the VA and keratometric values in patients suffering from post-lasik ectasia, post-PRK ectasia and post radial keratotomy (RK).14

In 28 eyes of 20 keratoconus patients implanted with ICRS with average follow-up of 18 months, the mean uncorrected visual acuity (UCVA) improved from 1.00 to 0.30 and the mean best corrected visual acuity (BCVA), from 0.51 to 0.12; both were statistically significant (p = 0.0001). The average keratometry decreased from 50.7 to 47.5 D (p = 0.0003), and the average astigmatism decreased from 5.5 to 3.5 D (p = 0.0058). The mean central corneal thickness (CCT) did not change significantly after surgery, No significant change was found in the posterior corneal elevation and the biomechanical parameters as measured by the ocular response analyzer (ORA), the corneal hysteresis or the corneal resistance factor.15

Long-term results of Ferrara rings implantation for management of keratoconus in 30 eyes of 28 patients was reported by Torquetti et al in patients with at least 5 years of follow-up. The mean UCVA improved from 0.15 preoperatively to 0.31 postoperatively and the mean BCVA, from 0.41 to 0.62 respectively with statistical significance (p = 0.003 and p = 0.002 respectively). Corneal topography demonstrated corneal flattening in all eyes. The mean minimum K value decreased from 48.99 D preoperatively to 44.45 D postoperatively and the mean maximum K value, from 54.07 to 48.09 D, respectively; these were statistically significant too (both p = 0.000).16
Ferrara et al. reported on a large series of 1,073 eyes of 810 patients consecutively operated from January 2006 to July 2008, one group implanted with the 160° of arc ring and other group implanted with the 210° of arc ring. UCVA and BCVA improved in both groups, the keratometry values, the asphericity and spherical equivalent decreased in both groups. The 210° intrastromal corneal ring segments reduced keratometry and asphericity more than the 160° intrastromal corneal ring segments. Complication rate was 3.82%.17

Torquetti et al. in a study on the predictors of clinical outcomes after intrastromal corneal ring segments implantation concluded that the more advanced the keratoconus the larger the magnitude of K and Q reduction after ICRS implantation. The best clinical outcomes are seen in patients between 20- and 30-year-old and initial cases of keratoconus (grade I).18

In this retrospective study we report on 20 eyes of 16 patients suffering from keratoconus who underwent Ferrara rings implantation. The indications for surgery were unsatisfactory BSCVA and/or contact lens intolerance.

Preoperatively, all patients had full ophthalmic examination by the same ophthalmologist including UCVA, BSCVA, refraction, corneal topography, intraocular pressure, corneal thickness, slit lamp examination and mydriatic fundus examination.

The chosen Ferrara segment thickness was determined according to the patient’s refraction and following the Ferrara rings nomograms.

Postoperatively and at every follow-up UCVA, BSCVA, refraction and corneal topography was performed.

SURGICAL TECHNIQUE

All patients were operated under topical anesthesia. A corneal incision of 1 mm at 80% depth of corneal thickness as measured intraoperatively by ultrasound pachymetry was performed along the steep axis of the cornea. Following the pocketing stage a tunnel was created using the Ferrara spatula and a pair of 160° Ferrara segments of variable thicknesses (150-350 µm) were implanted. Postoperatively, topical antibiotics eye drops were prescribed for the duration of 1 month.

RESULTS

Twenty eyes of 16 patients were operated of which 10 were males and six females. Four patients had both eyes operated.

The mean age at the time of surgery was 30 years (SD: 4.65). The mean follow-up is 7 years (SD: 1.71) (Tables 1 and 2). The mean UCVA improved from 0.09 to 0.47 (p = 0.0001), the mean BSCVA improved from 0.27 to 0.79 (p = 0.0001), the mean Kmax, Kmin, Kavg were reduced from 54.97 to 47.74 (p = 0.0001), 49.62 to 44.31 (p = 0.0001), 52.14 to 45.97 (p = 0.0001) respectively. The mean sphere and cylinder were reduced from –5.71 to –0.78 (p = 0.0001), –3.69 to –2.10 (p = 0.03). All tested parameters were statistically significant.

Flattening and regularization of corneal topography was recorded in all eyes. Stabilization of the cornea was achieved in most eyes.

In one case localized superficial corneal opacities was noted years after the procedure over one ICRS (Fig. 1A).

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<td>Pair 6 Pre Kavg-post Kavg</td>
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which did not affect the patient’s VA. In 7/20 eyes corneal precipitates were noted in the tunnels.

In two eyes, a single ICRS was removed due to extrusion. In one of these two eyes collagen corneal crosslinking (CXL) was performed to stabilize the cornea. One eye had a deep metallic corneal foreign body over the segment which caused persistent epithelial defect over the segment which did not respond to contact lens application and conservative medical treatment. The foreign body and the underlying segment were removed a year after the initial operation. The remaining single ISCR still resulted in improvement of UCVA and BSCVA.

In three eyes, CXL was performed following the ICRS implantation due to slight progressive deterioration in UCVA and BSCVA, the treatment was performed according to the Dresden protocol.

Moreover, we present herein the results on four eyes of three patients of the 20 cases with long-term Ferrara ring segment implantation:

Case 1
A 32 years old male suffers from keratoconus in his right eye (RE). His ophthalmic examination was as follows: UCVA: 0.1, BSCVA: 0.3, refraction: –1.25, –3.0 × 10, keratometry readings were \( K_{max} = 55.25 \), \( K_{min} = 47.00 \), \( K_{avg} \) (avg) 50.75, CCT: 476 µ. A pair of Ferrara rings of 0.2 mm thickness were implanted; no intraoperative or postoperative complications were noted. Postoperatively his UCVA improved to 0.75 remaining stable for 6 years with no further improvement with correction. At that stage, he noticed deterioration of vision the same eye with UCVA: 0.5, BSCVA: 0.6+ and refraction of +1.0, –3.0 × 10°, \( K_{max} = 51.37 \), \( K_{min} = 44.50 \), \( K_{avg} = 47.62 \). CXL was performed as per protocol, 1 month post-CXL his VA improved to predeterioration level. At the 7-year follow-up, UCVA was 0.9, \( K_{max} = 49.0 \), \( K_{min} = 43.25 \), \( K_{avg} = 46.0 \). In this case superficial corneal opacity over a segment of the ring appeared few years after ICRS implantation but did not compromise VA or corneal integrity (Figs 1A to E).

Case 2
A 33 years old male was referred to our center due to keratoconus. On examination of the LE, he had UCVA: 0.01, BSCVA: 0.05, refraction: –10, –6 × 160°, \( K_{max} = 59.12 \), \( K_{min} = 51.75 \), \( K_{avg} = 55.12 \). He was scheduled for Ferrara ICRS implantation and a pair of 0.3 mm rings was implanted. The intraoperative and postoperative course was uneventful. One year postoperatively, UCVA was 0.7; however, one segment was removed due to persistent erosion after a metallic corneal foreign body. At the 6-year follow-up UCVA: 0.1, BSCVA: 0.95, refraction: –2.5, –0.5 × 120°, \( K_{max} = 47.50 \), \( K_{min} = 46.12 \), \( K_{avg} = 46.75 \) (Figs 2A and B). Although there was reduction in the UCVA, the BSCVA has improved dramatically.

Case 3
A 25 years old female suffers from keratoconus in both eyes, on examination she had: RE: UCVA 0.2+, BSCVA: 0.4
Long-term Follow-up of Ferrara Rings Segments for the Treatment of Keratoconus

Fig. 1C: Preoperative Orbscan 11 of the RE (Bausch & Lomb, USA)

Fig. 1D: Topcon topography of both eyes at the last follow-up

Fig. 1E: RE Casia OCT (Tomey, Japan) at the last follow-up showing the implanted ICRS

Fig. 2A: Preoperative Topcon topography of the LE

with refraction: –1.50, –3.00 × 130°. K\text{max}: 46.00, K\text{min}: 44.50, K\text{avg}: 45.12 D. CCT 447 µ. LE UCVA: 0.2, BSCVA: 0.5 with refraction –3.00, –6.00 × 170°. K\text{max}: 50.62, K\text{min}: 45.12, K\text{avg}: 47.62. CCT 476 µ. She underwent ICRS implantation in both eyes; Op date RE: 18.08.2002 LE: 28.12.2003; a pair of 0.25 mm rings were implanted in the RE and of 0.2 mm in the LE. At the last follow-up 29.3.2013 (10 years and 11 years LE) RE: UCVA 0.4, BSCVA 0.75 with refraction –2.0 × 125°, K\text{max}: 44.62, K\text{min}: 40.87, K\text{avg}: 42.62. LE: UCVA 0.95, BSCVA: 1.0 with refraction: –1.5 × 160°, K\text{max}: 41.37, K\text{min}: 39.37, K\text{avg}: 40.37 (Figs 3A to C).

In the RE, UCVA and BSCVA deteriorated in September 2006 to 0.2 and 0.6 respectively with refraction of 2.5, –3 × 130°. CXL was performed returned to the predeterioration values.
DISCUSSION

As expected, implantation of Ferrara ring segments was effective in improving UCVA and BSCVA in keratoconic eyes which had unsatisfactory BSCVA and CL intolerance. The measured parameters of the degree of myopia, astigmatism and K readings all improved with statistical significance.

Corneal stabilization was achieved in the majority of the eyes. 4/20 eye had further CXL treatment. In three eyes CXL was performed years after the ISCR implantation due to a slight deterioration in UCVA and BSCVA. Although the reduction was minor we decided not to wait for further deterioration in VA before performing CXL. Following CXL, UCVA and BSCVA returned to the predeterioration
values. In a fourth eye CXL was performed in order to stabilize the cornea after extrusion and removal of one ICRS. CXL did not cause any complications and the epithelium healed normally in all four cases.

Even years after surgery rings did not cause significant pathologic corneal changes. The reported corneal opacity and precipitates in the channel did not affect VA or corneal integrity.

Case series reports are an important tool in evidence-based medicine as they demonstrate the results in each case. As demonstrated, patients in our case series were spared the need of corneal graft surgery. Each patient had improvement in his vision and as a result in quality of life.

CXL is an additional technique which may complement the use of ISCR for the stabilization of keratoconus. Ertan et al and Chan et al,19,20 have demonstrated an additive effect when performing ISCR implantation and CXL. Implanting ICRS first and then performing CXL is the most effective order as demonstrated by Coskunseven et al;21 this approach is logical because it is easier to reshape a biomechanically weak cornea than a stronger cornea after CXL.

Many years after successful procedure, deterioration in UCVA, BSCVA, refraction and keratometry values can occur, nevertheless, these eyes although account for only 15% of patients in our study can be reverted back to predeterioration values using complimentary CXL.

CONCLUSION

Ferrara intrastromal rings proved to be safe and effective in improving VA in keratoconic patients who are contact lens intolerant even at long-term follow-up. Intrastromal corneal rings should be offered as an alternative to corneal graft in patients suffering from keratoconus with unsatisfactory VA using spectacles and contact lens intolerant. We believe they should be informed about this surgical procedure before corneal grafting.

REFERENCES


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