Corneal Asphericity Changes after Implantation of Intrastromal Corneal Ring Segments in Keratoconus

Leonardo Torquetti, MD, PhD[1], Paulo Ferrara, MD, PhD[2]

PURPOSE: To report the corneal asphericity (Q) changes induced by the implantation of Ferrara intrastromal corneal ring segment (ICRS) in keratoconus.

METHODS: Intrastromal Ferrara ring segments were placed in 135 eyes of 123 patients with keratoconus. The mean follow-up time was 16.46 ± 5.28 [SD] months (range 4 to 24 months). Corneal topography was obtained from Pentacam (Oculus Pentacam®, USA). Statistical analysis included preoperative and postoperative asphericity (Q) and keratometry (K).

RESULTS: The ICRS implantation significantly reduced the mean corneal asphericity from –0.85 to –0.32 (p=0.000). There was significant Q reduction after implantation of all ring thicknesses, except by the 150 µm ring, which did not induced significant changes in Q values. It was observed a significant reduction in Q values in all evolution grades of keratoconus The mean K1 decreased from 46.58 to 44.27 (p= 0.000) and the mean K_2 decreased from 51.28 to 46.66 (p= 0.000).

CONCLUSION: The ICRS can effectively reduce the excess of prolateness found in keratoconus, modifying the cornea shape to a more physiologic, aspheric shape.

KEYWORDS: Ferrara ring, keratoconus, intrastromal ring segments, corneal asphericity.

J Emmetropia 2010; 1: 178-181

INTRODUCTION

Keratoconus is a progressive corneal thinning of unknown cause in which the cornea assumes a conical shape, with progressive irregular astigmatism and deterioration of visual acuity. The normal anterior corneal surface is prolate, and it could be described as conic (flattening of the radius of curvature from the apex toward the periphery)[1]. In keratoconus corneas, the steepening of the central cornea leads to an increase in cornea asphericity (Q).

The expression «aspherical surface» simply means a surface that is not spherical. The outer surface of the human cornea is physiologically not spherical but rather like a conoid. On average, the central part of the cornea has a stronger curvature than the periphery. The typical corneal section is a *prolate* ellipse, consisting of a more curved central part, the apex , with a progressive flattening towards the periphery. In the inverse profile, i.e. when the cornea is flattened in its center and becomes steeper towards the periphery, the term cornea *oblate* is used to define this condition. The asphericity of the cornea is usually defined by determining the asphericity of the coniconoid which best fits the portion of the cornea to be studied. The physiologic asphericity of the cornea shows a significant individual variation ranging from mild oblate to moderate prolate[2,3].

Most studies agree that the human cornea Q (asphericity) values ranges from -0.01 to -0.80[1,4,5]. Currently, the most commonly accepted value in a young adult population is approximately -0.23 ± 0.08[6], measured at a 4.5 mm optical zone.

This is the first study in the literature that shows the Q-values range in keratoconus patients, stratified by the evolution grade of the conus, and the changes induced in corneal asphericity by the implantation of the Ferrara intrastromal corneal ring segments (ICRS).

Submitted: 9/6/2010
Accepted: 11/9/2010

[1] Paulo Ferrara Eye Clinic. Assistant.
[2] Paulo Ferrara Eye Clinic. Director.

The author has financial interest in Ferrara intrastromal corneal ring segments.

Correspondence to: Paulo Ferrara, MD, PhD. Clinica de Olhos Dr. Paulo Ferrara, Av. Contorno 4747, conj. 615, Lifecenter – Funcionários – Belo Horizonte – MG - 30110-031 – Brasil – pferrara@ferrararing.com.br

ISSN: 2171-4703

METHODS

We retrospectively reviewed patient records of 135 eyes of 123 patients with keratoconus that were consecutively operated. The age of patients ranged from 17 to 48 years (mean 29.25 years ± 7.85 [SD]). The mean follow-up time was 16.46 ± 5.28 [SD] months (range 4 to 24 months). Twelve patients had the surgery performed in both eyes, the remainder had the surgery done in only one eye. After a complete ophthalmic examination and a thorough discussion of the risks and benefits of the surgery, the patients gave written informed consent. The main indication for Ferrara ring implantation was contact lens intolerance and/or progression of the ectasia. The progression of the disease was defined by: worsening of uncorrected visual acuity (UCVA) and best-corrected visual acuity (BCVA), progressive intolerance to contact lens wear and progressive corneal steepening documented by the topography.

CLINICAL MEASUREMENTS

A complete ophthalmologic examination performed before surgery included UCVA and BCVA assessment, biomicroscopy, fundoscopy, tonometry, corneal topography, pachymetry and asphericity (Q) measurement using Pentacam (Oculus, Germany). All clinical examinations were performed in a standardized manner by an independent, experienced examiner (PF).

On the first postoperative day, slit-lamp biomicroscopic examination was performed (Figure 1). Healing of the wound and migration of the segments were evaluated. At the last follow-up examination, manifest refraction, UCVA and BCVA, slit-lamp, and topographic examinations were performed.

SURGICAL TECHNIQUE

All surgeries were performed by the same surgeon (PF) using the manual technique for the ICRS implantation. The rings were implanted according to Ferrara Nomogram[10].

The surgery was performed under topical anesthesia after miosis achieved with 2% pilocarpine. An eyelid speculum was used to expose the eye and 2.5% povidone iodine eyedrops is instilled into the cornea and conjunctival cul-de-sac. The visual axis is marked by pressing the Sinskey hook on the central corneal epithelium while asking the patient to fixate on the corneal light reflex of the microscope light. Using a marker tinted with gentian-violet tinted, a 5.0 mm optical zone and incision site are aligned to the desired axis in which the incision would be made. This site can be the steepest topographic axis of the cornea (in case of implantation of two segments) or 90^0 (in case of implantation of only one segment – one of the tips of the ring was left on the steepest axis).

The depth of a 1.0 mm, square diamond blade is set at 80% of corneal thickness at the incision site and this blade is used to make the incision. Using a «stromal spreader», a pocket is formed in each side of the incision. Two (clockwise and counterclockwise) 270^0 semicircular dissecting spatulas were consecutively inserted through the incision and gently pushed with some, quick, rotary "back and forth" tunneling movements. Following channel creation, the ring segments were inserted using a modified McPherson forceps. The rings were properly positioned with the aid of a Sinskey hook.

The postoperative regimen consisted of moxifloxacin 0,5% (Vigamox®, Alcon, USA) and dexamethasone 0,1% (Maxidex®, Alcon, USA) eye drops four times daily for two weeks. The patients were instructed to avoid rubbing the eye and to use preservative-free artificial tears frequently – Polyethylene Glycol 400 0.4% (Oftane®, Alcon, USA).

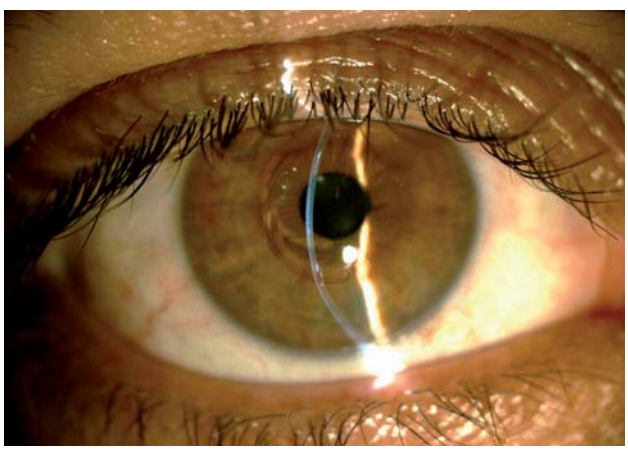

Figure 1.

STASTITICAL ANALYSIS

Statistical analysis included preoperative and postoperative asphericity (Q) at 4.5 mm optical zone and keratometry (K). The Q-factor analysis was performed by means of the corneal topographer. The corneal topography was obtained from Pentacam (Oculus Pentacam®, USA). Statistical analysis was carried out using the Minitab software (2007, Minitab Inc.). Student´s *t* test for paired data was used to compare preoperative and postoperative data.

RESULTS

The surgery was uneventful in all cases. The Q values reduced significantly after ICRS implantation. The mean preoperative Q value was - 0.85 and the mean postoperative Q value was – 0.32 (-0.53 difference, p = 0.000). The mean keratometry reduced from 48.60 to 45.30 D (3.30 difference, p = 0.000).

There was a significant reduction of the Q values for all FICR segment implanted, except by the 150 µm ring. (Table 1). It was observed a significant reduction in Q values in all evolution grades of keratoconus (Table 2). In the studied sample, it was not considered any case of keratoconus grade IV.

It was found a positive correlation between ring thickness and Δ Q; that is, the thicker the ring the more reduction of excess of prolatism effect on the cornea which it was implanted was achieved (Table 3). It was also found a positive correlation between ring thickness and Δ K; that is, the thicker the ring the more flattening effect on the cornea which it was implanted was achieved. The Pearson's correlation coefficient (r) was higher for Δ K than Δ Q, for all ring thicknesses.

DISCUSSION

In our study we found a significant reduction of Q after ICRS implantation. This can be explained by the corneal flattening effect that is achieved by the ring implantation. Once the cornea is flattened, its shape assumes a new configuration, more similar to the normal physiological cornea.

The Pearson's coefficient (r) showed a strong positive correlation among the ring thicknesses and Q and K values. The correlation was stronger for K than for Q values. It can be extrapolated that the ICRS can flatten the cornea more than reduce its asphericity, which can be desirable, once the excess of reduction of the Q values can tendency towards an oblate cornea profile, with unsatisfactory visual acuity.

One of the goals of treatment of keratoconus is to improve quality of vision beyond the simple corneal flattening and stabilization of the disease. Significant asphericity changes can occur after any corneal surgery[11,12] and these changes may explain the increase in spherical aberration and deterioration in the quality of monocular and binocular vision[13,14].

This study has crucial importance in ring selection for implantation in keratoconus. It has been established mean values of reduction of Q after implantation of each ring thickness. This data can be use to predict the final Q values after ICRS implantation. This is important, once the quality of postoperative vision is linked to, besides the corneal flattening, the corneal shape (oblate or prolate). It is well known that not only the excess of prolateness of the cornea found in keratoconus but also the cornea oblate can cause unsatisfactory visual quality. Therefore, the surgical plan can be aimed to achieve a normal, physiologic Q value (-0.23 ± 0.08)[6].

Table 1: Q variation ($\Delta Q = Q_{postop} - Q_{preop}$) and K variation ($\Delta K_{mean} = K_{postop} - K_{preop}$) from preoperative to postoperative, according to the ICRS thickness implanted

Single Segments (µm)	ΔQ (range)	p value	ΔK (range)	p value
150 (n = 13)	-0.07 (-0.46 to -0.39)	**0.34**	0.78 D (45.5 to 44.7)	0.042
200 (n = 36)	-0.31 (-0.78 to -0.47)	<0.001	1.82 D (48.2 to 46.4)	<0.001
250 (n = 28)	-0.34 (-0.81 to -0.47)	<0.001	2.74 D (48.9 to 46.2)	<0.001
Paired Segments (µm)				
150 – 150 (n = 13)	-0.57 (-0.77 to -0.19)	<0.001	3.40 D (47.1 to 43.7)	<0.001
150 – 200 (n = 16)	-0.73 (-1.02 to -0.31)	<0.001	4.35 D (49.4 to 45.0)	<0.001
150 – 250 (n = 9)	-0.80 (-0.64 to 0.16)	<0.001	3.86 D (47.0 to 43.1)	0.001
200 – 200 (n = 18)	-0.86 (-1.19 to -0.33)	<0.001	5.65 D (51.0 to 45.3)	<0.001
200 – 250 (n = 9)	-1.02 (-1.07 to -0.06)	0.001	6.27 D (50.3 to 44.1)	<0.001
250 – 250 (n = 5)	-0.99 (-1.06 to -0.06)	0.007	5.30 D (49.0 to 43.7)	0.001

The range (in ΔQ and ΔK) refers to mean preoperative values to mean postoperative values.

Table 2: Q variation (ΔQ = Qpostop - Qpreop) and K variation (ΔKmean = Kpostop - Kpreop) from preoperative to postoperative, according to the keratoconus evolution grade

Keratoconus grade	ΔQ (range)	p value	ΔK (range)	p value
I (n = 26)	-0.45 (-0.61 to -0.16)	<0.001	2.06 D (45.9 to 43.8)	0.001
II (n = 80)	-0.56 (-0.81 to -0.25)	<0.001	3.40 D (48.1 to 44.7)	<0.001
III (n = 41)	-0.51 (-1.09 to -0.57)	<0.001	3.90 D (51.1 to 47.2)	<0.001

The range (in ΔQ and ΔK) refers to mean preoperative values to mean postoperative values.

Table 3: Pearson's correlation coefficient (r) for ΔQ and ΔK_m from preoperative to postoperative, according to the ICRS thickness implanted

Single Segments (µm)	ΔQ (r)	ΔK (r)
150 (n = 13)	0.71	0.85
200 (n = 36)	0.92	0.97
250 (n = 28)	0.68	0.92
Paired Segments (µm)		
150 - 150 (n = 13)	0.92	0.97
150 - 200 (n = 16)	0.65	0.94
150 - 250 (n = 9)	0.70	0.83
200 - 200 (n = 18)	0.26	0.85
200 - 250 (n = 9)	0.74	0.94
250 - 250 (n = 5)	0.01	0.96

In summary, our findings indicate that the anterior corneal asphericity in keratoconus patients can be reduced by Ferrara ICRS implantation. The thicker the implanted segment (or pair of segments) the greater the reduction in corneal asphericity. This is especially important for ring selection based on preoperative Q value. Further work is needed to generate sufficient data to confirm the relationship between Q reduction and ICRS thickness. Moreover, the relationship between asphericity and quality of vision (not assessed in this study) needs to be established.

REFERENCES

1. Davis WR, Raasch TW, Mitchell GL, et al. Corneal asphericity and apical curvature in children: a cross-sectional and longitudinal evaluation. Invest Ophthalmol Vis Sci 2005; 46: 1899-1906.
2. Kiely PM, Smith G, Carney LG. The mean shape of the human cornea. Opt Acta (Lond) 1982; 29: 1027-1040.
3. Calossi A. The optical quality of the córnea. Fabiano Editore, Italy, 2002.
4. Holmes-Higgin DK, Baker PC, Burris TE, Silvestrini TA. Characterization of the aspheric corneal surface with intrastromal corneal ring segments. J Refract Surg 1999; 15: 520-528.
5. Eghbali F, Yeung KK, Maloney RK. Topographic determination of corneal asphericity and its lack of effect on the refractive outcome of radial keratotomy. Am J Ophthalmol 1995; 275-280.
6. Yebra-Pimentel E, González-Méijome JM, Cerviño A, ET AL. Asfericidad corneal en una poblácion de adultos jóvenes. Implicaciones clínicas. Arch Soc Esp Oftalmol 2004; 79: 385-392.
7. Colin J, Cochener B, Savary G, et al. Correcting keratoconus with intracorneal rings. J Cataract Refract Surg. 2000; 26: 1117-1122.
8. Siganos D, Ferrara P, Chatzinikolas K, et al. Ferrara intrastromal corneal rings for the correction of keratoconus. J Cataract Refract Surg 2002; 28: 1947-1951.
9. Colin J, Cochener B, SavaryG, et al. INTACS inserts for treating keratoconus; one-year results. Ophthalmology 2001; 108: 1409-1414.
10. Torquetti L, Berbel RF, Ferrara P. Long-term follow-up of intrastromal corneal ring segments in keratoconus. J Cataract Refract Surg. 2009 Oct; 35: 1768-1773.
11. Anera RG, Jiménez JR, Jiménez del Barco L, et al. Changes in corneal asphericity after laser in situ keratomileusis. J Cataract Refract Surg 2003; 29: 762-768.
12. Jiménez JR, Anera RG, Díaz JA, Pérez-Ócon F. Corneal asphericity after refractive surgery when the Munnerlyn formula is applied. J Opt Soc Am A Opt Image Sci Vis 2004; 21: 98-103.
13. Jiménez JR, Anera RG, Jiménez del Barco L. Equation for corneal asphericity after corneal refractive surgery. J Refract Surg 2003; 19: 65-69.
14. Jiménez Cuesta JR, Anera RG, Jiménez R, Salas C. Impact of interocular differences in corneal asphericity on binocular summation. Am J Ophthalmol 2003; 135: 279-284.

First author:
Leonardo Torquetti, MD, PhD

Paulo Ferrara Eye Clinic
Assistant