The New Ferrara Ring Nomogram: The Importance of Corneal Asphericity in Ring Selection

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The author has financial interest in Ferrara intrastromal cornea ring

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RESUMO

Objetivo Descrever a inclusão da asfericidade corneana (Q) como um novo parâmetro para seleção do anel no nomograma do anel de Ferrara.

Local Clínica de Olhos Dr. Paulo Ferrara

Materiais e Métodos Cinquenta olhos de 42 pacientes portadores de ceratocone foram submetidos ao implante do anel de Ferrara, em maio e junho de 2009. O tempo médio de seguimento pós-operatorio foi de 5,48 ± 0,97 [DP] meses). A tomografia corneana foi realizada pelo Pentacam (Oculus Pentacam®, USA) no pré e pós-operatório. Avaliou-se os dados pré e pós-operatórios relativos a asfericidade (Q), acuidade visual com correção (AVCC) e ceratometria (K).

Resultados O implante do anel de Ferrara reduziu a asfericidade média, de – 0,86 para -0,42 (p=0,000). Observou-se uma redução significativa nos valores de Q em todos os casos. A ceratometria média reduziu de 49,10 para 45,90 (p = 0,000). A AVCC média aumentou de 20/77 para 20/47 (p = 0,001).

Conclusão A consideração da asfericidade (Q) para seleção do anel de Ferrara pode melhorar os resultados visuais após o implante do anel.

ABSTRACT

Purpose To report the inclusion of the corneal asphericity (Q) as a new parameter for ring selection in the Ferrara Ring nomogram.

Setting Dr. Paulo Ferrara Eye Clinic

Material and Methods Intrastromal Ferrara ring segments were placed in 50 eyes of 42 patients with keratoconus, operated in May and June 2009. The mean follow-up time was 5.48 ± 0.97 [SD] months). Corneal topography was obtained from Pentacam (Oculus Pentacam®, USA). Statistical analysis included preoperative and postoperative asphericity (Q), best-corrected visual acuity (BCVA) and keratometry (K).

Results The Ferrara intrastromal ring implantation significantly reduced the mean corneal asphericity from – 0.86 to -0.42 (p=0.000). It was observed a significant reduction in Q values in all cases. The mean K decreased from 49.10 to 45.90 (p = 0.000). The BCVA improved from 20/77 to 20/47 (p = 0.001).

Conclusion The consideration of the asphericity (Q) for Ferrara intrastromal ring selection can improve the visual results after ring implantation.

Introduction

The Ferrara intrastromal corneal ring segment (ICRS) is an important tool for corneal surface regularization in keratoconus and similar keratectasias. Many studies have demonstrated the efficacy of intrastromal rings to treat many corneal conditions as keratoconus,[1-7] post–LASIK corneal ectasia,[8] and post-radial keratotomy ectasia[9]. The ICRS implantation usually improves the uncorrected visual acuity (UCVA), best-corrected visual acuity (BCVA) by decreasing the irregular astigmatism usually found in these conditions.

Long-term stability studies[10] show that the intrastromal ring flattens the cornea and keeps this effect for a long period of time. There is no significant re-steepening of the cornea over time. Therefore the ICRS can be a valuable tool to provide topographic and visual stability, delay the progression of keratoconus and postpone a corneal grafting surgery.

There is a continuous improvement in the Ferrara ICRS design and nomogram, as the knowledge about its effects evolves. In the first generation of the nomogram (1997 – 2000) only the evolutive grade of keratoconus was considered for ring selection (Table 1). As it was observed that in many cases there was hipo and hypercorrection it was replaced by the second generation of the nomogram (2002 – 2006) in which the spherical equivalent (SE) was considered for ring selection.

Table 1. Ferrara Ring Nomogram. First generation.

Diameter 5.00 mm	Thickness	Diopters to be corrected
	0,150 mm	-2.00 to – 4.00
cone I	0,200 mm	-4.25 to – 6.00
cone II	0,250 mm	-6.25 to – 8.00
cone III	0,300 mm	-8.25 to –10.00
cone IV	0,350 mm	-10.25 to –12.00

The third and actual generation of the nomogram (2006 – 2009) considers the topographic astigmatism and distribution of the ectasia area over the cornea (Tables 2 and 3).

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).[11] 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[12,13].

Most studies agree that the human cornea Q (asphericity) values ranges from -0.01 to -0.80.[11,14,15] Currently, the most commonly accepted value in a young adult population is approximately -0.23 ± 0.0816.

In a recent paper (to be presented at ASCRS2010 - Boston), we retrospectively reviewed the charts of 123 patients (145 eyes) and found that there was an almost direct correlation between Q value reduction and thickness of rings implanted; i.e., the thicker the ring (or pair of rings) implanted the most significant was the Q reduction (Graphic 1).

This study shows the first results of the New Ferrara ring nomogram (fourth generation) in which the asphericity is the first parameter to be considered ring selection.

Material and Methods

Intrastromal Ferrara ring segments were placed in 50 eyes of 42 patients with keratoconus, operated in May and June 2009. The mean follow-up time was 5.486 ± 0.97 [SD] months. Thirteen 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

TABLE 2. Ferrara Ring Nomogram - Ring selection according to the distribution of the corneal ectasia.

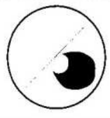
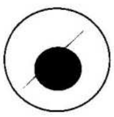
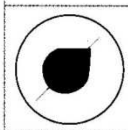
Map	Distribution of Ectasia	Description
	0 % / 100%	All the ectatic area is located at one side of the cornea
	25 % / 75%	75% of the ectatic area is located at one side of the cornea
	33 % / 66%	66% of the ectatic area is located at one side of the cornea
	50 % / 50%	The ectatic area is symmetrically distributed on the cornea

TABLE 3. Third generation of the Ferrara Ring Nomogram: topographic astigmatism.

Segment thickness choice in symmetric bow-tie keratoconus	
Topographic astigmatism (D)	**Segment thickness**
<1.00	150 / 150
1.25 to 2.00	200 / 200
2.25 to 3.00	250 / 250
> 3.25	300 / 300
Asymmetrical segment thickness choice in sag cones with 0/100% and 25/75% of asymmetry index (Table 2).	
Topographic astigmatism (D)	**Segment thickness**
<1.00	none / 150
1.25 to 2.00	none / 200
2.25 to 3.00	none / 250
3.25 to 4.00	none / 300
4.25 to 5.00	150 / 250
6.25 to 6.00	200 / 300
Asymmetrical segment thickness choice in sag cones with 0/100% and 33/66% of asymmetry index (Table 2).	
Topographic astigmatism (D)	**Segment thickness**
<1.00	none / 150
1.25 to 2.00	150 / 200
2.25 to 3.00	200 / 250
3.25 to 4.00	250 / 300

and/or progression of the ectasia. The progression of the disease was defined by: worsening of UCVA and BCVA, progressive intolerance to contact lens wear and progressive corneal steepening documented by Pentacam.

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.

All surgeries were performed by the same surgeon (PF) using the standard technique for the ICRS implantation, as previously described.7,8,9 The rings were implanted according to fourth generation (Q-based) Ferrara Nomogram (Graphic 1). Based on this nomogram, one could predict the Q-value reduction after implantation of a specific ring (or pair of rings) thickness; for example, a single segment of 200 μm reduces the asphericity in 0.31 (Graphic 1), therefore this segment would be the most appropriate in patient with a preoperative Q value of -0.54, to achieve a postoperative Q value close to -0.23 (theoretical normal value).

Results

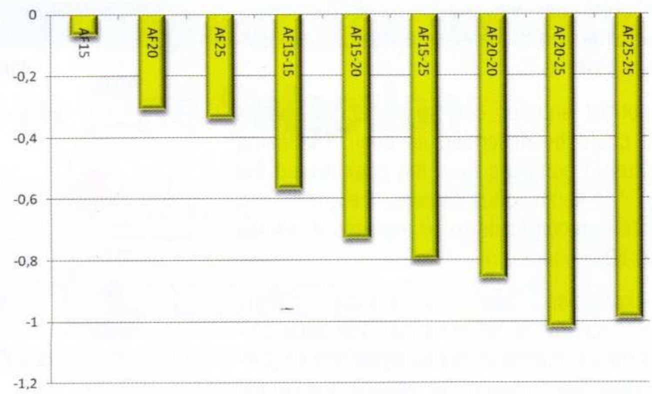
The Q values reduced significantly after ICRS Implantation. The mean preoperative Q value was -0.86 and the mean postoperative Q value was – 0.42 (-0.44 difference, p = 0.000). The mean keratometry reduced from 49.10 to 45.90 D (3.20 difference, p = 0.000). (Table 4)

The BCVA improved from 20/77 to 20/47 (p = 0.001) (Graphic 2). Seventy percent of patients achieved a 20/40 or better visual acuity at last visit.

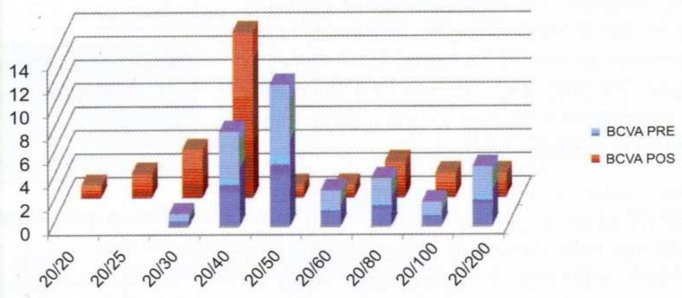
Discussion

The nomogram has evolved as the knowledge about the predictability of results has grown. Initially, surgeons implanted a pair of symmetrical segments in every case. The incision was always placed on the steep meridian to take advantage of the coupling effect achieved by the rings.

First, only the grade of keratoconus was considered for the ring selection, which means that in keratoconus grade I the more suitable Ferrara ring for implantation was that of 150 μm and in the keratoconus grade IV the more appropriate ring was of 350 μm. However, some cases of extrusion could be observed as in keratoconus grade IV the cornea usually is very thin and the thick ring segment sometimes was not properly fitted into the corneal stroma.



Graphic 1 - Q variation (ΔQ) from preoperative to postoperative, according to the ICRS thickness implanted.



Graphic 2 - Preoperative and postoperative BCVA.

Table 4. Preoperative and postoperative parameters. The p value was < 0.001 for all parameters (Students' t test)

	Preoperative	Postoperative
Q value	-0,86	-0,42
Sph. Equivalent	-3,38	-0,94
BCVA	20/77	20/47
Km	49,1	45,9
Top. Astigmatism	-3,1	-0,6

The second generation of the nomogram considered the refraction for the ring selection, besides the distribution of the ectactic area on the cornea. Therefore, as the spherical equivalent increased, the selected ring thickness also increased. However, in many keratoconus cases the myopia and astigmatism could not be caused by the ectasia itself but by an increase in the axial length of the eye (axial myopia). In these cases, a hypercorrection by implanting a thick ring segment in a keratoconus in which a thinner segment was indicated was observed.

In the third generation of the Ferrara Ring Nomogram, ring selection will depend on the corneal thickness, the amount of topographic corneal astigmatism (sim K) and the distribution of the ectactic area on the cornea (Tables 2 and 3). The Ferrara ring implantation can be considered as an orthopedic procedure and the refraction is not important on this nomogram. For symmetric bow-tie patterns of keratoconus, two equal segments are selected. For peripheral cones, the most common form type, asymmetrical segments are selected. It is important to emphasize that the ring segment thickness cannot exceed 50% of the thickness of the cornea on the track of the ring.

Using this third generation of the nomogram we usually found that in some patients there was significant corneal flattening without considerable improvement of UCVA and BCVA. We realized that, in this cases, the cornea usually presented oblate (positive Q values) postoperatively, what could explain the lack of significant improvement in these cases.

This finding lead us to retrospectively review the charts of 147 eyes operated in 2008 (paper in press), concerning the asphericity changes induced by the implantation of each thickness of ring (or pair of rings). Surprisingly, we found a direct correlation between ring thickness and reduction of Q values; i.e. the thicker the ring the more the effect in the reduction of Q.

Our previous studies (Ferrara Ring: An Overview – Cataract and Refractive Surgery Today Europe - http://bmctoday.net/crstodayeurope/pdfs/1009_04.pdf. Accessed December 29, 2009) showed that, using the previous nomograms, the BCVA was 20/60 or better in 70% of patients. When using the Q-based nomogram we found a BCVA of 20/40 or better in 70% of patients.

The results obtained through this new nomogram are very satisfactory and reproducible since we use thinner segments to achieve a significant amount of corneal regularization with very satisfactory postoperative visual acuity.

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