Refractive and topographic results after exchange of Intacs SK for Ferrara intrastromal corneal ring segments after unsuccessful implantation for keratoconus correction

Tiago Pacheco Teixeira Monteiro, MD, FEBO; José Carlos Ferreira Mendes, MD; Fernando Faria Correia, MD; Nuno Franqueira, MD; Fernando Vaz, MD

ABSTRACT: In the past, the main goal of intrastromal corneal ring segment (ICRS) implantation was to reduce keratometry. Current treatment nomograms based on classification of the ectasia phenotype aim to provide both therapeutic and refractive correction.

We present the case of a 39-year-old woman diagnosed in 2011 with keratoconus in both eyes, with low best spectacle-corrected distance visual acuity (BCVA) (3/10 Snellen decimal) in the left eye and contact lens intolerance. After surgical implantation of two symmetric 300 μm Intacs SK ICRS (Addition Technology, USA) based on the Amsler-Krumeich classification, BCVA was 2/10 despite a reduction in mean and maximum keratometry; topographic astigmatism and vertical coma (Z3−1) remained unchanged. Two years later, both Intacs SK ICRS were removed and a single Ferrara ICRS with 150° arc length and 200 μm thick segment was implanted. One year later, BCVA improved to 8/10, with significant reduction in both corneal astigmatism and vertical coma.

In patients unsuccessfully treated with ICRS, explantation or exchange for a Ferrara type-ICRS based on the ectasia phenotype was found to be safe and effective.

Keratoconus is an ectatic corneal disorder in which progressive thinning causes the cornea to become conical, resulting in irregular astigmatism and decreased visual acuity (VA). Options for managing keratoconus include spectacles, rigid gas-permeable or soft contact lenses, intrastromal corneal ring segments (ICRS), corneal collagen crosslinking (CXL), and keratoplasty. In cases of contact lens intolerance and low spectacle-corrected distance visual acuity (BCVA), ICRS implantation is a safe and effective procedure for correction of irregular astigmatism and higher order aberrations, namely the vertical coma aberration, improving the uncorrected and corrected distance visual acuity (CDVA). The Ferrara-type ICRS is currently the most frequently used type of ICRS, essentially because it has a wider range of optical zones, arc lengths and thickness profiles, which allows a larger number of possible combinations for implantation.

However, most studies on ICRS outcomes report variable numbers of patients in whom the surgical procedure is ineffective or even responsible for a loss of CDVA. Besides surgical complications, loss of BCVA after ICRS implantation has been attributed to incorrect choice of nomogram for the procedure. Most nomograms available in the past used the grade of ectasia rather than the phenotype to choose the correct number, arc length and thickness of the ICRS to implant. Besides the irregular corneal astigmatism, the presence of corneal high order aberrations, namely the vertical coma (Z3−1), greatly impacts the level and quality of vision of patients with keratoconus. In order to achieve a satisfactory visual and refractive outcome with ICRS implantation, the ICRS nomogram has to take into account both the irregular astigmatism and corneal high order aberrations. There are currently two types of ICRS models available for implantation: Intacs and Intacs SK (Addition Technology, USA), and Ferrara ICRS (AJL, Spain). The standard Intacs have a hexagonal cross-section, are available in 11 sizes (from 210 μm to 450 μm) and have the same arc length of 150 degrees; the optical zone of implantation is 7.0 mm. Intacs SK is a new ICRS design with a smaller 6.0 mm optical zone to correct higher grades of ectasia and an elliptical cross-section to minimize the glare usually associated with smaller optical zones. The acronym “SK” denotes severe keratoconus or steep keratometry. The Ferrara ICRS has a triangular cross-section that induces a prismatic effect on the cornea.
The apical diameter is 5.0 or 6.0 mm, and the flat basis width is 600 μm or 800 μm, with variable thickness (150 μm, 200 μm, 250 μm, and 300 μm) and arc length (60, 90, 120, 150, 160 and 210 degrees).

The reversibility and adjustability of the refractive effect of ICRS have been previously studied in myopic eyes and in patients with keratoconus. These support the idea that ICRS explantation is not a contraindication to implantation of a more appropriate ICRS combination or ICRS type, whenever the primary surgery is unsuccessful.

**CASE PRESENTATION**

In 2011, a 39-year-old woman was referred to our centre for treatment of keratoconus. UCVA in the right eye (OD) was 0.6 and CDVA was 0.8 (+0.50; −2.00 D × 80°); UCVA in the left eye (OS) was 0.05 and CDVA was 0.3 (−2.25 D × 120°). Biomicroscopic examination showed clear corneas, no scars or striae, and no crystalline lens opacity; fundus examination was normal. Corneal topography (Pentacam HR, Oculus, Germany) confirmed the diagnosis of bilateral...
keratoconus, forme fruste in the OD and Amsler grade 2 in the OS (Figure 1); the ectasia phenotype was described as a “Duck phenotype” – paracentral with comatic and topographic non-coincident axis separated by more than 30° (Figure 2). The patient was found to be contact lens intolerant. At that time, she underwent ICRS implantation in the OS: two symmetric Intacs SK (Addition Technology, USA) with 300 μm thickness at the 6.0 mm optical zone, and corneal incision at 80% corneal depth on the steepest meridian (at 40 degrees). Surgery was performed with a manual technique, and no intraoperative complications were observed.

After the early post-operative period, the UCVA and CDVA did not improve, and a loss of BCVA was observed at 6, 12 and 24 months post-surgery: 0.2 (+1.00, −2.50 D × 115°). Corneal topography (Figures 3 and 4) revealed a decrease in the anterior curvature parameters (K_1, K_2 and K_max, Table 1), but both the topographic cylinder (3.0 D preoperatively and 3.0 D postoperatively) and corneal vertical coma (Z_3) remained unchanged after surgery (2.30 μm preoperatively and 2.27 μm postoperatively). A new rigid contact lens trial was attempted, but the patient remained intolerant to use because of dry eye symptoms.

| Table 1. Visual, refractive and topographic results 6 months after Intacs SK implantation. |
|---|---|---|
| Before | After |
| UCVA (Snellen decimal) | 0.05 | 0.10 |
| BCVA (Snellen decimal) | 0.30 | 0.20 |
| Manifest sphere (D) | 0.00 | 1.00 |
| Manifest cylinder (D) | −2.25 | −2.50 |
| K_1 (D) | 44.20 | 41.70 |
| K_2 (D) | 47.20 | 44.50 |
| K_max (D) | 50.30 | 47.30 |
| Corneal cylinder (D) | 3.00 | 2.80 |
| Vertical coma (μm) | −2.30 | −2.27 |
| Asphericity (Q) | −1.04 | −0.49 |

Figure 3. Corneal topography Pentacam HR (Oculus) of the left eye after Intacs SK implantation.

Figure 4. Ectasia phenotype characterization after Intacs SK implantation.
RESULTS AFTER EXCHANGE OF ICRS IN KERATOCONUS

Since we observed a decrease in BCVA after surgery that remained unchanged during 24 months of follow-up with no signs of ectasia progression, we decided to review the preoperative topography and adopt a new strategy of ICRS implantation. As the intrastromal tunnels created for the first surgery were correct as regards depth of implantation and centration, we opted to explant both Intacs SK ICRS and to implant a single Ferrara-type ICRS using the same intrastromal tunnel; this was performed at the 6.0 mm optical zone, the same optical diameter recommended for this type of phenotype correction with Ferrara-type ICRS. Intacs SK explantation was carried out using an inverted Sinskey hook, after which a single Ferrara-type ICRS-type segment (150° arc length and 250 μm thickness) was implanted on the inferior temporal intrastromal tunnel, centred on the topographic flat axis. No intraoperative complications were observed during the ICRS exchange surgery. During the follow-up, UCVA and BCVA improved to 0.6 and 0.8 respectively, and a dramatic improvement was observed on corneal topography (Figure 5 and Table 2), with a decrease in the irregular corneal astigmatism (from 3.0 D after Intacs SK to 0.4 D after Ferrara ICRS) and in corneal vertical coma (from 2.27 μm after Intacs SK to 0.3 μm after Ferrara ICRS). The refractive and topographic improvement remained stable during the following 30-month follow-up period (Figure 6).

DISCUSSION

The original ICRS had a 360-degree intracorneal ring and were first implanted in sighted eyes in 1991. The segments shorten the arc length of the cornea, which is proportional to the thickness of the ring; the thicker the ICRS and the smaller the optical zone, the greater the degree of correction. ICRS initially gained approval in the U.S. and Europe for use in the Table 2. Comparison of visual refractive and topographic results after Intacs SK implantation and after Intacs SK explantation and Ferrara ICRS implantation.

<table>
<thead>
<tr>
<th></th>
<th>Before Intacs SK</th>
<th>After Intacs SK</th>
<th>After Ferrara ICRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCVA (Snellen decimal)</td>
<td>0.05</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>BCVA (Snellen decimal)</td>
<td>0.30</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Manifest sphere (D)</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Manifest cylinder (D)</td>
<td>-2.25</td>
<td>-2.50</td>
<td>-2.50</td>
</tr>
<tr>
<td>(K_1) (D)</td>
<td>44.20</td>
<td>41.70</td>
<td>41.70</td>
</tr>
<tr>
<td>(K_2) (D)</td>
<td>47.20</td>
<td>44.50</td>
<td>44.50</td>
</tr>
<tr>
<td>(K_{max}) (D)</td>
<td>50.3 0</td>
<td>47.3</td>
<td>47.30</td>
</tr>
<tr>
<td>Corneal cylinder (D)</td>
<td>3.00</td>
<td>2.80</td>
<td>2.80</td>
</tr>
<tr>
<td>Vertical coma (μm)</td>
<td>-2.30</td>
<td>-2.27</td>
<td>-2.27</td>
</tr>
<tr>
<td>Asphericity (Q)</td>
<td>-1.04</td>
<td>-0.49</td>
<td>-0.49</td>
</tr>
</tbody>
</table>

Figure 5. Corneal topography Pentacam HR (Oculus) of the left eye after Intacs SK exchange for Ferrara-type ICRS.
RESULTS AFTER EXCHANGE OF ICRS IN KERATOCONUS

JOURNAL OF EMMETROPIA - VOL 7, JULY-SEPTEMBER

reduction or elimination of myopia. Between 2000 and 2005, they had begun to be applied in the treatment of keratoconus, with implantation shown to be a safe and reversible procedure, improving objective visual outcomes and functional vision in most keratoconus patients. At that time, ICRS emerged as a surgical alternative to improve contact lens tolerance and avoid or delay penetrating keratoplasty. The first nomograms developed for ICRS implantation used anterior corneal curvature values and the spherical equivalent, and were based on the Amsler-Krumeich classification, which describes the disease in four different stages of severity. Based on the concept of disease grading, the refractive, visual and topographic results were generally good, but there were some reports of VA loss after implantation and the need for ICRS explantation or exchange. In the last decade, a new era of keratoconus diagnosis emerged. Together with the advent of corneal tomography and corneal high order aberration mapping, the classification of ectasia was reformulated in order to include the subjective refraction, topography, taberrometric profile (namely the vertical coma \( Z_{-1} \)) and corneal asphericity-ectasia phenotype classification. Instead of classifying the disease in stages or order of severity, it can be classified according to its clinical phenotype, allowing the surgeon to address the disease morphology and not the disease severity.

---

### Figure 6

Corneal topography Pentacam HR (Oculus) of the left eye during the first 30 months of follow-up after ICRS exchange surgery. (A: Before Intacs ICRS exchange, B: 12 months after ICRS exchange; C: 24 months after ICRS exchange; D: 30 months after ICRS exchange).

---

this new approach enables the corneal surgeon to perform both a therapeutic and refractive procedure.

The Ferrara-type ICRS emerged as a major alternative to the original ICRS Intacs-type because of the different arc lengths and thicknesses available, allowing a better and more detailed nomogram for implantation.

In the clinical case presented, we decided to review the preoperative topography and adopt a new strategy, since we had observed a decrease in BCVA after surgery that remained unchanged during 24 months of follow-up with no signs of ectasia progression. Considering the ectasia phenotype classification described by Alfonso et al., our patient's ectasia phenotype before Intacs SK implantation corresponded to the “Duck” phenotype, described as paracentral ectasia with non-coincident topographic and coma axis. In these cases, the recommended strategy is to implant a single segment Ferrara-type 150 degree arc length ICRS on the flattest topographic axis, in order to correct both the topographic and the comatic astigmatism. As the intrastromal tunnels created for the first surgery were correct for both depth of implantation and centration, we choose to explant both Intacs SK ICRS and implant a single Ferrara-type ICRS using the same intrastromal tunnel; this was performed at the 6.0 mm optical zone, the same optical diameter recommended for this type of phenotype correction with a Ferrara-type ICRS.
This clinical report also describes the reversibility of the ICRS surgical procedure. The possibility of explanting an ICRS in cases with poor refractive and topographic results or in cases of decentred or superficial intrastromal tunnel depth has been described and has been shown to be a safe and effective procedure.26-28,34.

In conclusion, when managing keratoconus patients, describing the ectasia as a phenotype (taking into consideration the subjective refraction, topography, corneal aberrometry and asphericity) instead of on a scale of severity, is a possible approach to obtain better refractive and topographic results, as demonstrated in the previous published cohorts by Alfonso et al.8,9.

REFERENCES
RESULTS AFTER EXCHANGE OF ICRS IN KERATOCONUS

First author:

Tiago Pacheco Teixeira Monteiro, MD, FEBO
Hospital de Braga, Braga, Portugal.
Escola de Ciências da Saúde da Universidade do Minho, Braga, Portugal.


