Intrastromal Corneal Ring Segments Implantation in Patients With Keratoconus: 10-Year Follow-Up

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Intrastromal corneal ring segments (ICRS) have been used as an additive surgical procedure for keratoconus correction, which provides an alternative to delay if not avoid corneal grafting in patients with keratoconus. ICRS act by an “arc-shortening effect” on the corneal lamellae and flatten the central cornea. The main advantages of ICRS are safety, reversibility, stability, and the fact that the surgical process does not affect the central corneal visual axis.

There are some reports in the literature regarding the long-term follow-up of eyes with keratoconus implanted with ICRS. These reports, with a variable period of follow-up (2 to 5 years), evaluated a small sample of patients. In the current study, we evaluated the long-term safety and efficacy after implantation of the Ferrara ICRS (Ferrara Ring; AJL, Boecillo, Spain) in patients with keratoconus. To our knowledge, this study has the largest follow-up period for eyes implanted with ICRS for correction of keratoconus in the literature.

PATIENTS AND METHODS

This retrospective study included 36 eyes of 30 patients with keratoconus implanted with ICRS, operated on between July 1996 and January 2002. Six patients had a single eye treatment, whereas 15 patients had both eyes treated. There were 18 women and 12 men with a mean age of 39.44 ± 10.18 years (range: 25 to 66 years). The evolutive grade of keratoconus was classified according to Amsler-Krumeich classification: 2 eyes were grade I, 13 eyes were grade II, 14 eyes were grade III, and 7 eyes were grade IV.

ABSTRACT

PURPOSE: To evaluate the long-term safety and efficacy of Ferrara intrastromal corneal ring segments (ICRS) (Ferrara Ring; AJL, Boecillo, Spain) in patients with keratoconus.

METHODS: The chart records of 36 eyes of 30 patients with keratoconus implanted with ICRS, operated on between July 1996 and January 2002, were retrospectively reviewed. The following parameters were studied: uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), keratometry (K), and central corneal thickness. The outcomes were evaluated at 5 and 10 years after ICRS implantation.

RESULTS: The mean UDVA (logMAR) improved from 1.01 ± 0.28 (20/200 Snellen) to 0.71 ± 0.38 (20/100 Snellen) at 5 years (P < .05) and 0.67 ± 0.25 (20/90 Snellen) at 10 years (P = .735). The mean CDVA (logMAR) improved from 0.45 ± 0.45 (20/55 Snellen) to 0.24 ± 0.19 (20/35 Snellen) at 5 years (P < .05) and 0.29 ± 0.09 (20/38 Snellen) at 10 years (P = .292). The mean maximum K value decreased from 54.99 ± 6.33 to 50.58 ± 5.11 D at 5 years (P < .05) and 50.65 ± 5.17 D at 10 years (P = .854). The mean minimum K value decreased from 48.85 ± 5.70 to 46.90 ± 5.08 D at 5 years (P < .05) and 47.12 ± 4.22 D at 10 years (P = .945). The central corneal thickness decreased from 457.42 ± 58.21 to 421.34 ± 74.12 μm at 5 years (P = .039) and 434.32 ± 77.65 μm at 10 years (P = .427).

CONCLUSIONS: Intrastromal corneal ring segments can effectively improve UDVA and CDVA 10 years after implantation in patients with keratoconus.

All patients were informed about the possible intraoperative and postoperative complications and gave written informed consent in accordance with institutional guidelines and the tenets of the Declaration of Helsinki. The following parameters were studied: uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), keratometry (K), and central corneal thickness. The outcomes were evaluated at 5 and 10 years after ICRS implantation.

The main indication for ICRS implantation was contact lens intolerance and/or progression of the ectasia. The progression of the disease was defined by worsening of UDVA and CDVA, progressive intolerance to contact lens wear, and progressive corneal steepening documented by the topography (more than 1 diopter [D] increase of mean keratometric values in 1 year). Patients were excluded if any of the following criteria applied after preoperative examination: advanced keratoconus with curvatures greater than 60 D and significant apical opacity and scarring, hydropsis, thin corneas, thickness less than 300 µm in the ring track, intense atopia, and any ongoing infectious process, local or systemic. Patients who did not meet the inclusion criteria were not evaluated for this study. There was contact lens intolerance in 24 eyes and evidence of disease progression in 12 eyes.

The nomograms used for surgical planning were based on the position of the area of ectasia on the cornea, spherical equivalent, and topographic astigmatism.8

**SURGICAL TECHNIQUE**

All surgeries were performed using the manual technique, by the same surgeon (PF). The surgery was performed under topical anesthesia after miosis was achieved with 2% pilocarpine. The visual axis was 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, a 5.0-mm optical zone and incision site were aligned to the desired axis in which the incision would be made. This incision site was always at the steepest topographic axis of the cornea given by the topographer.

A square diamond blade was set at 80% of corneal thickness at the incision site and this blade was used to make the incision. Using a “stromal spreader,” a pocket was formed in each side of the incision. Two (clockwise and counterclockwise) 270° 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 tobramycin 0.3%–dexamethasone 0.1% eye drops four times a day for a week, after which the dose was tapered over 3 weeks. In addition, patients received topical lubricants (Lacrima; Alcon Laboratories, Inc., Fort Worth, TX) four times a day for at least 3 months.

Postoperative examinations were performed at postoperative days 1 and 7, after 1 and 6 months, and then every year. The UDVA, CDVA, slit-lamp evaluation, corneal topography, funduscopy, and tonometry were performed at each control visit. The corneal topography was obtained from EyeMap (Alcon Laboratories, Inc.) and Pentacam (Oculus Optikgeräte, Wetzlar, Germany).

We evaluated only the clinical outcomes at 5 and 10 years after the surgery because some patients missed some postoperative visits during the period of follow-up.

**STATISTICAL ANALYSIS**

Statistical analysis was done using the GraphPad Instat 3 for Macintosh (version 3.1a; GraphPad Software, Inc., La Jolla, CA). Student’s t test for paired data was used to compare preoperative and postoperative data.

**RESULTS**

Acuity and keratometry results are listed in Table 1 and Figures 1-2. Seventy percent of patients gained two or more lines of UDVA and 10% of patients lost two or more lines of UDVA. We found that 56.5% of patients gained two or more lines of CDVA at 5 years and 66.7% of patients gained two or more lines of CDVA at 10 years of follow-up (Figure 3).

Regarding the reoperation rate, ICRS exchange was required in 2 eyes and keratoplasty in 2 eyes. These eyes were excluded from the study.

To illustrate, we present a case of a patient who was contact lens intolerant and had a visual acuity of 20/80 (-5.00 -2.00 × 120). She received two ring segments in December 1997. Her last follow-up visit was in May 2011, at which time she presented with a CDVA of 20/30 (plano -2.50 × 90) and a stable topography (Pentacam) (Figures A-B, available in the online version of this article).

**DISCUSSION**

Implantation of ICRS is a minimally invasive and reversible surgical treatment that reduces refractive error by improving the corneal shape and delaying or preventing keratoplasty.1,8,9 Successful implantation of ICRS depends on several factors, including correct placement, optical zone diameter, and accurate depth of implantation.6,7,10
Our postoperative results showed a significant improvement in UDVA and CDVA. Our data reinforce the reproducibility and efficacy of the technique.\textsuperscript{10,11} There are few studies regarding the long-term follow-up after ICRS implantation. Alió et al.\textsuperscript{2} and Torquetti et al.\textsuperscript{8} described results after 4 and 5 years, respectively, but most studies have relatively short follow-ups, between 6 months and approximately 1 year.\textsuperscript{12,13} To the best of our knowledge, this study has the longest follow-up of eyes implanted with ICRS ever published.

**TABLE 1**  
Preoperative and 5- and 10-Year Follow-up Examination Data of Eyes Implanted With Ferrara Intrastromal Corneal Ring Segments

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Preoperative</th>
<th>5-Year Postoperative</th>
<th>P</th>
<th>5-Year Postoperative</th>
<th>10-Year Postoperative</th>
<th>P</th>
</tr>
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<tbody>
<tr>
<td>K1 (D)</td>
<td>48.85 ± 5.70</td>
<td>46.90 ± 5.08</td>
<td>&lt; .05</td>
<td>46.90 ± 5.08</td>
<td>47.12 ± 4.22</td>
<td>.945</td>
</tr>
<tr>
<td>K2 (D)</td>
<td>54.99 ± 6.33</td>
<td>50.58 ± 5.11</td>
<td>&lt; .05</td>
<td>50.58 ± 5.11</td>
<td>50.65 ± 4.70</td>
<td>.873</td>
</tr>
<tr>
<td>Km (D)</td>
<td>51.83 ± 5.66</td>
<td>48.70 ± 5.02</td>
<td>&lt; .05</td>
<td>48.70 ± 5.02</td>
<td>48.82 ± 4.38</td>
<td>.953</td>
</tr>
<tr>
<td>UDVA (logMAR)</td>
<td>1.01 ± 0.28</td>
<td>0.71 ± 0.38</td>
<td>&lt; .05</td>
<td>0.71 ± 0.38</td>
<td>0.67 ± 0.25</td>
<td>.735</td>
</tr>
<tr>
<td>CDVA (logMAR)</td>
<td>0.45 ± 0.45</td>
<td>0.24 ± 0.19</td>
<td>&lt; .05</td>
<td>0.24 ± 0.19</td>
<td>0.29 ± 0.09</td>
<td>.292</td>
</tr>
<tr>
<td>Pach (μm)</td>
<td>457.42 ± 58.21</td>
<td>421.34 ± 74.12</td>
<td>&lt; .05</td>
<td>421.34 ± 74.12</td>
<td>434.32 ± 77.65</td>
<td>.427</td>
</tr>
</tbody>
</table>

K1 = minimum keratometry; D = diopters; K2 = maximum keratometry; Km = mean keratometry; UDVA = uncorrected distance visual acuity; CDVA = corrected distance visual acuity; Pach = pachymetry

**Figure 1.** Snellen corrected distance visual acuity (logMAR) at (A) 5 and (B) 10 years postoperatively.

**Figure 2.** Change in lines of Snellen corrected distance visual acuity at (A) 5 and (B) 10 years postoperatively.
The results of our study agree with those of other studies. Alió et al. performed a retrospective study to evaluate the long-term (up to 48 months) results after Intacs implantation in patients with keratoconus. After 6 months, the mean UDVA increased significantly (P < .01) from 0.46 (20/50) preoperatively to 0.66 (20/30), and the average keratometry decreased by 3.13 D. Coskunseven et al. evaluated the results of Keraring ICRS in 50 eyes of patients with keratoconus. Of these, 47 had UDVA of 20/40 (range: counting fingers to 20/30). At the last follow-up examination, 14 of the 50 eyes had a UDVA of 20/40 or better (range: counting fingers to 20/25). Nine eyes maintained the preoperative CDVA, whereas 39 eyes experienced a CDVA gain of one to four lines.

Kwitko and Severo reported that CDVA after Ferrara ICRS implantation in eyes with keratoconus improved in 86.4%, was unchanged in 1.9%, and was worse in 11.7%. UDVA improved in 86.4%, was unchanged in 7.8%, and was worse in 5.8%. The mean corneal curvature decreased from 48.76 ± 3.97 D preoperatively to 43.17 ± 4.79 D postoperatively.

In a 2-year follow-up study after implantation of Intacs, Colin and Malet described a gain of one or more lines of CDVA in 61.0% eyes at 1 year and 68.3% eyes at 2 years. Fewer than 15% of eyes experienced a CDVA loss of one or more lines during the 2 years following Intacs implantation. There was loss of one or more lines of CDVA in 14.63% of eyes.

Regarding the number of lines gained and lost after ICRS implantation, we found that 10% of patients lost UDVA and 20.7% lost CDVA. All of these patients had grade III or IV keratoconus. The patients who lost UDVA and CDVA but had grade II keratoconus had reoperation due to ring repositioning, removal, or exchange. Therefore, advanced keratoconus and the reoperation could be considered as risk factors for loss of visual acuity after ICRS implantation. Due to the limited size of our sample, we could not statistically establish these two factors as predictors of a bad outcome.

The nomogram used for ring selection in the patients studied was based on the preoperative spherical equivalent. We no longer use this nomogram because newer nomograms provide better reliability and predictability of results. However, because the main purpose of this study was to evaluate the long-term safety and efficacy of ICRS, we do not consider the use of that nomogram as bias factor.

There are some limitations to this study. First, the mean age of patients at the time of surgery was 39 years. We agree that keratoconus tends to be stable after approximately 30 years of age. Therefore, the results regarding stability could be influenced by the mean age of the studied patients. However, we could include in this study only patients who came back for revision at 5 and 10 years after the surgery. Because we are a referral center for ICRS implantation in Brazil and receive patients from all over the country, some patients are lost to follow-up. This could be considered a bias of selection, but only the patients who came back for follow-up could be included in this study.

Other interesting data to be studied would be the stratification of results according to the evolutive grade of keratoconus. Due to the small sample of patients, our analysis could not provide reliable results. Prospective, multicentric, randomized studies with a larger sample of patients would be useful to show the long-term differences (if any) of outcomes in different grades of keratoconus.

As shown in previous studies, the ICRS flattens the cornea and the effect persists for a long period. There is no significant resteeptening of the cornea over time, in most cases, except when the ring is implanted in advanced cases of keratoconus or in very young patients (unpublished data).

Our study demonstrated that Ferrara ICRS implantation is a safe and efficacious option for the treatment of patients with keratoconus. The improved functional vision associated with this treatment modality can postpone or potentially eliminate the need for corneal transplantation. In patients whose visual outcomes following ICRS implantation are unsatisfactory or decrease due to disease progression, the segments can be removed easily and safely and corneal transplantation performed. Further randomized studies with larger samples are needed to confirm the stability of outcomes following Ferrara ICRS implantation, particularly in young patients and those with progressive disease.

**AUTHOR CONTRIBUTIONS**

Study concept and design (GF, PF, LT); data collection (FA, LC); analysis and interpretation of data (LPNA, APM, JM-L, LT); drafting of the manuscript (GF, PF, LT); critical revision of the manuscript (FA, LPNA, LC, PF, APM, JM-L, LT); statistical expertise (LPNA, APM); supervision (LT)
REFERENCES

Figure A. Preoperative corneal topography (Alcon Laboratories, Inc., Fort Worth, TX) of an eye with keratoconus implanted with intrastromal corneal ring segments in 1997.

Figure B. Postoperative Pentacam corneal topography (Oculus Optikgeräte, Wetzlar, Germany) of an eye with keratoconus implanted with intrastromal corneal ring segments in 1997 (examination data from 2011).