Efficacy and Complications

A. John Kanellopoulos, MD,*†‡ Lawrence H. Pe, MD,*† Henry D. Perry, MD,* and Eric D. Donnenfeld, MD*‡

Purpose: To evaluate the safety and efficacy of modified intracorneal ring segment implantation (INTACS) in the management of moderate and advanced keratoconus (KCN).

Methods: A modified procedure of intracorneal ring segment (INTACS) implantation was performed in eyes with moderate to advanced keratoconus that were intolerant to contact lens or spectacle correction. The main outcome measures were uncorrected visual acuity (UCVA), best spectacle corrected visual acuity (BSCVA), refraction, and keratometry. The preoperative values were compared with the values 6 and 12 months postoperatively.

Results: Implantation was performed on 20 eyes of 15 patients; 9 were female and 6 were male. The mean age was 30.2 years (SD ± 5.44; range, 23–40). At the 6-month follow-up, UCVA improved from 20/154 (SD ± 0.11) preoperatively to 20/28 (SD ± 0.21) postoperatively (P < 0.05); BCSVA improved from 20/37 (SD ± 0.21) preoperatively to 20/22 (SD ± 0.13) postoperatively (P < 0.05). Spherical refractive error improved from –3.38 D (SD ± 3.12) to –1.15 D (SD ± 1.84); cylindrical refractive error improved from –3.75 (SD ± 2.04) preoperatively to –1.21 (SD ± 0.84) postoperatively (P < 0.05); average keratometry decreased from 49.50 D (SD ± 1.64) preoperatively to 46.35 D (SD ± 1.50) postoperatively. The changes remained stable to the 12-month follow-up. There was 1 case of anterior chamber perforation. There were 6 eyes that had ring exposure secondary to corneal thinning over the implants 3–6 months postoperatively, and a dense corneal infiltrate developed in patient 1 at 7 months postoperatively.

Conclusions: The procedure appears to be effective in improving UCVA and BSCVA of patients with clinical keratoconus. In our small study group, however, there were significant (6/20) postoperative problems with regards to thinning and ring exposure.

Intracorneal ring segments (INTACS) implantation is a refractive procedure that has been used clinically for the correction of mild to moderate myopia1–3 and also in the recent past in the surgical management of keratoconus9–15 and iatrogenic postoperative corneal ectasias.16–19 In the largest recently published studies, the horizontal orientation of the rings was favored and additionally the asymmetric ring size by other investigators.9

Twenty consecutive cases of INTACS implantation with a slightly modified technique for mild to moderate keratoconus were prospectively evaluated for safety, efficacy, and possible complications.

Our clinical objective was to improve uncorrected and best spectacle corrected visual acuity in keratoconus patients who were intolerant to spectacle or contact lens correction. We viewed this procedure as an intermediate step in improving visual function before performing a penetrating keratoplasty.

MATERIALS AND METHODS

The study design is a prospective, nonrandomized case series. The patients included in the study had mild to moderate keratoconus corresponding to stages 2 and 3 of the Krumeich classification.20 The patients had to be intolerant to contact lens and spectacle correction. Their central corneas had to be clear and their best corrected visual acuity had to ≥20/200, and their central corneal pachymetries had to be at least 300 μm. These were consecutive patients seen or referred to our institution for possible penetrating keratoplasty.

Preoperative and postoperative assessments included uncorrected visual acuity (UCVA), best spectacle corrected visual acuity (BSCVA), and manifest refraction measured at least 2 weeks following discontinued gas permeable contact lens use when applicable; scotopic pupil measurement with the Colvard pupillometer; slit-lamp examination, Goldmann applanation tonometry, dilated fundus examination with indirect ophthalmoscopy, simulated keratometry, topography, optical
pachymetry were measured with the ORBSCAN II (Bausch and Lomb) and ultrasonic pachymetry with the NIDEK US-1800 (Echoscan, Achi, Japan).

The surgical technique was similar to the method used in the treatment of myopia. The intracorneal ring segments (Keravision, Fremont, CA) were implanted horizontally similar to the technique described by Boxer Wachler et al and Colin et al. We used a modified nomogram of ring size selection (Table 1). The working principle behind nomogram is that the thicker ring produces more flattening. We always place the thinner intracorneal ring segments on the upper cornea and the thicker ring in the lower cornea to induce more flattening inferiorly as the apex of the cone was located inferior to the center in most cases.

The corresponding center of the rings was also positioned to adjust to the center of the cone; therefore, the center of the virtual circle created by the 2 rings was positioned inferotemporally by 0.5–1.5 mm toward the center of the cone and not the geometric center of the cornea (Figs. 1 and 2). The orientation of the rings was horizontal, and the incision site in all cases was temporal and at the 1 o’clock position superior to the horizontal middle meridian of the cornea. The procedure was performed under topical anesthesia with lidocaine HCl gel 2% (Xylocaine jelly, AstraZeneca AB, Sweden). The corneal thickness at the incision site was determined from the Orbscan pachymetry readings and was double checked with ultrasonic pachymetry intraoperatively for added safety. When optical and ultrasonic pachymetries were more than 10 μm apart, the ultrasonic measurement at the marked incision site was used. Following that, a diamond blade was adjusted to 70% of total corneal thickness at the incision site for the axial 1.2- to 1.4-mm incision. A minimum of 450 μm was respected, but this was not necessary in any of the cases, as all required “deeper” blade setting. Following the incision, creation of the intrastromal corneal tunnels was performed with the 1.2-mm specialized blunt dissecting instrument, aided with the use of the suction centering device guide for all ring sizes used. Following this, the PMMA ring segments were implanted in the intrastromal channels. A 10-0 nylon suture was placed at the end of the procedure to close the incision site, and this suture was removed within a month. The actual corneal depth of the ring segment was evaluated immediately following the procedure to ensure two thirds depth placement. All patients received ofloxacin 0.3% (Exocin, Allergan, Ireland) and prednisolone acetate 1% drops (PredForte, Allergan) 4 times daily for 1 week. Patients were seen for follow-up visits on the first day, first week, first month, third month, and every 3 months, as well as emergency visits for unforeseen problems with their procedures.

The mean values of visual acuity, refraction, and keratometry were statistically compared (Wilcoxon signed rank test) to postoperative values at the 6- and 12-month postoperative follow-up.

The surgeries were performed by a single surgeon (A.J.K.) at a cornea and external disease specialty practice in Athens, Greece.

**RESULTS**

Twenty eyes of 15 patients (9 [60%] female and 6 [40%] male) were included in the series; 12 of the eyes were right (60%) and 8 were left (40%). The average age was 30.2 years (SD 5.44) with a range 23 to 40.

At the 6-month of follow-up, UCVA improved from a preoperative mean of 20/154 (SD ± 0.11) to a postoperative mean of 20/28 (SD ± 0.21) (P = 0.00) (graph 1), while the BSCVA improved from a preoperative 20/37 (SD ± 0.21) to

---

**TABLE 1. Nomogram for Intrastromal Segment Size Selection**

<table>
<thead>
<tr>
<th>Spherical Equivalent</th>
<th>Upper Segment (mm)</th>
<th>Lower Segment (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to −2.00</td>
<td>0.25</td>
<td>0.35</td>
</tr>
<tr>
<td>−2.00 to 3.00</td>
<td>0.25</td>
<td>0.40</td>
</tr>
<tr>
<td>−3.00 to −5.00</td>
<td>0.25</td>
<td>0.45</td>
</tr>
<tr>
<td>−5.00 to −6.00</td>
<td>0.35</td>
<td>0.45</td>
</tr>
<tr>
<td>More than −6.00</td>
<td>0.40</td>
<td>0.45</td>
</tr>
</tbody>
</table>

---

**FIGURE 1.** INTACS placement right eye 1 day postoperatively showing horizontal orientation of rings, with the center formed by the rings slightly inferior and temporal to maximize the flattening effect on the cone (A). B: Silt beam showing depth of ring placement (approximately two thirds of the corneal thickness).
a postoperative 20/22 (SD ± 0.13) \((P = 0.00)\) (graph 1). Both of these were significant with statistical analysis. Spherical refractive error improved from a mean of \(-3.38 \text{ D (SD ± 3.12)}\) to a mean of \(-1.15 \text{ D (SD ± 1.84)}\) postoperatively \((P = 0.00)\); cylindrical refractive error improved from a preoperative mean of \(-3.75 \text{ D (SD ± 2.04)}\) to a postoperative mean of \(-1.21 \text{ D (SD ± 0.84)}\), which were likewise statistically significant \((P = 0.00)\) (graph 2). The mean average keratometry decreased from a mean preoperative value of 49.45 \text{ D (SD ± 1.64)}, to a postoperative mean of 46.35 \text{ D (SD ± 1.50)} postoperative \((P = 0.00)\) (Table 2, graph 3).

At 1 year postoperatively, 13 eyes were available for follow-up, 7 eyes were excluded from the study after the 6-month follow-up because their implants had to be removed for various reasons. UCV A remained at a mean of 20/28 (SD ± 0.21) \((P = 0.00)\), BSCVA slightly decreased to 20/22 (SD ± 0.13), and the average keratometric measurement slightly increased from 46.35 \text{ D (SD ± 1.50)} at 6 months to 46.50 \text{ D (SD ± 1.22)}. The changes were not statistically different from the values at the 6th postoperative month (Table 2).

In 1 patient, we encountered perforation of the anterior chamber during the blunt dissection for the superior intrastral channel. The lower ring segment was still placed, while the upper segment was not placed. There was no aqueous leak noted early or later postoperatively. The procedure for the upper ring segment was repeated 1 month later, through a new incision nasally at which time an intracorneal ring segment was successfully placed in the upper part of the cornea.

We did encounter a significant number (35%) of postoperative complications with the placement of the intracorneal rings with this technique. There were 6 cases of intracorneal ring segment movement and exposure through the axial wound (Fig. 3), these occurred 3–6 months postoperatively. In the majority of these cases (4), the upper ring segment appeared to move through the incision and ranged from 0.5 to 2 mm of an overlap over the corneal tissue that was superior to the lower ring segment. There were 2 cases of inferior ring migration and exposure. In all 6 cases, there was significant corneal thinning observed via slit-lamp biomicroscopy over the extruding ring edge prior to exposure (Fig. 4).

We also encountered 1 case in which there was a corneal melt and significant corneal infiltrate over 1 of the ring segments, necessitating segment removal 7 months postoperatively (Fig. 5). The cases of corneal ring movement and

![FIGURE 2](image)

**FIGURE 2.** This topography difference map shows on the top right the preoperative condition, on bottom -right the postoperative condition, and on the center left the actual topographic shift depicting 6 D of flattening. These images show flattening of the cone (center red circle) as well as a shift of the cone center toward the anatomic cornea center (red arrow).

| TABLE 2. (Kanellopoulos et al) Table of Mean Values Pre and Post-operative Results at 6 Months |
|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| **Preoperative (N = 20)**                                     | **Post op 6 months (N = 20)**                                 | **Post op 12 months (N = 13)**                                |
| UCVA                                                          | 20/154 (SD ± 0.11)                                            | 20/28 (SD ± 0.21)                                            | 20/29 (SD ± 0.13)                                           |
| BSCVA                                                         | 20/37 (SD ± 0.21)                                             | 20/22 (SD ± 0.13)                                            | 20/23 (SD ± 0.11)                                           |
| Keratometry                                                   | 49.45 D (SD ± 1.64)                                          | 46.35 D (SD ± 1.50)                                          | 46.50 D (SD ± 1.22)                                         |
| Sphere                                                        | \(-3.38 \text{ D (SD ± 3.12)}\)                               | \(-1.15 \text{ D (SD ± 1.84)}\)                             | \(-1.46 \text{ D (SD ± 2.19)}\)                            |
| Cylinder                                                      | \(-3.75 \text{ D (SD ± 2.04)}\)                             | \(-1.21 \text{ D (SD ± 0.84)}\)                             | \(-1.25 \text{ D (SD ± 0.89)}\)                            |
| SE                                                            | \(-5.33 \text{ D (SD ± 3.40)}\)                             | \(-1.64 \text{ D (SD ± 1.84)}\)                             | \(-1.87 \text{ D (SD ± 1.75)}\)                            |

UCVA, uncorrected visual acuity; BSCVA, best spectacle corrected visual acuity; SE, spherical equivalent.
exposure were treated with repositioning of the segments and placement of a mattress cornea suture (10-0 nylon) to close the axial incision. Repeated exposure and/or significant cornea thinning over the ring segments necessitated removal of the ring segments all 6 cases.

**DISCUSSION**

In this limited case series, we found the intracorneal ring segment experience to be quite notable for its ability to improve visual acuity and short-term visual rehabilitation in patients with moderate to advanced keratoconus. It appears to be a simple in-office procedure, and the clinical visual improvement corresponded with a significant topographic flattening effect as well as a cone deviation toward the center of the cornea (Fig. 2). Our technique, as outlined in Methods, was focused on maximal segment asymmetry to maximize this clinical effect.

In previous reports, Colin et al. had pointed out the potential advantages of the horizontal placement of the implants to improve functional visual acuity. Following this study, Boxer Wachler et al. used a modified implantation technique, which was the actual inspiration for our series. In the Boxer Wachler et al. study, the rings were implanted horizontally and asymmetrically. The superiorly placed ring was invariably of a smaller size than the inferior one with very impressive efficacy. In our clinical setting, we had the choice of 2 additional ring sizes, the 0.40- and 0.45-mm segments, which are approved for clinical use in the European Union (CE mark). We therefore attempted to customize further the modified implantation technique described previously by Boxer Wachler et al. Another variation from that study in our technique was the decentration of the placement of the rings toward the sagittal center of the topographic cone versus the anatomic center of the cornea. We added this feature because we had observed clinically in our earlier cases that this further improves UCVA. It is difficult to interpret these data, especially when comparing manifest cylinder preoperatively in a group of mostly RGP contact lens users and the same group several months following the procedure and discontinuation of contact lens use. Nevertheless, the improvement in all these parameters appears to a result of cone flattening and possible deviation toward the visual axis, as demonstrated by serial topographies.

Our experience, however, raises significant concerns about the actual stability of the ring segments in the cornea, and the potential risks of intrastromal corneal ring segment corneal extrusion, as well as the possibility of corneal infection as have been noted in the past. Keratoconic corneas have highly irregular thickness and irregular stromal collagen structure and distribution. One patient did develop an infiltrate over 1 of the corneal ring segments at the 6-month follow-up; we eventually removed the segment because of tissue thinning and the increasing size of the infiltrate. There were no organisms cultured from scrapings taken from the area after the segment removal. The infiltrate regressed with topical treatment of ofloxacin 0.3% and prednisolone acetate 1%; however, it left hefty a scar in the inferior corneal area.

**FIGURE 3.** Ring movement with overlap of the superior ring over the inferior ring edges at the incision site.

**FIGURE 4.** Corneal thinning over INTACS with exposure of the ring segments.

**FIGURE 5.** Infiltrate forming around the inferior ring segment 6 months postoperatively.
Possible recommendations for the better management of these patients include the consideration of permanent or longer term suturing of the axial incision site, a measure that may reduce the possibility of the ring segment coming out of the incision, and/or strong advice to the patients to avoid eye rubbing, as this may contribute to stromal thinning and segment migration.

The possibility of intraoperative “anchoring” of the ring segments between them, potentially with suturing, may reduce the possibility of their migration and overlap. This experience does also raise the question of whether placement of the incision at a different site may reduce the high incidence of complications with ring segment movement that was encountered in our patient population. Perhaps an incision at the 12 o’clock position may reduce the possibility of one of the ring segments moving. The increased incidence of segment exposure in this series in comparison to previous studies may be related to the use of “thicker” segments of 0.40 and 0.45 mm in our study and/or the slight ring segment decentration toward the cone apex that we employed in our technique.

Our postoperative results are comparable with those of other studies in regard to efficacy. We have found in general that patients with keratoconus have notable Snellen UCVA improvement in regard to their manifest refractive error. The same observation holds in our experience in this small group, as most patients achieved excellent UCVA postoperatively despite significant manifest refractive error. Our findings, though, differ significantly from those of previous studies in regard to safety and postoperative complications encountered.2–13 We are not able to address the high extrusion rate noted in our series when compared with no extrusion rate noted in previous studies. Perhaps the longer follow-up in our series may be a factor as well as possible underreporting in previous studies.

We theorize that despite the natural course of progressive corneal thinning in keratoconus in the age group studied, intrastromal corneal ring segments are a very promising alternative as far as the physiologic cornea shape change, resulting in significant short-term visual rehabilitation for patients with mild to moderate keratoconus.

Another consideration may be that asymmetric segment placement may be indicated in oblique keratoconus cases (the most common) but may not be indicated in central “nipple” keratoconus. We identified all of our cases in this small group as oblique cones.

As an intervention concept, this effect in keratoconus corneas merits further investigation. Possibly another biocompatible material may prove more compatible with long-term implantation. It is our recommendation that surgeons be very cautious in clinical practice regarding the possibility of the ring segments migrating and extruding with this surgical technique. Clinicians and patients alike should be aware of the potential complications and risks. We view this technique as a temporary measure prior to consideration of penetrating keratoplasty, the gold standard in the surgical management of this disease process.

REFERENCES

AUTHOR QUERIES

DATE  5/13/2005
JOB NAME  CORN
JOB NUMBER  99570
ARTICLE  ICO200100
QUERIES FOR AUTHORS  Kanellopoulos et al

THIS QUERY FORM MUST BE RETURNED WITH ALL PROOFS FOR CORRECTIONS

AU1) What are these graphs? there are only figs and tables cited.
AU2) No file for Table 2 posted.
AU3) Does this fig print in color? if not, leg needs to be corrected.
AU4) Please check Section head.
AU5) Please provide history line information.
AU6) Please check fig.1a-label not entered inside the graphics.
AU7) Please chk figure label.