Unilateral implantation of a pseudoaccommodating toric intraocular lens in 2 patients after radial keratotomy

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We report 2 cases involving patients with a history of radial keratotomy (RK) who presented with astigmatism and a cataract and were successfully treated with implantation of a pseudoaccommodating toric intraocular lens (IOL) (Trulign). The first patient presented with right-eye corrected distance visual acuity and corrected near visual acuity of 20/70 and 20/40, respectively. Following cataract extraction and IOL placement, the manifest refraction was −0.25 + 0.50 × 180. At 3 months, the uncorrected distance visual acuity (UDVA) and uncorrected near visual acuity (UNVA) in the right eye were 20/30 and 20/20, respectively. The second patient presented with UDVA in his left eye of 20/60. After cataract extraction and implantation of the same pseudoaccommodating toric IOL, he experienced 2 months of transient iritis. Three months after surgery, the left-eye UDVA and UNVA were 20/20. Given the known risk for long-term hyperopic shift and diurnal fluctuations following RK, these patients appeared to be ideal candidates for the pseudoaccommodating toric IOL.

Financial Disclosure: Neither author has a financial or proprietary interest in any material or method mentioned.

JCRS Online Case Reports 2014; 2:73–77 © 2014 ASCRS and ESCRS

For several years, radial keratotomy (RK) was the most widely performed refractive surgery worldwide. Before the procedure was largely supplanted by excimer laser photorefractive keratectomy and laser in situ keratomileusis (LASIK) in the early 1990s, there were an estimated 250,000 RK surgeries performed annually. Despite the popularity, the excitement for RK was tempered by high rates of hyperopic shifts, diurnal variation, glare and halos, and increased vulnerability to traumatic lesions.

Early experience with intraocular lens (IOL) power calculations in patients with a previous RK having cataract surgery proved challenging because of flattening of the central cornea. Consequently, initial techniques to estimate the needed IOL power led to overestimation of the corneal refractive power and underestimation of the implanted IOL, resulting in postoperative hyperopia. Nevertheless, clinical outcomes have improved since the addition of several techniques, including the advent of topography, the use of posterior corneal curvature to calculate corneal power, and the development of new optical formulas (Holladay 2 and double-K).

Despite satisfactory results with monofocal IOLs, the literature on the use of advanced IOL options in post-RK patients is limited. Recently, Tahzib et al. reported implantation of an Artisan toric phakic IOL and an aphakic IOL (Ophtec BV) in 2 patients with a history of RK. Similarly, Gupta et al. reported 2 cases in which patients with a history of RK had implantation of a multifocal IOL in the nondominant eye and a monofocal IOL in the dominant eye. To our knowledge, this is the first report of a patient successfully treated with a pseudoaccommodating toric IOL following RK.

CASE REPORTS

Case 1

A 68-year-old man presented to our clinic in December 2013 with 6 months of decreased near vision. Nineteen years
earlier, he had had bilateral RK with 8 radial incisions in the right eye. The postoperative visual acuity was unknown. He had had no eye examinations since the RK surgery but had no specific interval complaints.

At presentation, the corrected distance visual acuity (CDVA) and corrected near visual acuity (CNVA) in the right eye were 20/70 and 20/40, respectively. The manifest refraction was +2.50 +0.75 × 165. The intraocular pressure (IOP) was 11 mm Hg. Ophthalmic examination showed a 2+ nuclear sclerotic cataract and a normal fundus.

The central topographic keratometry (K) values in the right eye were 39.1/138/38.1/45, measured with an Atlas topographer (Carl Zeiss Meditec AG). The axial length (AL) and anterior chamber depth (ACD) were measured with an IOLMaster (Carl Zeiss Meditec AG) and were 25.38 mm and 2.77 mm, respectively. The IOL power was calculated on the basis of the central topographic K values, the AL, and the ACD using the double-K and Holladay 1 methods. Surgical planning for preoperative astigmatism was calculated using the corneal astigmatism, not the manifest refraction, because the lenticular astigmatism had been removed. The corneal astigmatism was determined by averaging the central topographic astigmatism and the equivalent K readings measured at 2.0 mm and 3.0 mm with the rotating Scheimpflug camera (Pentacam, Oculus Surgical, Inc.). The toric axis was selected by averaging the steep meridians of the central topographic keratometry and the average of the steep meridians measured by the rotating Scheimpflug camera equivalent K readings at 1.0 mm, 2.0 mm, and 3.0 mm. The corneal astigmatism was +1.34 diopters (D).

Intraoperatively, a 2.8 mm keratome was used to perform a corneal incision temporally at 20 degrees to avoid the RK incisions. However, this would be predicted to increase the postoperative astigmatism by approximately +0.2 D. A subsequent capsulorhexis of approximately 4.0 × 4.5 mm (aided by corneal marks with the short axis of the capsulorhexis oriented along the planned long axis of the IOL) was followed by phacoemulsification of the cataract. Irrigation/ aspiration and inflation of the capsule with an ophthalmic viscosurgical device were performed. Thorous capsule polishing was performed using the bimanual technique. After expansion of the wound to 3.0 mm, a pseudoaccommodating toric IOL (Trulign, Bausch & Lomb) with 24.0 D of power and +1.25 D of cylindrical correction was successfully implanted in the capsular bag. After the steep meridian was confirmed intraoperatively using the Mastel surgical astigmatometer, the toric IOL was aligned to 131 degrees according to the results from the Trulign toric calculator. The wound was self-sealing and did not require suturing.

Within 2 weeks of surgery, the patient had spectacle independence and denied problems with glare, contrast sensitivity, or difficulty with night driving. Three months after surgery and subsequent neodymium:YAG (Nd:YAG) capsulotomy, the uncorrected distance visual acuity (UDVA) was 20/30, which could be corrected to 20/25. The uncorrected near visual acuity (UNVA) was 20/20. The manifest refraction was –0.25 +0.50 × 180. The IOP was 17 mm Hg. Slitlamp examination showed a clear cornea and lens with the IOL in good position.

**Case 2**

A 45-year-old man presented at our clinic in February 2014 after 2 months of cloudy vision that was worse in the morning and in the afternoon. Eighteen years earlier, he had had bilateral RK with 4 incisions. He had had no eye examinations since the RK surgery but denied having any interval complaints.

In our clinic, the UDVA in the left eye was 20/60, which could be corrected to 20/40. The manifest refraction was –1.00 +0.75 × 25. The IOP was 14 mm Hg. Slitlamp examination of the left eye showed a 3+ subcapsular cataract and a 2+ cortical cataract. The fundus was normal. Optical coherence tomography showed a healthy macula without edema.

Mean central topographic keratometry measurements were 41.72/75/40.65/176 (Figure 1). The AL and ACD were 25.01 mm and 3.98 mm, respectively. As in Case 1, the IOL power was calculated using the double-K and Holladay 1 formula based on the central keratometry, AL, and ACD, and the toric power and axis were calculated using the equivalent K readings and central corneal topography (Table 1). The results indicate astigmatism and a marked change in the axis of the steep vector in the central cornea, as commonly observed in post-RK patients. From these data, the astigmatism was determined to be +0.76 D. Cataract surgery was performed using the same technique as in

Figure 1. Case 2, left eye. Preoperative axial curvature (left) and keratometry (right), indicating mild irregular astigmatism.
Case 1. A temporal incision was performed, again increasing predicted postoperative astigmatism by \( C_{0.2} \) to \( C_{0.25} \) D. Intraoperatively, a pseudoaccommodating toric IOL (Trulign) with 21.0 D of power and \( C_{1.25} \) D of cylindrical correction was successfully implanted with complete alignment of the toric axis with the steep meridian at 83 degrees, based on the online Trulign toric calculator.

At 2 weeks post surgery, the patient reported some mild pain, photophobia, and halos around the peripheral vision in the left eye. Ophthalmic examination showed a 1 C cell, a clear cornea, and a lens with a centered IOL (Figure 2). The patient was treated with topical prednisone drops for 2 months. At 3 months post surgery, the pain, photophobia, and cell had resolved. The uncorrected visual acuity was 20/20 at near and distance. Ophthalmic examination showed posterior opacification, which was removed with a Nd:YAG capsulotomy. Overall, the patient was pleased with his vision.

DISCUSSION
We present 2 cases of successful implantation of a pseudoaccommodating toric IOL in patients with previous RKs. After cataract extraction and placement of the pseudoaccommodating toric IOL, visual acuity had improved, the patients were satisfied with their postoperative results, and after a transient 2-month period of iritis in the second patient, both patients denied problems with glare, decreased contrast sensitivity, or difficulties with night driving.

Adapted from the parent Crystalens, the Trulign pseudoaccommodating toric IOL has a 5.0 mm optic body with a toric component and 4 flexible, hinged haptics. Relying on contraction of the ciliary muscles on the retained lens capsule, it provides approximately 1.5 D of accommodation. In preclinical testing, eyes implanted with the pseudoaccommodating toric IOL had an 85.8% reduction in cylinder, with 95.5% having less than \( C_{1.00} \) D of postoperative cylinder at 3 months.11 Compared with spherical controls, the eyes implanted with the pseudoaccommodating toric IOL had significantly better CDVA (20/25 versus 20/32, \( P = .007 \)). The Trulign IOL was approved by the U.S. Food and Drug Administration in May 2013.

Besides placement of a pseudoaccommodating toric IOL, we considered 2 other approaches to correcting the patient’s cataract and astigmatism while providing the possibility of a spectacle-free outcome. First, comparable results have been achieved with a nontoric multifocal IOL with limbal relaxing incisions to correct the astigmatism. Of 42 eyes treated with a multifocal IOL and limbal relaxing incisions, 32 (76%) achieved a UDVA of 20/25 or better.12 This approach might be preferred if there is concern for rotation of the toric IOL in the lens capsule because every 3 degrees of misalignment results in a 10% loss of the astigmatic correction.13 Second, LASIK has been used to correct

| Table 1. Case 2, left eye. Equivalent K readings (D) calculated on rings centered on pupil center. |
|---------------------------------------------|
| Measurement | 1.0 | 2.0 | 3.0 | 4.0 | 4.5 | 5.0 | 6.0 | 7.0 |
| EKR          |     |     |     |     |     |     |     |     |
| K1           | 40.4 (27°) | 40.8 (173°) | 40.9 (151°) | 41.0 (152°) | 41.1 (153°) | 41.2 (154°) | 41.5 (155°) | 42.0 (157°) |
| K2           | 40.7 (117°) | 41.2 (83°) | 41.4 (61°) | 41.6 (62°) | 41.8 (63°) | 41.9 (64°) | 42.3 (65°) | 42.8 (67°) |
| Mean zonal EKR | 40.5 | 41.0 | 41.1 | 41.3 | 41.4 | 41.6 | 41.9 | 42.4 |
| Zonal SD    | 0.54 | 0.68 | 0.86 | 0.94 | 0.98 | 1.02 | 1.19 | 1.50 |
| Zonal SEM   | 0.012 | 0.007 | 0.006 | 0.005 | 0.004 | 0.004 | 0.005 |
| Zonal samples | 2009 | 8326 | 18 839 | 33 555 | 42 505 | 52 480 | 75 595 | 102 883 |

EKR = Equivalent K readings; K1 = flattest meridian; K2 = steepest meridian; SEM = standard error of the mean Calculations based on Holladay 1. EKR readings for K1 and K2 show the axis in parentheses.

Figure 2. Case 2, left eye. Slitlamp photograph 3 months after implantation of a pseudoaccommodating toric IOL.
astigmatism in patients with previous RK surgery. Although satisfactory refractive results have been achieved, LASIK following RK has led to several postoperative complications, including opening of the RK incisions, noninfectious diffuse lamellar keratitis, epithelial ingrowth, and stromal opacities. Given these complications, we did not believe these 2 patients were LASIK candidates.

Despite the success of our 2 cases, these results should be interpreted cautiously. Compared with monofocal IOLs, multifocal IOLs are significantly more likely to cause glare, reduce contrast sensitivity, and impair night driving. This paired with the increased risk for glare in RK patients could generate an unfavorable synergistic effect. Therefore, we believe the pseudoaccommodating toric IOL is the best option in RK patients with astigmatism who desire distance and near vision postoperatively because unlike refractive and diffractive multifocal IOLs, the accommodating effect of the pseudoaccommodating toric IOL does not redistribute light and has similar rates of glare, contrast sensitivity, and night-driving impairment as monofocal IOLs.

Besides the noted optical advantages, we believe patients previously treated with RK would benefit from a pseudoaccommodating IOL over a monofocal IOL as a way to treat the known side effects of RK. First, hyperopic shift is well documented in post-RK patients. Although there is a natural increase in the prevalence of hyperopia with age, patients with a history of RK have a substantially higher rate of shift toward hyperopia than the general population. During a 10-year follow-up period, a mean change in spherical equivalent of +0.28 D was observed in the general adult population; the largest change was +0.43 D in the fifth to sixth decades of life. Conversely, post-RK patients followed from 6 months to 10 years postoperatively developed a mean of +0.91 D of hyperopia. Moreover, the hyperopic shift in post-RK patients was constant during the follow-up period and not simply due to immediate postoperative changes. These results suggest that RK induces changes in the cornea that result in a long-term hyperopic shift above what is expected in the general population. Besides the long-term changes in refractive error, post-RK patients often experience diurnal vision fluctuations, which can account for nearly a half diop- ter of spherical change between morning and afternoon. The pseudoaccommodating IOL may protect against these challenges by allowing the patient to accommodate through both daily and long-term refractive changes, while also giving a broader functional range of useful vision.

In summary, we believe the implantation of a pseudoaccommodating toric IOL is a safe and efficacious option for patients with a history of RK who require cataract surgery and astigmatic correction and desire spectacle independence. This approach resulted in excellent UDVA and UNVA visual acuity and provided some long-term protection against diurnal variation and hyperopic shift commonly experienced by patients after RK.

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