CONSULTATION SECTION: CATARACT

Radial keratotomy and cataract surgery: A quest for emmetropia

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A 75-year-old man with an ocular history of 8-cut radial keratotomy (RK) in both eyes presented for cataract surgery evaluation. He was previously correctable in spectacles in years prior despite his irregular corneas to 20/25 in the right eye and 20/30 in the left eye. He recently noticed a change in his overall visual function with significant nighttime glare and difficulty reading despite spectacle correction. Of note, he was unable to tolerate contact lenses and was resistant to refitting despite additional encouragement. Cataract surgery was delayed for many years, given he was correctable in spectacles and the concern of uncovering a highly aberrated cornea after removing his cataracts (Figures 1 and 2). Of note, the patient was interested in returning to the spectacle independence he enjoyed in the past.

Ocular examination revealed a corrected distance visual acuity (CDVA) of 20/30 in the right eye and 20/60 in the left eye, with a manifest refraction of +4.50 −0.50 × 177 in the right eye and +5.75 −1.75 × 14 in the left eye. Glare testing was 20/50 in the right eye and 20/100 in the left eye, with retinal acuity meter testing of 20/25 in each eye. Pupils, confrontation visual fields, and intraocular pressures were normal. Pertinent slitlamp examination revealed corneal findings of 8-cut RK with nasal-gaping arcuate incisions in both eyes and lens findings of 2+ nuclear sclerosis with 2+ cortical changes in the right eye and 3+ nuclear sclerosis with 3+ cortical changes in the left eye. Cup-to-disc ratios of the optic nerves measured 0.5 with temporal sloping in the right eye and 0.6 with temporal sloping in the left eye. The dilated fundus examination was unremarkable.

What intraocular lens (IOL) options would you offer this patient and how would you counsel regarding realistic expectations? What additional diagnostic testing would be helpful in your assessment? How would you calculate the IOLs?

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Like many patients who underwent RK in the past, this unfortunate gentleman has developed significant hyperopia and higher-order aberrations (HOAs). That he had acceptable vision with spectacles before his cataracts tells us that he will likely do well if we can achieve his spherocylindrical target. Hyperopes tend to be easy to please. However, because the patient is looking for spectacle independence, the preoperative conversation becomes as important as the surgical approach.

I often say the following to patients while showing them the topography images and a model eye for reference: "This image uses color to show the focusing power of your cornea, which is the front part of your eye. In a normal eye, there's a very uniform color pattern, allowing light to be focused to a sharp image. In your right eye, the focusing power in this blue area close to the center is 36 diopters (D), and less than a millimeter away, it is 44 D. That is a 6-unit shift over 1 mm. Which power shall I use to select your IOL? Of course, you don't know, and neither do I. In fact, our science has no way of predicting exactly which IOL is right for an eye as irregular as yours. And even if we have the 'right' implant power, your eye focuses very irregularly. It is like trying to focus a camera through a broken piece of glass."

Explaining HOAs in a postrefractive eye in this way helps the patient own the uncertainty of their surgery, and it sets the stage for the discussion that complete spectacle independence is probably impossible. It also helps the patient understand the unique value of an advanced technology IOL.

My first choice for this patient would be an IOL that is adjustable after implantation, and the one approved adjustable product in the United States is the light-adjustable lens (LAL, RxSight, Inc.). This IOL can be adjusted by 2 diopter sphere (DS) and a similar amount of cylinder, which produces a very satisfactory result in most post-RK eyes. Patients often experience an extended depth-of-focus (EDOF) effect as well, giving them a range of vision from distance to at least intermediate and often near.

Another appropriate choice could be a small-aperture IOL (IC-8 Apthera, Bausch & Lomb, Inc.). Although the latter lacks tunability, it can reduce the impact of this patient's

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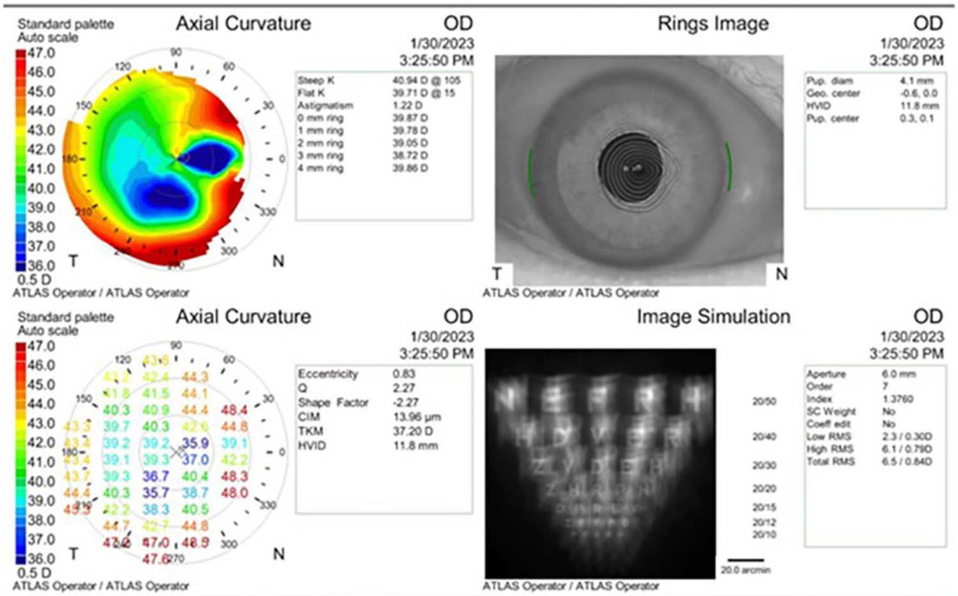

Figure 1. Corneal topography and Placido imaging demonstrating irregular astigmatism in the right eye.

HOAs and be somewhat forgiving of defocus. If the target spherical equivalent was achieved, and the lens was targeted for about −0.75 DS, the patient would likely achieve a reasonable range of vision for distance and even near. In post-RK eyes, the IC-8 IOL can be implanted bilaterally with good results, although patients may notice some degree of visual dimming in low light.

Monovision is an option for post-RK patients, but it is often disappointing because binocularity is usually required to achieve adequate distance vision, and most patients can accept at least occasional use of readers for near vision. Unless they have had success with monovision contact lenses in the past, I usually recommend a target of distance vision in both eyes.

Disclosures: *J.A. Hovanesian is a consultant to Bausch & Lomb, Inc.*

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The deep corneal marks of RK lead to a biomechanically unstable cornea, resulting in irregular astigmatism, diurnal fluctuating vision, glare, and halos. This subset of patients pose challenges at every stage of cataract surgery that ranges from IOL power calculation to intraoperative challenges, unsatisfactory postoperative visual outcomes due to refractive surprise, and associated HOAs.

I would consider implanting a monofocal IOL for this case. Various formulas can be used to calculate the IOL power; however, the accuracy of each formula can vary in eyes with RK. Studies have depicted less than 75% accuracy within ±0.5 D of target refraction, with the most advanced biometry measurement devices and IOL calculation formulas for eyes with previous RK.[1] I would consider choosing the ASCRS IOL calculator with the target refraction power set as −1.0 D. For post-RK eyes, I would also consider calculating the IOL power obtained with Haigis-L, Shammas, and Barrett True-K formulas and then averaging the values.

Another major concern in this case is the associated HOAs. The level of HOAs well tolerated by patients is below 0.33 µm. HOA values around 0.66 µm become more noticeable and are associated with image degradation, and for values above 1.00 µm, patients complain about poor visual quality.[2,3] Higher-order root mean square (RMS) wavefront error roughly doubles for each millimeter of increase in pupil diameter. Studies have demonstrated a nonlinear increase in the higher-order RMS values in symptomatic postrefractive surgery eyes and in normal preoperative eyes with an increase in aperture.[2]

Presuming the refractive error after cataract surgery is zero, the patient still will not be satisfied because of HOAs that lead to distortion of images. The convoluted images in adaptive optics seem to be affected by higher RMS; hence, the visual quality will be affected, although simulated keratometry (K) values are not very high. This patient would benefit from the application of pinhole optics that can be achieved either by performing a pinhole pupilloplasty (PPP) or implanting a pinhole IOL.[4,5] I would consider doing a PPP as I can optimize the pupil size that imparts best visual acuity to the patient (Supplemental Figure 1, available at http://links.lww.com/JRS/A927). During preoperative examination, the patient is made to see the visual chart with the pinhole device that has multiple aperture sizes ranging from 0.5 to 4.0 mm in size with an increment in values of 0.5 mm. The aperture size that imparts best visual acuity to the patient is recorded, and an intraoperative attempt is made to achieve the optimum pinhole size. The reticle placed in the eyepiece of the surgical microscope helps to gauge the size of pinhole intraoperatively. The pinhole optics achieved by performing a PPP procedure compensates for any possibility of residual refractive error and additionally imparts an EDOF that would immensely benefit the patient.

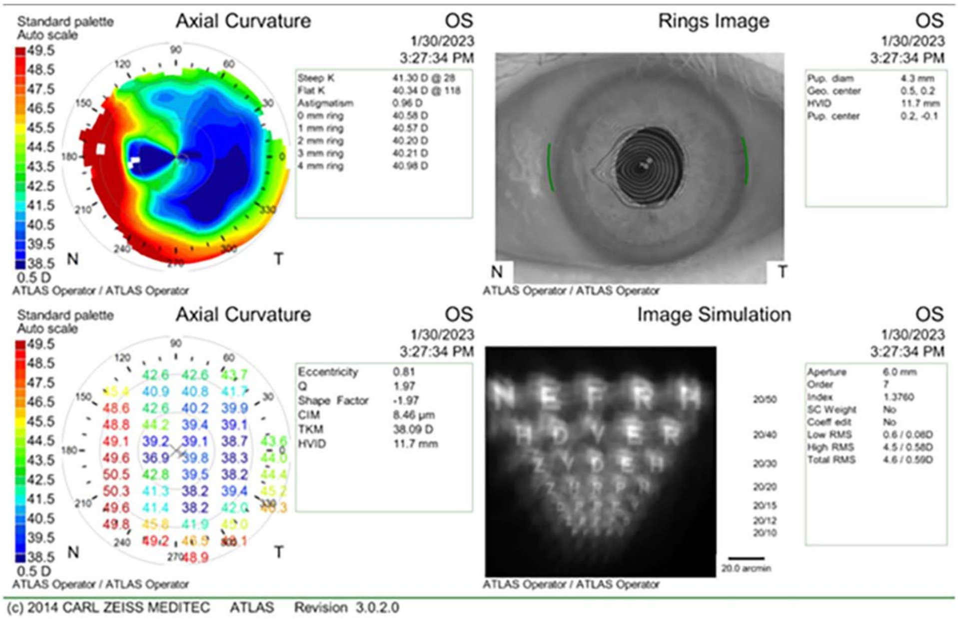

Figure 2. Corneal topography and Placido imaging demonstrating irregular astigmatism in the left eye.

REFERENCES

1. Wang L, Koch DD. Intraocular lens power calculations in eyes with previous corneal refractive surgery: review and expert opinion. Ophthalmology 2021; 128:e121–e131
2. McCormick GJ, Porter J, Cox IG, MacRae S. Higher-order aberrations in eyes with irregular corneas after laser refractive surgery. Ophthalmology 2005;112:1699–1709
3. Salmon TO, van de Pol C. Normal-eye Zernike coefficients and root-mean-square wavefront errors. J Cataract Refract Surg 2006;32:2064–2074
4. Narang P, Holladay J, Agarwal A, Gracy H, Kumar DA, Sivagnanam S. Pinhole pupilloplasty for higher order aberrations: assessment of visual quality and depth of focus. J Refract Surg 2020;36:812–819
5. Narang P, Agarwal A, Kumar DA, Sivagnanam S, Agarwal A. Pinhole pupilloplasty after previous radial keratotomy. J Cataract Refract Surg 2021;47:955–959

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The surgical tools we typically consider in 8-cut RK patients coming to cataract surgery are topography-guided photorefractive keratectomy (TG-PRK), toric IOLs, and pinhole IOLs. TG-PRK in our center is performed on the Schwind Amaris 1050 Hz system. Topographic data are collected from the Sirius (combination Scheimpflug/Placido) topographer and, where mapping is possible, exported to the custom ablation manager software for analysis and planning. I would consider TG-PRK in cases with poor spectacle-corrected vision (below 20/30), adequate corneal thickness (planned residual stromal bed above 300 μm), irregular astigmatism above an amount correctable with pinhole optics, small or decentered optical zones, and cases in which subepithelial haze has formed in the central flattened zone that could be removed with the excimer laser. Our results of TG-PRK in 123 RK eyes were recently analyzed with an improvement in CDVA of 0.16 ± 0.01 logMAR at baseline to 0.11 ± 0.01 logMAR at 12-month follow-up (P = .003) (Supplemental Figure 2, available at http://links.lww.com/JRS/A928) (Moloney, Lin, Pacific Laser Eye Centre, submitted for publication).

Pinhole optics is typically considered for the more irregular cornea, in this case the right. The pupil size is adequate (I seek <5.0 mm mesopic size to avoid excessive polychoric effects). I would exercise caution if there were any history of diabetes or other retinal vascular disease requiring possible laser and obtain a screening optical coherence tomography of the macula. I would consider a pilocarpine trial in this eye preoperatively, with the patient instructed to apply a dose in the late evening to trial the effect of reduced scotopic sensitivity. I would use intraoperative digital image guidance (in our center, VERION [Alcon Laboratories, Inc.]) to center the IOL on the pupil rather than the visual axis, again to minimize polycoria. A 2.75 to 3.0 mm wound is recommended to avoid compression and ovalization of the pinhole inlay. I would place this incision on the steepest axis if possible. Sometimes, the spacing of radial incisions or the ergonomics of surgery will not allow this; in the case provided, I would consider a superior wound in the right eye but not consider this essential. At the time of surgery, I would polish the anterior lens epithelial cells, aiming to minimize bag fibrosis and late alteration of the lens position.

The left eye could receive a standard toric IOL given the bowtie pattern and a clear history of good spectacle-corrected vision. I would likely select an aspheric platform with negative spherical aberration anticipating positive shift in this cornea. I would use the Barrett True-K formula and central K values obtained from the 2 mm ring in the eye to receive pinhole optics and 3 mm ring in the standard toric eye (in our practice, I consider Holladay equivalent K readings from these zones on Pentacam).[1] I would target low myopia.

Alternatively, either cornea could receive TG-PRK to regularize the shape, followed by a period of washout, remeasurement, and possible monofocal IOL placement. With regard to the left cornea, although the bowtie is regular at 1 mm, there is skew emerging at wider diameters. If the patient describes ghosting even when well corrected in spectacles, this plan could be offered. A myopic target is planned postlaser if progressive hyperopia is noted historically.

REFERENCES

1. Li M, Wang JD, Zhang JS, Mao YY, Cao K, Wan XH. Comparison of the accuracy of three intraocular lens power calculation formulas in cataract patients with prior radial keratotomy. Eur J Med Res. 2023;28(1):20.

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This patient, like many patients in the modern era of refractive cataract surgery, is expecting a good outcome and some degree of spectacle independence. The most important piece of the preoperative evaluation for all patients is discussing expectations and educating them on the journey we will traverse together over the next several months to help them achieve their desired outcome.

When approaching a case like this, we aim to evaluate all potential sources of blur. A gas-permeable lens overrefraction (GPOR) is an underused yet excellent tool to evaluate how the anterior cornea is contributing to visual degradation. In this case, if the patient's CDVA improved to 20/25 (right eye) and 20/50 (left eye), then the anterior cornea is responsible for 1 line of blur. If the patient's vision failed to improve with GPOR, we know that the cornea is not largely contributing to the patient's blurred vision. This is an important step for informing our surgical plan and discussing IOL options with the patient.

In this case, it appears that the corneal irregularity is more pronounced in the left eye, and if the patient achieved a notable improvement in CDVA with GPOR, we would implant the small-aperture IOL (Apthera), the only IOL that can compensate for blurred vision originating from the cornea. We would implant this IOL in the left eye first and gauge how the left eye responded before proceeding with the right eye. If the patient was thrilled with their distance and near vision and had no issues related to contrast sensitivity, then we would consider bilateral implantation of the small-aperture IOL, which has been previously described with favorable outcomes.[1] If the patient had issues with dimming of vision or contrast sensitivity troubles, we would recommend an LAL in the right eye. In a patient with prior RK, we know that the cornea is difficult to adjust postoperatively, and the LAL is an excellent option in this patient population owing to its postoperative adjustability. Furthermore, in this specific case, the excellent quality of vision offered by the LAL would nicely complement the range of vision offered by the small-aperture IOL in the left eye.

For additional testing, beyond corneal topography and biometry, another valuable tool that would be great in this case is the ray-tracing aberrometer (iTrace, Tracey Technologies), which can help us better understand the degree of irregular astigmatism present in the cornea. A similar option for evaluating the degree of corneal irregularity is the OPD-Scan III (Nidek, Inc.), a multifunctional device that provides wavefront aberrometry. Both of these devices are used in our practice.

For IOL power calculation, we recommend using the ASCRS online calculator, a web-based tool that allows for simultaneous calculation of multiple formulas specifically for RK. Included among the formulas in the calculator is the Barrett True-K formula, which is built into most biometers and has been shown to offer favorable results for post-RK patients according to multiple recent studies.[2–4]

REFERENCES

1. Ang RE. Visual performance of a small-aperture intraocular lens: first comparison of results after contralateral and bilateral implantation. J Refract Surg 2020;36:12–19
2. Curado SX, Hida WT, Vilar CMC, Ordones VL, Chaves MAP, Tzelikis PF. Intraoperative aberrometry versus preoperative biometry for IOL power selection after radial keratotomy: a prospective study. J Refract Surg 2019;35:656–661
3. eite de Pinho Tavares R, de Almeida Ferreira G, Ghanem VC, Ghanem RC. IOL power calculation after radial keratotomy using the Haigis and Barrett True-K formulas. J Refract Surg 2020;36:832–837
4. Turnbull AMJ, Crawford GJ, Barrett GD. Methods for intraocular lens power calculation in cataract surgery after radial keratotomy. Ophthalmology 2020;127:45–51

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In the case presented, the patient is status post–8-cut RK with nasal astigmatic keratotomy and visually significant cataracts bilaterally. Unsurprisingly, the prior RK has led to a continual progressive hyperopia with irregular corneal astigmatism. Past medical records indicate that he could achieve a best CDVA of 20/25 and 20/30, respectively, albeit the corneal image qualities produced are suboptimal because of the irregular astigmatism. The axial maps on Placido topography demonstrate relatively orthogonal astigmatism within the central 2 mm zone, but there are significant flat zones (ie, right cornea over the 0-degree and 270-degree mid-periphery), which overlie RK incisions and irregularities within them (ie, incision gape). Ultimately, this patient wants visual freedom with his cataract surgery. A few years ago, this would have been virtually impossible, but we have more options for this most challenging bucket of patients: post-RK with irregular astigmatism.

Although eye dominance was not discussed, given that the CDVA was worse in the left eye even before the cataract formation and still has the worse vision, this would be the eye to start with. The Apthera small-aperture IOL would provide the best potential uncorrected option for both uncorrected distances through near vision, albeit as an off-label indication (Supplemental Figure 3, available at http://links.lww.com/JRS/A929). The Apthera IOL has a paracentral FilterRing that creates a 1.36 mm diameter central aperture and functionally behaves like a 1.6 mm pupil. This lens uses pinhole optics, enabling the central rays to enter the eye while blocking the diverging rays that are entering because of the aberrated cornea.[1] This not only improves the quality of vision in patients with irregular corneas but also increases the depth of focus and can mitigate the effects of up to 1.5 diopter cylinder (DC).[2] Thus, the patient's ∼1.0 D of irregular against-the-rule cylinder would be neutralized by the small-aperture optics, while providing a visual quality that would be superior to a monofocal toric IOL. However, in addition to inducing irregular astigmatism, RK also flattens the anterior and posterior cornea, reduces the central optical zone, and leads to an overestimation of corneal power and an underestimation of the effective lens position. This decreases the recommended IOL power when traditional formulas are used, which can cause a hyperopic result. The Barrett True-K formula, RK eye, should be used with a target between −0.75 D and −1.00 D. Because this lens gives up to 3 D of functional range of vision, by targeting low myopia, the patient will be able to achieve good near vision while maintaining his distance visual acuity. The postoperative −0.75 D offset with this IOL will likely result in uncorrected distance visual acuity (UDVA) ∼20/25 and will provide this eye a warranty on the longevity of its UDVA. The left eye will trend hyperopic over time. Although the near vision will worsen, the UDVA will remain stable for many years because there is the −0.75 D of a reserve, providing a new benefit no prior IOL could for RK patients.

After 6 to 8 weeks of healing, the first eye refraction will be stabilized and may be able to help with nuancing the second IOL calculation. A few IOL options can be used for the second eye (left): a zero sphericity monofocal IOL (enVista, Bausch & Lomb, Inc.), an LAL, or an Apthera IOL, dependent on the patient's satisfaction with the Apthera IOL in the first eye, particularly to ensure that dimness or contrast sensitivity in low lighting conditions is not an issue. Of note, although the on-label indication for the Apthera IOL is for monocular implantation in the nondominant eye with a monofocal IOL in the dominant eye, clinicians have reported successful bilateral Apthera IOL implantation for cataract surgery patients with irregular corneas.[3,4] This would provide the best option for the highest quality of uncorrected vision, not only for the range of vision but even for the distance. The next best option for accuracy would be the LAL, which can treat up to ±2.00 DS and −0.5 to −3.0 DC, and ensure a high degree of fine tuning postoperatively. The main limitations would be the suboptimal quality of vision because of the irregular cornea, and that the reduction of spectacle dependence for distance vision would be very temporary because of the progressive hyperopia.

REFERENCES

1. Lay M, Wickware E, Rosenfield M. Visual acuity and contrast sensitivity. In: Rosenfield M, Logan N, Edwards K, eds. Optometry: Science, Techniques and Clinical Management, 2nd ed. Oxford, UK: Butterworth-Heinemann; 2009:178–179
2. Read L. The IC-8 IOL: Big Advantages Through Small Apertures. The Ophthalmologist. September 2019. Available at: https://theophthalmologist.com/subspecialties/the-ic-8-iol-big-advantages-through-small-apertures. Accessed June 30, 2023
3. Ang RW. Visual performance of a small-aperture intraocular lens: first comparison of results after contralateral and bilateral implantation. J Refract Surg 2020;36:12–19
4. Franco F, Branchetti M, Vicchio L, Serino F, Piergentili M, Spagnuolo V, Santoro F, Virgili G, Giansanti F. Implantation of a small aperture intraocular lens in eyes with irregular corneas and higher order aberrations. J Ophthalmic Vis Res 2022;17:317–323

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Patients with a history of RK are a challenge for cataract surgeons because the corneal shape typically will not remain stable over time. As well, many RK patients have some degree of irregular astigmatism, which is present in both eyes of this patient. The challenges in this case boil down to these 3 issues: (1) Even with advanced IOL formulas for RK patients, it is difficult to end up on the target.[1] (2) Even if we end up on the target, typically there will be a hyperopic shift over the following years. This patient likely had RK surgery 30 years ago and is now quite hyperopic because of the gradual flattening of the cornea over time. (3) Other than the Apthera IOL, no IOL can compensate for irregular astigmatism, so it is unlikely that the patient will end up with 20/20 UDVA. The central cornea within the visual axis is quite irregular. Even if TG-PRK could reshape the cornea to reduce the irregular astigmatism, we can expect that some degree of irregular astigmatism will recur over time, as the corneas of patients with RK do not typically remain stable.

Because the history confirms visually significant cataracts, cataract surgery is indicated. However, the patient will need to be informed that spectacle independence cannot be promised. The patient can decide between the LAL, the Apthera small-aperture IOL, a toric IOL, or a monofocal IOL. The advantages of the LAL include the ability to adjust both the sphere and cylinder once the corneal shape has stabilized after cataract surgery. This allows for the patient to end up with a low refractive error and thus the best possible UDVA compared with a toric or monofocal IOL. It is important to plan for the cornea to flatten over time, so ending up with mild myopia may allow RK patients to maintain better UDVA for a longer period as compared to ending up precisely at Plano. The main disadvantage is that the LAL will require multiple visits for light treatments.

The small-aperture IOL has the potential to provide better quality of vision in eyes with irregular astigmatism compared with a toric or monofocal IOL. Typically, surgeons will attempt to end up with a refractive error of −0.75 to −1.00 to allow for the greatest range of vision with the Apthera IOL. Theoretically, over time, the Apthera IOL may allow RK patients to maintain good UDVA because it has a wider depth of field compared with single-focus IOLs. One main challenge with monofocal, toric, and Apthera IOLs is ending up on the target, as current formulas for RK patients still result in wide SDs of visual outcomes.[1] In my practice, we use the ASCRS formula for RK patients and the Barrett True-K formula (no history) for planning our IOL power selection. Turnbull et al. found that with the Barrett True-K formula (no history), only 69.2% of eyes were within ±0.5 D of the target.[1]

While currently I have been using the LAL for RK patients with a refractive endpoint of −0.50 DS, further experience with the Apthera IOL may potentially switch my preference.

REFERENCE

1. Turnbull AMJ, Crawford GJ, Barrett GD. Methods for intraocular lens power calculation in cataract surgery after radial keratotomy. Ophthalmology 2020; 127:45–51

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Several details about both eyes make me think of implanting a small-aperture IOL. First, corneal aberrometry and topography expose a bilateral asymmetric profile with HOAs over 0.750 μm in the right eye and 0.550 μm in the left eye. We have an important indicator before developing cataracts in both eyes. The CDVA was 20/25 (right eye) and 20/30 (left eye), so we can infer that despite that the quality of vision might not have been great, the right eye could perform reasonably.

My first choice of IOL would be an Apthera for the left eye because we want to neutralize corneal HOAs. Specifically, it is clear that high comatic aberrations exist. Implanting an Apthera IOL could improve optical quality by neutralizing the effects of HOAs and RK incisions and, simultaneously, extend the depth of focus for daily activities.[1,2] After performing the left eye, I would analyze with the patient the suitability to do the same in the right eye. If the patient is not satisfied with the result of the procedure, I would choose a monofocal IOL or, theoretically, an LAL. I use the word *theoretically* because I do not have experience with the LAL but appreciate the technology's ability to overcome difficulties in IOL power calculation through postoperative adjustment.[3] Thanks to advances in IOL formulas for post-RK eyes, I no longer perform GPOR before or after cataract surgery on patients who have a history of RK.

My decision to move from a monofocal to an Apthera IOL was based on aberrometry measurements. My cutoff for the transition is around 0.5 μm of corneal HOAs in healthy eyes. My refractive target is −0.75 D in a nondominant eye. If both of a patient's eyes have a high magnitude of corneal HOAs, like this specific case, bilateral implantation of an Apthera IOL may be considered.[4] Finally, I think it is important to highlight that the small-aperture Apthera IOL does not affect posterior segment visualization, so it will not interfere to follow the evolution of the patient's cup-to-disc ratio.[5]

REFERENCES

1. Shajari M, Mackert MJ, Langer J, Kreutzer T, Wolf A, Kohnen T, Priglinger S, Mayer WJ. Safety and efficacy of a small-aperture capsular bag-fixated intraocular lens in eyes with severe corneal irregularities. J Cataract Refract Surg 2020;46:188–192
2. Hooshmand J, Allen P, Huynh T, Chan C, Singh R, Moshegov C, Agarwal S, Thornell E, Vote BJ. Small aperture IC-8 intraocular lens in cataract patients: achieving extended depth of focus through small aperture optics. Eye (Lond) 2019;33:1096–1103

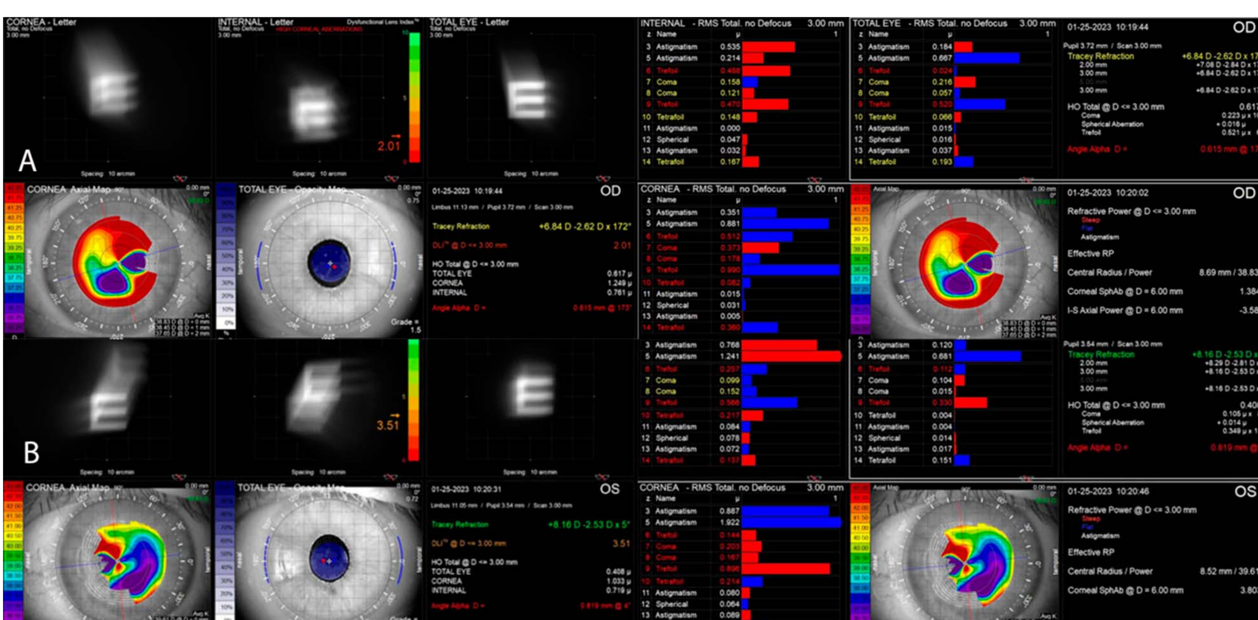

Figure 3. Ray-racing aberrometry demonstrating the HOAs in the cornea vs internal in the right (*A*) and left (*B*) eyes. Note: there is some cancelling effect of the corneal HOAs by the internal presumed cataract HOAs.

3. Schojai M, Schultz T, Schulze K, Hengerer FH, Dick HB. Long-term follow-up and clinical evaluation of the light-adjustable intraocular lens implanted after cataract removal: 7-year results. J Cataract Refract Surg 2020;46:8–13
4. Dick HB, Elling M, Schultz T. Binocular and monocular implantation of small-aperture intraocular lenses in cataract surgery. J Refract Surg 2018;34:629–631
5. Srinivasan S, Khoo LW, Koshy Z. Posterior segment visualization in eyes with small-aperture intraocular lens. J Refract Surg 2019;35:538–542

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EDITOR'S COMMENTS

The greatest challenge in treating patients with previous corneal refractive surgery is expectations inevitably exceed what current technology can deliver. RK incisions routinely cause progressive flattening and hyperopia, fluctuating vision, and irregular astigmatism. Fortunately, possibilities of TG-PRK and small-aperture technology may allow us to attempt to meet the optical goals of these complex patients.

There are 3 steps to consider when approaching patients with complex corneas needing cataract surgery: (1) surgeon-driven consenting process including review of and topography, tomography and aberrometry; (2) scleral contact lens over-refraction to distinguish the visual disturbance originating from the cornea vs the lens; and (3) explanation of the potential for IOL exchange postoperatively due to IOL calculation challenges and inherent fluctuating corneal curvature. Ideally, biometry is measured during the time the patient performs their most intensive visual tasks. Measurements in the am and pm or midday are helpful. This compulsive measurement strategy will give the surgeon an idea of the true fluctuation in vision throughout the day. Finally, consent forms should explicitly state and be initialed by the patient that their best vision will always be with a scleral contact irrespective of technology as the patient may have unrealistic expectations.

The iTrace ray-tracing aberrometry for this patient revealed a cancelling effect of his corneal HOAs with his natural cataractous lens (Figure 3). For that reason, cataract surgery was delayed as long as possible to avoid uncovering his significant corneal HOAs after removing his lens. A scleral contact lens over-refraction was later performed preoperatively to distinguish how much vision loss was associated with the irregular astigmatism vs the cataract. When it was clear that the cataract was impacting his vision more than the corneal aberrations, we decided to proceed with cataract surgery. The iTrace ray tracing also has a small-aperture (IC-8) simulator at the 1 mm and 2 mm zones that allows for a simulation of the visual quality at 1.36 mm (effective 1.6 mm) addressed by the small-aperture technology (Figure 4). A pilocarpine 1% test is also helpful to assess the potential and sensitivity to dimming. Other monofocal IOL options including the LAL for postoperative adjustability were considered; however, LAL technology does not correct for highly irregular Placido imaging, over 3D of cylinder, and extensive HOAs. Therefore, this technology was ruled out as a first option.

IOL calculations in this patient population are incredibly difficult to master. The review of literature estimates +/- 0.50 D in 42% to 76.6% of patients.[1–3] Many surgeons will aim for −0.75 to −1.00 for all RK calculations in general to adjust for morning flattening and hyperopic shift over time. The most current approach includes the ASCRS IOL calculator RK with the average 1 mm to 4 mm corneal readings,

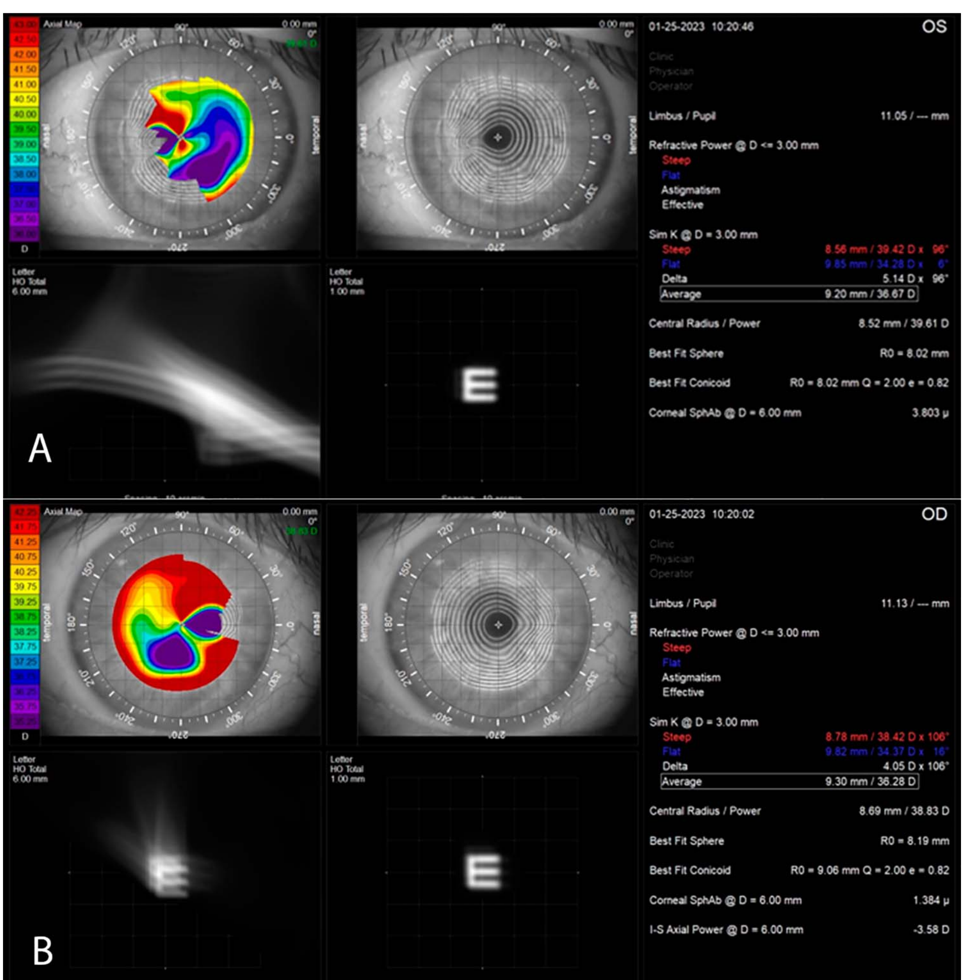

Figure 4. Simulation of HOA correction for right (*A*) and left (*B*) eyes.

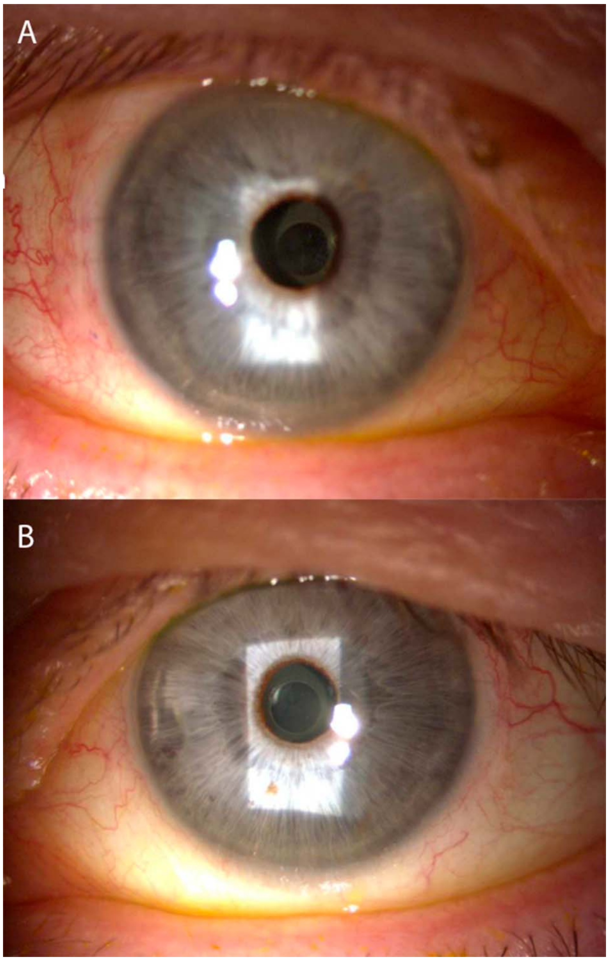

Figure 5. Postoperative images of the Apthera/IC-8 IOL in the right (*A*) and left (*B*) eyes. Note the centration of the small-aperture IOL in the visual and pupillary axis.

Pentacam PWR_SF_Pupil_4.0 mm Zone or EKR65, Barrett True-K RK (history and partial history), Double-K Holladay 1 for RK and Haigis (with or without −0.75 D offset).[1–3] Other nonpublished nomograms prior to smaller optical zone advanced keratometry measurements attempted to adjust myopia based on RK cuts, depth, length to the limbus, and optical zone (ie, 4-cut: calc −0.50 −1.00 D, 8-cut: calc −1.0 −1.50 D, 12-cut: calc −1.50 −2.00 D, 16-cut calc: −2.00 −2.50 D) (Radial keratotomy "myopic aim" nomogram prior to advanced keratometry technology. Personal correspondence from Samuel Masket, MD, 2008).

This patient was eagerly awaiting the small-aperture Apthera/IC-8 technology. The Apthera IOL pinhole technology has an IOL inlay with a 1.36 mm pinhole aperture. We learned from the U.S. clinical trials and our colleagues outside the U.S. that for best depth-of-focus results the IOL should be aimed −0.75 D and placed in the nondominant eye. Dilation should be at least 6.5 to 7.0 mm to for visualization around the inlay in the event a Nd:YAG laser posterior capsulotomy is needed. Last, the recommended incision size is 3.0-3.2 mm to avoid ovalization of the inlay during insertion. This technology is only on-label in the U.S. for normal/regular corneas and monocular implantation. The patient was counseled at length of the off-label use in an RK eye and that bilateral use was not studied in the U.S. clinical trials but has been used outside the U.S.[4,5] The patient wanted to start with the left eye, as this was his worse-seeing eye, and dominant eye. I explained at length that he may have dimming inherent to the small-aperture technology.

The ASCRS IOL Calculator for RK and Barrett True-K RK (no history) were used at a target refraction of −1.00 D. This myopic aim would theoretically help with hyperopic shift over time and depth of focus with the small-aperture technology. For monofocal IOLs, Barrett True-K (history and partial history) with RK history of refraction prior to cataract yielded the best predicted results with 75% to 76.6% within ±0.50 according to the literature. However, Barrett True-K (no history) and Haigis performed better than most formulae with 69.2% within ±0.5 D.[2]

Cataract surgery was performed in the left eye with a 3.2 mm sclera tunnel incision, as a clear corneal incision could have stretched or intersected with the RK incisions. In addition, the urge to push the IOL through a smaller corneal incision should be resisted as this may cause ovalization of the inlay. Finally, all attempts were made to center the capsulorhexis on the visual axis to allow for the best alignment of the central aperture of the IOL.

Immediately postoperatively, the patient was 20/30 J2 uncorrected and felt he could rely on his left eye for all visual functions. We waited 6 weeks for stabilization of the cornea prior to consideration for surgery in the other eye. Stabilization in RK eyes is typically achieved when the postoperative corneal topography matches the preoperative corneal topography and the refraction is reliable. The patient subsequently had surgery in the right eye due to anisometropia and requested the same technology in his right eye with a minimonovision strategy and a target refraction of −1.50.

Postoperatively, UDVA was 20/25 in the right eye and 20/25-2 in the left eye. UNVA was J1 in the right eye and J3 in the left eye. Postoperative refraction of right and left eyes at 3 months was −0.50 −2.50 × 5 (SE −1.75) and +1.25 −2.50 × 24 (SE plano), respectively. Based on the corneal topography, the residual cylinder was expected as the Apthera/IC-8 IOL only corrects 1.50 D of cylinder reliably and the average Sim K and refractive measurements were approximately 4.0 D in the right eye and 5.0 D in the left eye on iTrace. Fortunately, the IOLs were well centered within the undilated pupil and positioned on the visual axis (Figure 5).

This case demonstrates an off-label bilateral use of the Apthera/IC-8/IOLs in a contact lens intolerant patient with irregular astigmatism and HOAs caused by RK. Although the patient continues to notice expected fluctuating vision throughout the day, he denies dimming as a significant issue and is now fully functional without spectacle correction for 80% of his visual needs.

REFERENCES

1. Leite de Pinho Tavares R, de Almeida Ferreira G, Ghanem VC, Ghanem RC. IOL power calculation after radial keratotomy using the Haigis and Barrett True-K formulas. J Refract Surg 2020;36:832–837
2. Turnbull AMJ, Crawford GJ, Barrett GD. Methods for intraocular lens power calculation in cataract surgery after radial keratotomy. Ophthalmology 2020; 127:45–51
3. Wang L, Koch DD. Intraocular lens power calculations in eyes with previous corneal refractive surgery: review and expert opinion. Ophthalmology 2021; 128:e121–e131
4. Ang RW. Visual performance of a small-aperture intraocular lens: first comparison of results after contralateral and bilateral implantation. J Refract Surg 2020;36:12–19
5. Franco F, Branchetti M, Vicchio L, Serino F, Piergentili M, Spagnuolo V, Santoro F, Virgili G, Giansanti F. Implantation of a small aperture intraocular lens in eyes with irregular corneas and higher order aberrations. J Ophthalmic Vis Res 2022;17:317–323