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ORIGINAL RESEARCH

Implantation of Small-Aperture IOL in Patients with Cataract and Preexisting Corneal Comorbidities

Chameen Samarawickrama[1–3], Muhammad Khan[1,2]

[1]Translational Ocular Research and Immunology Consortium (TORIC), Westmead Institute of Medical Research, Sydney, NSW, Australia; [2]Department of Ophthalmology, University of Sydney, Sydney, NSW, Australia; [3]Department of Ophthalmology, Westmead Hospital, Sydney, NSW, Australia

Correspondence: Chameen Samarawickrama, Department of Ophthalmology, University of Sydney, Sydney, NSW, Australia, Email chameen.sams@sydney.edu.au

Purpose: To evaluate the outcomes of small-aperture IC-8 IOL implanted in patients with significant preexisting corneal comorbidities.

Patients and Methods: This retrospective chart review included case records of 45 consecutive patients (67 eyes) with preexisting corneal irregularities who underwent cataract surgery and implantation of a small-aperture IC-8 IOL. Outcome measures included uncorrected distance visual acuity (UDVA), spherical equivalent refraction (SER), and spherical equivalent refractive prediction accuracy of five IOL formulas (Barrett Universal II, Emmetropia Verifying Optical (EVO), Kane, Hill-Radial Basis Function (Hill RBF), prediction enhanced by artificial intelligence and output linearization by Guillaume Debellemanière, Damien Gatinel, and Alain Saad (Pearl DGS) using biometry measurements from IOLMaster 700 and Pentacam.

Results: Of the 67 eyes, 56 underwent IC-8 IOL implantation only, while 11 required piggyback IOL as a secondary procedure. Mean postoperative UDVA in IC-8 only eyes was 0.24 ± 0.30 logMAR, with 61.1% (33/54) achieving UDVA of 6/9 or better. Mean postoperative SER in these eyes was −0.17 ± 1.27 D, with 54.2% (26/48) and 81.3% (39/48) of eyes achieving postoperative SER within 0.50 and 1.00 D, respectively. Refractive prediction accuracy of 5 IOL formulas was similar, with no significant differences in the precision and accuracy of IOL formulas and biometry measurements evaluated. Eyes that underwent piggyback implantation showed a UDVA of 0.42 ± 0.39 logMAR, with 36.4% (4/11) of eyes achieving UDVA of 6/9 or better postoperatively.

Conclusion: IC-8 IOL implantation in patients with irregular corneas was safe and effective, yielding good visual and refractive outcomes in this niche population, who typically have suboptimal outcomes. The authors suggest updating the clinical guidelines for the use of IC-8 to aid IOL selection in this challenging patient population.

Keywords: small-aperture IC-8 IOL, corneal comorbidities, cataract surgery, refractive prediction accuracy

Introduction

Cataract surgery in complex corneas is challenging. Diseases such as keratoconus, previous penetrating keratoplasties, radial keratectomies, and corneal scarring induce aberrations in the cornea or alter the anterior-to-posterior corneal ratio, which decreases the accuracy of biometry measurements and intraocular lens (IOL) power calculations.[1–4] Further, corneal irregularities make the estimation of effective lens position less certain. Ultimately, this variability results in an increased risk of refractive surprises.[5] Adding to the challenge is the increased presence of higher-order aberrations (HOAs) in complex corneas, which degrade the visual acuity and quality of vision.[6–8] Standard monofocal IOLs do not reduce HOAs,[9] which means that even if emmetropia is achieved, patients continue to complain of sub-optimal vision post-surgery.

In optics, it is known that the use of a pinhole improves vision by blocking peripheral light rays that may induce aberrations within the eye, allowing only the paraxial light rays to enter, effectively reducing the blur circle on the

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retina.[10,11] Clinically, it is common for patients with abnormal corneas to notice a significant improvement in their vision with a pinhole. It is hypothesized that the use of IOL with an inbuilt pinhole would serve the same purpose and improve the vision in this complex cohort of patients.

The IC-8 pinhole IOL (Apthera, Bausch & Lomb, Inc., Bridgewater, NJ, USA) is a small-aperture IOL originally designed to enhance the range of vision by using pinhole optics to collimate light rays to reach the retina through the central aperture. It has a 1.36 mm central aperture surrounded by a 3.23 mm black circular mask composed of polyvinylidene difluoride and carbon nanoparticles, effectively creating a pinhole within a hydrophobic acrylic IOL.

The optics of a small-aperture IOL has the potential to minimize corneal HOAs and it is hypothesized that the use of small-aperture IOL in eyes with complex corneas, such as keratoconus, pellucid marginal degeneration, etc., may result in favorable visual outcomes. As such, this study aimed to evaluate the visual and refractive outcomes following cataract surgery with implantation of the IC-8 IOL in patients with preexisting corneal comorbidities and determine which biometry measurements and IOL power formulas are most accurate for this cohort with complex corneas.

Materials and Methods

This study adhered to the principles of the Declaration of Helsinki and was approved by the Western Sydney Local Health District Human Research Ethics Committee (2502–05 QA), with a waiver of consent, as data were collected during routine clinical practice and analyzed after anonymization. Case records of forty-five sequential patients (67 eyes) with cataract and coexisting corneal irregularities who underwent IC-8 IOL implantation at Lakeview Hospital, Sydney, Australia, were included in this retrospective chart review.

Inclusion criteria were patients with cataract who also had any preexisting corneal comorbidity that induced irregular astigmatism, such as corneal ectasias (eg., keratoconus, pellucid marginal degeneration) but that were stable for over the past 2 years, angle kappa and alpha < 0.5 mm, corneal scarring (eg., due to trauma, Herpes Simplex keratitis) peripheral from the visual axis that in the investigator's opinion may be amenable to correction with a small aperture IOL, and previous corneal surgery (eg., previous radial keratotomy, previous penetrating keratoplasties). Pinhole acuity assessment after best refractive correction indicated the potential to improve postoperative acuity with a small-aperture IOL. Pharmacologically dilated pupil size must be ≥ 7 mm. All patients had at least a 1-month follow-up.

Biometric measurements (axial length, anterior chamber depth, lens thickness, and white-to-white) were obtained from the swept source optical coherence tomography (SS-OCT) -based biometer (IOLMaster 700, Carl Zeiss Meditec, Jena, Germany) and Scheimpflug corneal tomographer (Pentacam, Oculus Optikgeräte GmbH, Wetzlar, Germany) using the standard settings. The prediction accuracy of five different IOL power calculation formulas (Hill-Radial Basis Function (Hill RBF), Kane, prediction enhanced by artificial intelligence and output linearization by Guillaume Debellemanière, Damien Gatinel, and Alain Saad (Pearl DGS), Barrett Universal II (BUII), and Emmetropia Verifying Optical (EVO) formulas) in predicting the required IOL power was assessed using the standard keratometry (K) and total keratometry (TK) measurements from the IOLMaster 700 and the SimK readings/total corneal refractive power (TCRP) measurements from Pentacam.

Contact lens wearers were instructed to cease rigid gas-permeable/scleral contact lens use at least 4 weeks prior to preoperative biometry measurements. Patients were required to demonstrate stable keratometry readings, defined as 3 similar K readings at least 2 weeks apart, before preoperative biometry measurements were utilized.

All procedures were conducted by the same surgeon (CS) in the same facility following standard pre-surgical assessment, counselling/consenting, and postoperative care. Surgery was performed using standard phacoemulsification techniques under local anesthesia through a 2.4 mm temporal corneal incision that was enlarged to 3.2 mm to accommodate the IC-8 IOL. Postoperatively, patients were prescribed chloramphenicol eye drops four times a day (QID) for 3 days and dexamethasone eye drops QID, which tapered by 1 drop each week for a total of 4 weeks.

IOL selection for the fellow eye, if required, was based on the patient's preference and the surgeon's assessment. If the cornea of the fellow eye was normal, a standard monofocal IOL was implanted. If, however, the fellow eye had an irregular cornea and the patient was satisfied with their first operation and interested in undergoing IC-8 implantation, they were counseled and consented prior to IC-8 IOL implantation. The IC-8 is only available in spherical powers, but its optical design effectively compensates for approximately 1.5 diopters (D) of astigmatism.[12,13] For eyes with low astigmatism, the refractive target was emmetropia, as it was thought that the IC-8 would adequately neutralize the astigmatism. For eyes with moderate to severe astigmatism (N = 11), where patients were not suitable for contact lens use and preferred increased glasses independence, a secondary piggyback IOL (Sulcoflex IOL; Rayner Intraocular Lenses, Ltd., Worthing, United Kingdom or 1st Q Sulcus IOL; 1stQ GmbH, Mannheim, Germany) placed in the ciliary sulcus was used to address the residual refractive error. As such, these patients were targeted for myopia during primary IC-8 IOL implantation.

Outcome Measures

Outcome measures included uncorrected distance visual acuity (UDVA) measured using the Snellen chart, spherical equivalent refraction (SER), and the spherical equivalent refractive prediction accuracy of the five IOL formulas in predicting postoperative SER. Each of the five formulas incorporating standard keratometry (K) and total keratometry (TK) values from both devices (IOLMaster 700, Pentacam) was used to assess the predicted refraction with the implanted IOL. The prediction error was calculated by subtracting the predicted SER from the actual postoperative SER. The mean prediction error, standard deviation (SD) of the prediction error, and mean absolute prediction error (MAE) were calculated.

Statistical Analysis

Statistical analysis was carried out using Statistical Package for Social Sciences (SPSS) 27 (IBM Corp., Armonk, NY, USA). Descriptives for continuous data included means, SDs, and proportions where applicable. Snellen visual acuities were converted to the logarithm of the minimum angle of resolution (logMAR) for analysis and reporting.

The refractive prediction accuracy of various IOL formulas, such as EVO, Kane, BUII, Hill RBF, and Pearl DGS was assessed using keratometry and TK measurements from the IOLMaster 700, and simulated K (SimK) and total corneal refractive power (TCRP) measurements from Pentacam, and the results were expressed in terms of trueness, accuracy, and precision, which were calculated and compared using Eyetemis (https://eyetemis.com/), an online analysis tool endorsed by ESCRS, validated for assessing IOL prediction accuracy. Trueness was assessed by comparing the trimmed mean of the SEQ-PE, per formula, to zero using a one-sample robust *t*-test. Precision that represents the spread of the data was evaluated by comparing the trimmed mean values of the distances between the SEQ-PEs and the trimmed mean of the SEQ-PE for every two groups using the robust two-sample test. To compare the accuracy of two or more groups, the trimmed mean of absolute SEQ-PE was compared between each pair of groups using the robust two-sample test. Eyetemis uses a Holm correction for multiple comparisons to give an adjusted *P* value for pairwise comparisons.[14] A p-value less than 0.05 was considered significant. Due to the asymmetric development and progression of keratoconus in 2 eyes of a patient, the intereye correlation for corneal anatomical parameters such as central corneal thickness, thinnest corneal thickness, and posterior elevation is lower (r=0.68–0.70) than in healthy individuals (~0.98).[15] As such, prediction error comparisons were performed with the eyes treated as an independent unit of analysis.

Results

The demographics and corneal comorbidities of 67 eyes available for analysis are shown in Table 1. Figure 1 shows the corneal tomography (Pentacam) image of a typical keratoconus case from our study subjects.

Of the 67 eyes, 56 underwent IC-8 IOL implantation only, while 11 required piggyback IOL as a secondary procedure. Twenty-two patients underwent bilateral IC-8 IOL implantation. The postoperative visual and refractive outcomes are presented separately for non-piggyback (n = 56) and piggyback (n = 11) cases.

For patients who only received the IC-8 IOL, the mean CDVA improved from 0.56 (6/24) ± 0.54 logMAR preoperatively to 0.16 (6/9) ± 0.23 logMAR postoperatively (Figure 2). Although all eyes had considerably abnormal corneas, a spectacle CDVA of 6/6 or better was seen in 39.1% (18/46) of eyes and 6/9 or better in 73.9% (34/46). The mean postoperative UDVA was 0.24 (6/9) ± 0.30 logMAR, with 6/6 or better vision seen in 29.6% (16/54) of eyes and 6/9 or better vision in 61.1% (33/54) (Figure 3). The mean postoperative SER was −0.17 ± 1.27 D, with 54.2% (26/48) and 81.3% (39/48) of eyes achieving postoperative SER at or within 0.50 and 1.00 D, respectively. Table 2 summarizes the visual and refractive outcomes among eyes of the common corneal comorbidities included in this study.

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Table 1 Demographics and Corneal Comorbidities

N	67 Eyes (45 patients)
Age (years) (Mean ± SD)	66.5 ± 13.0
Gender, n (%)	
Male	24 (53.3%)
Female	21 (46.7%)
Corneal comorbidities, n (%)	
Keratoconus	32 (47.8%)
Herpetic disease	7 (10.4%)
Corneal irregularity post-surgery (eg, Salzman nodular degeneration)	7 (10.4%)
Corneal Scarring	5 (7.5%)
Previous corneal transplant	5 (7.5%)
Post-trauma astigmatism	4 (6.0%)
Radial Keratotomy	4 (6.0%)
Pellucid Marginal Degeneration	2 (3.0%)
High astigmatism	2 (3.0%)
Mixed irregular astigmatism	2 (3.0%)

Abbreviation: SD: Standard deviation.

In the 11 eyes that underwent secondary piggyback IOL implantation, the mean preoperative CDVA was 0.48 (6/18) ± 0.77 logMAR, and the final postoperative CDVA following piggyback insertion was 0.14 (6/7.5) ± 0.23 logMAR, with 66.7% (6/9) of eyes achieving CDVA of 6/9 or better postoperatively (Figure 2). Mean postoperative UDVA was 0.42 (6/

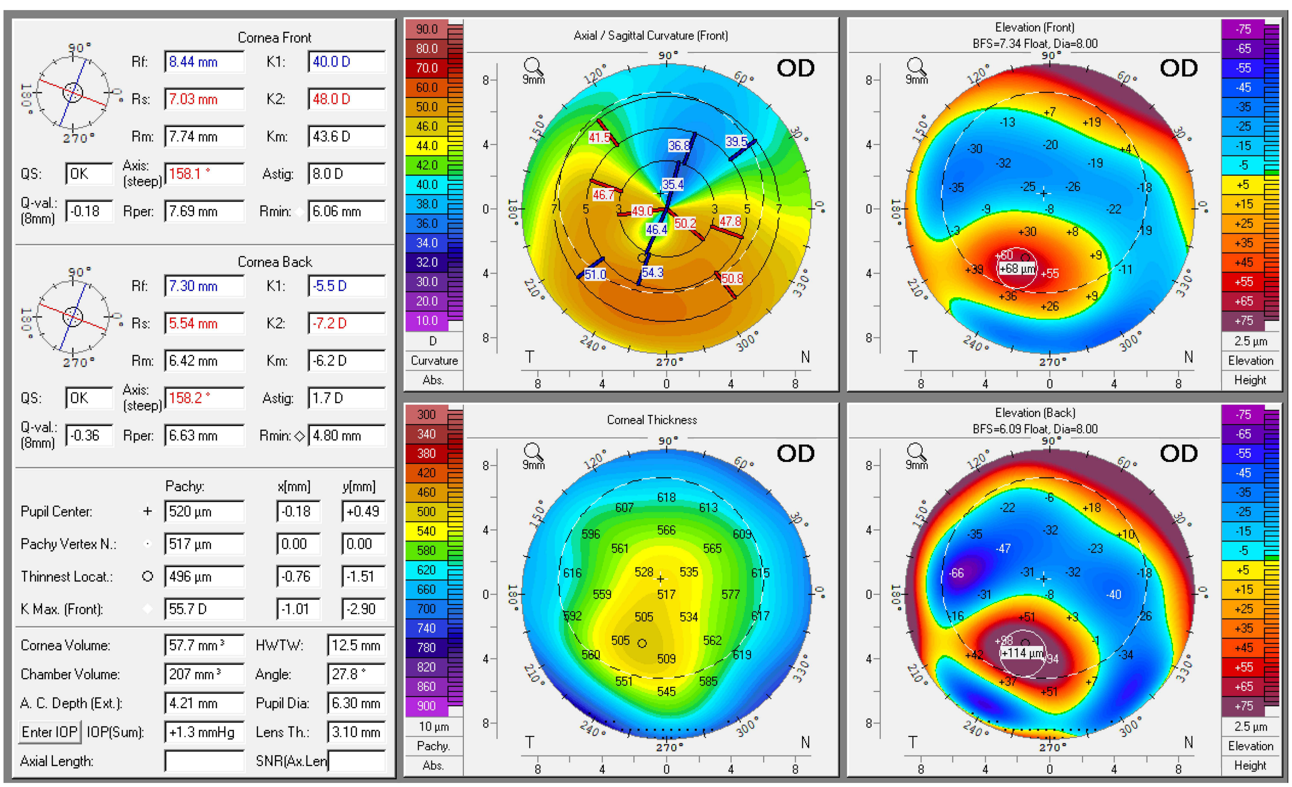

Figure 1 Corneal tomography (Pentacam) image of the right eye of one of our study subjects diagnosed with keratoconus. The "+" sign refers to the corneal apex.

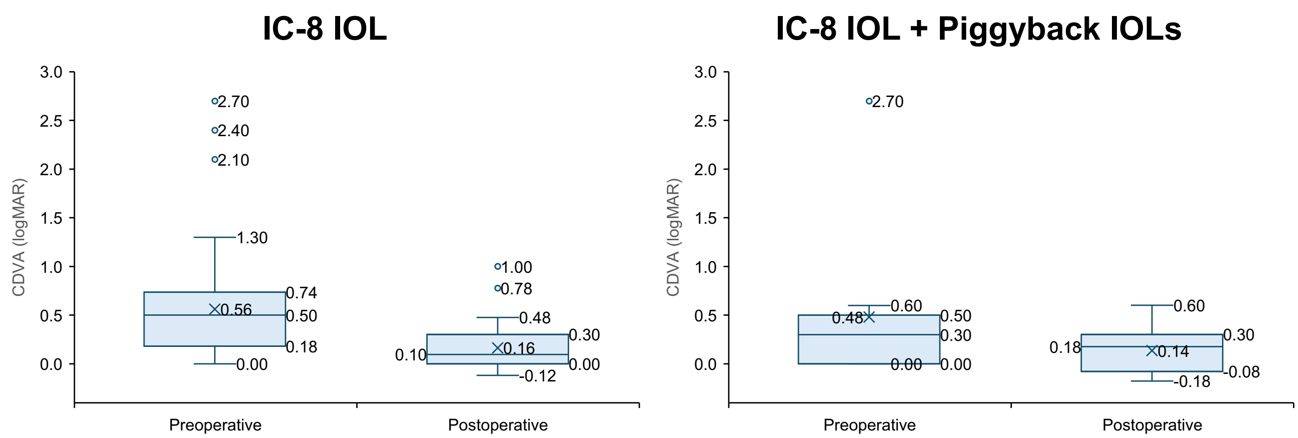

Figure 2 Box plot representing preoperative and postoperative logMAR CDVA of eyes implanted with IC-8 IOL only and IC-8 with piggyback IOLs (The horizontal lines represent the third quartile, the median, and the first quartile as well as the upper and lower fences that represent values more and less than 3rd and 1st quartiles, respectively, by 1.5 times the difference between the 3rd and 1st quartiles. X represents the mean. Dots represent values outside the upper and lower fences).

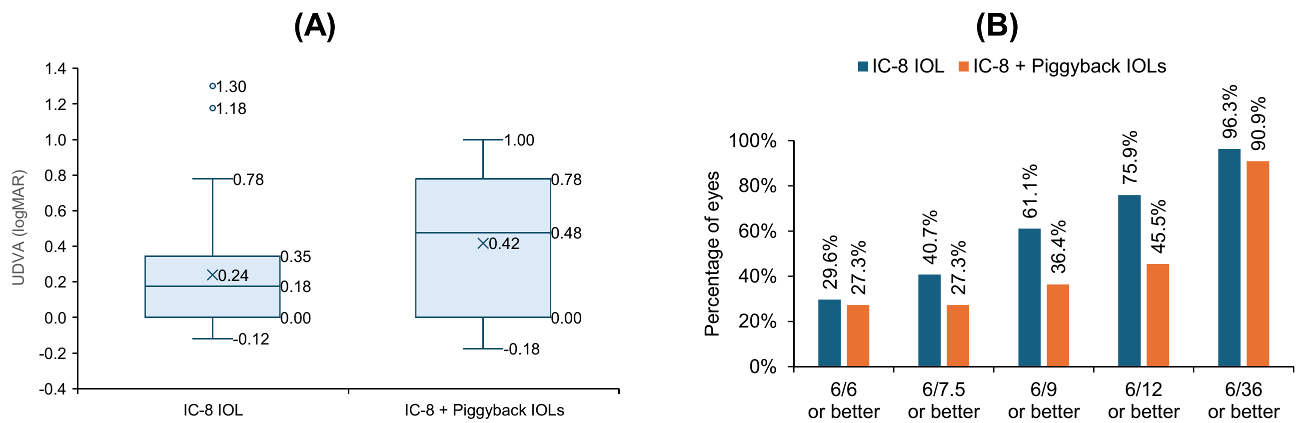

Figure 3 (**A**) Box plot representing postoperative logMAR UDVA of eyes implanted with IC-8 IOL only and IC-8 with piggyback IOLs (The horizontal lines represent the third quartile, the median, and the first quartile as well as the upper and lower fences that represent values more and less than 3rd and 1st quartiles, respectively, by 1.5 times the difference between the 3rd and 1st quartiles. X represents the mean. Dots represent values outside the upper and lower fences). (**B**) Frequency distribution chart representing the proportion of eyes implanted with IC-8 IOL only and IC-8 with piggyback IOLs achieving UDVA 6/x or better.

18) ± 0.39 logMAR, with 36.4% of eyes achieving UDVA of 6/9 or better (Figure 3). The final mean SER post piggyback was −0.85 ± 2.88 D, with 36.4% (4/11) of eyes achieving postoperative SER at or within 0.50 D.

Assessment of the spherical equivalent prediction accuracy of 5 IOL formulas with four different biometry measurements (standard keratometry and total keratometry measurements from IOLMaster 700 and SimK and TCRP measurements from Pentacam) showed no statistically significant differences between them. The precision and absolute SEQ-PE of all the IOL formulas were comparable, with no statistically significant differences in the pairwise comparison of trimmed mean SEQ-PE (data not shown). For the IOLMaster, the comparison of the 10 refractive prediction errors obtained from the 5 IOL formulas using K and TK readings showed comparable refractive prediction accuracy (all $p > 0.05$), although IOLMaster K readings tended to show lower prediction error. Similarly, for Pentacam, when the refractive prediction accuracy of 10 predicted errors obtained from the 5 IOL formulas using Pentacam SimK and TCPRK readings was compared, the prediction accuracy of all IOL formulas was found to be comparable (all $p > 0.05$), although Pentacam SimK readings tended to show lower prediction error (data not shown). Finally, the trimmed mean refractive prediction errors obtained from the 5 IOL formulas using IOLMaster K readings and Pentacam SimK readings were compared. Figure 4 shows the trimmed mean SEQ-PE (trueness) of all 10 prediction errors. All 10 prediction errors were not statistically significantly different from zero ($p > 0.05$) (except for BUII using Pentacam SimK reading that

Table 2 Visual and Refractive Outcomes Following IC-8 IOL Implantation in Different Corneal Conditions

	Corneal Irregularity Post-Surgery	Corneal Scarring	Herpetic Disease	Keratoconus	Previous Corneal Transplant	Radial Keratotomy
Overall N	7	5	6	24	5	4
UDVA						
Mean ± SD	0.01 ± 0.12	0.42 ± 0.25	0.34 ± 0.25	0.19 ± 0.32	0.30 ± 0.21	0.24 ± 0.20
% eyes with UDVA 6/6 or better	71.4%	0.0%	0.0%	36.4%	20.0%	25.0%
% eyes with UDVA 6/9 or better	100.0%	40.0%	50.0%	68.2%	20.0%	50.0%
% eyes with UDVA 6/12 or better	100.0%	40.0%	50.0%	86.4%	80.0%	75.0%
% eyes with UDVA 6/36 or better	100.0%	100.0%	100.0%	95.5%	100.0%	100.0%
CDVA						
Mean ± SD	−0.01 ± 0.10	0.35 ± 0.30	0.25 ± 0.20	0.16 ± 0.24	0.14 ± 0.21	0.12 ± 0.15
% eyes with CDVA 6/6 or better	85.7%	20.0%	16.7%	33.3%	40.0%	50.0%
% eyes with CDVA 6/9 or better	100.0%	40.0%	50.0%	80.0%	80.0%	75.0%
% eyes with CDVA 6/12 or better	100.0%	60.0%	66.7%	86.7%	80.0%	100.0%
% eyes with CDVA 6/36 or better	100.0%	100.0%	100.0%	93.3%	100.0%	100.0%
MRSE						
Mean ± SD	−0.18 ± 0.49	−1.28 ± 1.26	1.13 ± 2.45	−0.44 ± 0.58	−0.72 ± 1.49	1.25 ± 1.55
% of eyes with MRSE within 0.50 D	85.7%	40.0%	66.7%	44.4%	25.0%	50.0%
% of eyes with MRSE within 1.00 D	85.7%	60.0%	66.7%	88.9%	75.0%	75.0%

Notes: Includes corneal conditions with a count of >2.

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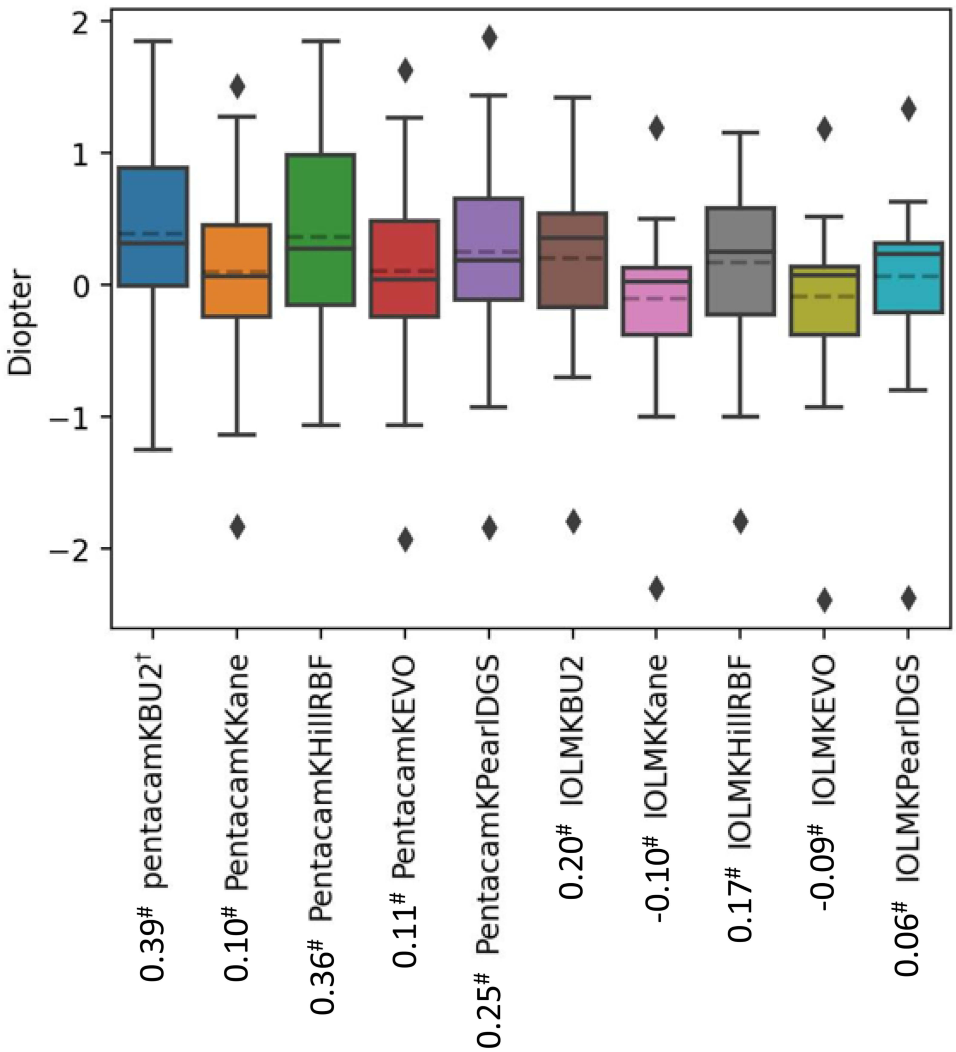

Figure 4 Box plot of SEQ-PE (trueness) in eyes implanted with IC-8 IOL. † indicates that the trimmed mean is significantly different from zero. # indicates trimmed mean.

showed the highest mean prediction error of 0.39 D, p = 0.048). The precision and absolute SEQ-PE accuracy of all these 10 prediction errors were also comparable (p >0.05; Figures 5 and 6).

Discussion

This study demonstrates that the use of the IC-8 pinhole IOL resulted in good visual outcomes in patients with irregular corneas, a cohort that typically has sub-optimal outcomes due to the presence of irregular astigmatism and HOAs. Though irregular corneas typically result in greater refractive surprises due to variability in biometry measurements and lower accuracy of IOL formulas, post-surgery 75.9% of patients (IC-8 only subgroup) achieved unaided driving vision (6/12 or better), which represents a significant improvement in patient quality of life. This is the largest study to date on the use of the IC-8 IOL in irregular corneas, with several smaller studies (n ≤17 eyes) also showing an improvement in vision.[16–18] In select patients with extremely high astigmatism or where a significant refractive surprise occurred, sulcus-based piggyback IOLs were successfully inserted to improve visual outcomes, a technique only reported as a single case report in the literature.[11] Further, a high proportion of patients (n = 22 patients) received bilateral IC-8 IOLs to achieve very good visual outcomes, again, only commented in the literature in very small numbers (n ≤10).[16,19,20]

The patients included in this study had a range of corneal comorbidities. While the keratoconus eyes have localized corneal thinning and irregular steepening, RK eyes have central corneal flattening with peripheral steepening. Eyes with

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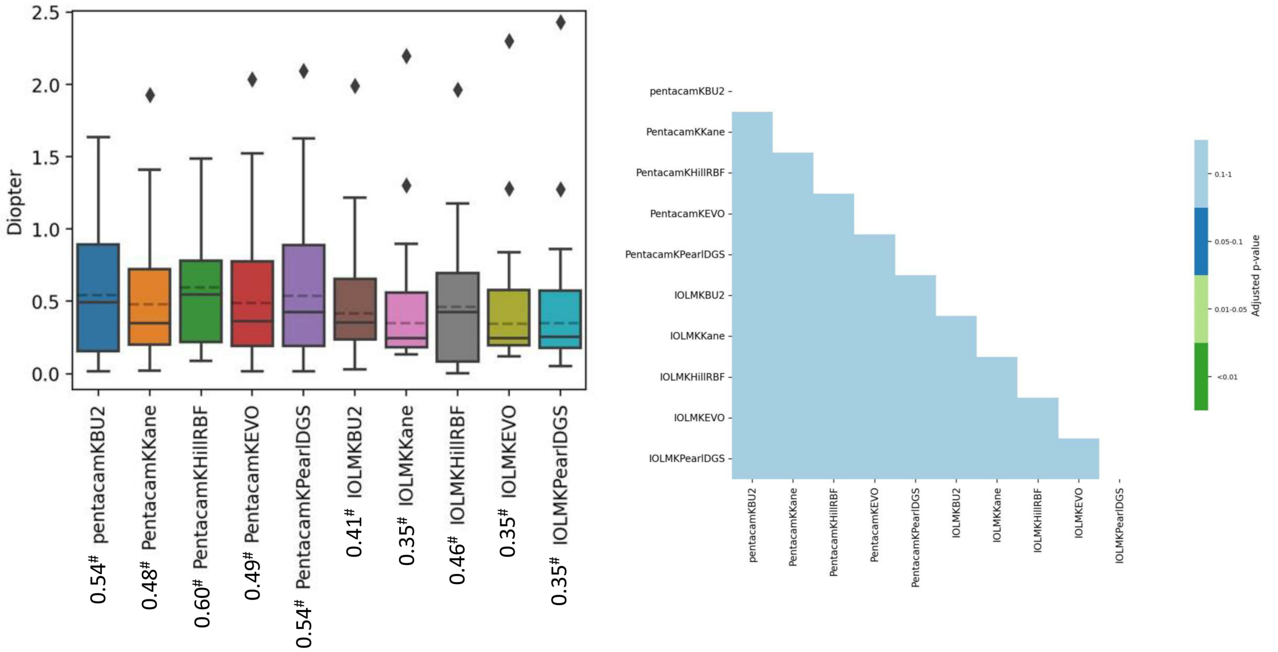

Figure 5 Box plot showing the precision of spherical equivalent refractive prediction error (SEQ-PE) in eyes implanted with IC-8 IOL. The heatmap provides adjusted P values for paired comparisons. # indicates trimmed mean.

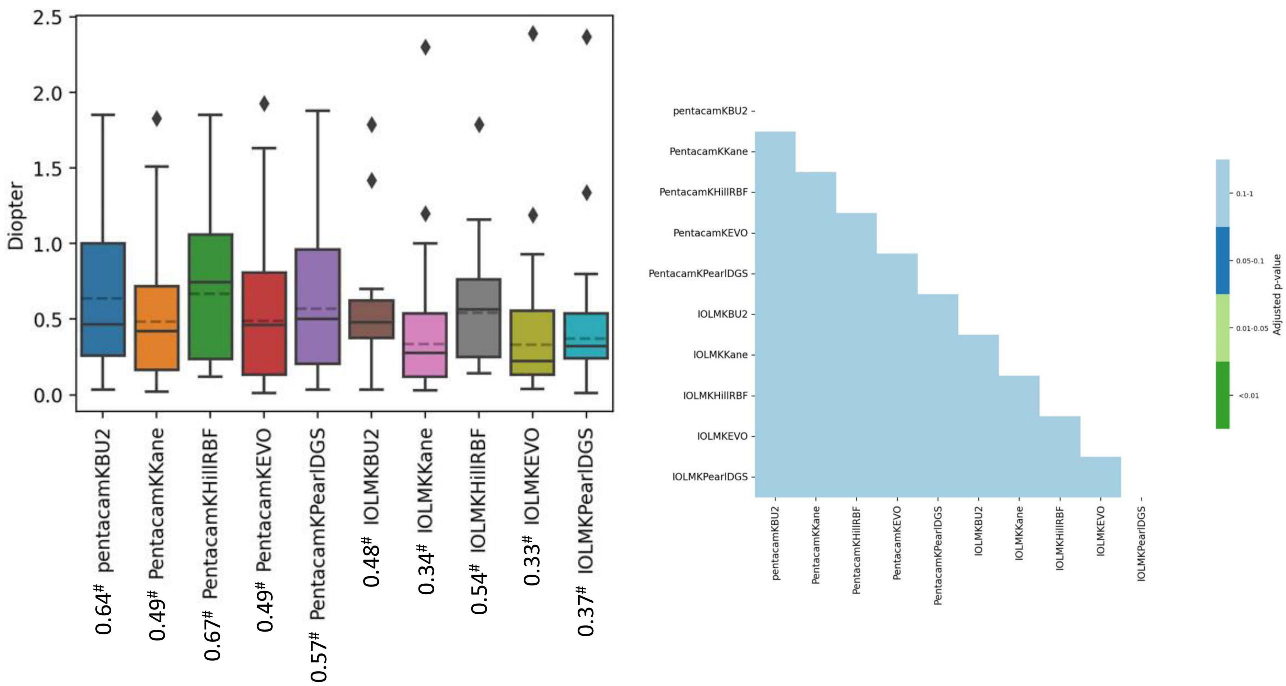

Figure 6 Box plot showing the absolute spherical equivalent refractive prediction error (SEQ-PE) accuracy in eyes implanted with IC-8 IOL. The heatmap provides adjusted P values for paired comparisons. # indicates trimmed mean.

post-penetrating keratoplasty may have high irregular stigmatism due to uneven suturing, and those with herpetic keratopathy show highly asymmetrical irregularity matching the location of previous dendritic or stromal ulcers. Despite these diverse corneal features, corneal irregularity was a common characteristic among them. As such, the present study reports the collective visual and refractive outcomes. A separate analysis of eyes with different corneal comorbidities provides insights into how visual and refractive outcomes may vary with the differences in the topographic characteristics. The separate analysis of these comorbidities showed that following the IC-8 IOL implantation, in eyes with keratoconus, radial keratotomy, previous corneal transplant, and post-surgical corneal irregularity, UDVA of 6/12 or better was achieved in 75–100% of the eyes, and CDVA of 6/12 or better was achieved in 80–100% of the eyes (Table 2). In eyes with peripheral corneal scarring and herpetic disease, the UDVA of 6/12 or better was achieved in 40 to 50%, and CDVA of 6/12 or better in 60 to 66.7% of eyes, potentially due to highly asymmetric corneal irregularity.

Technological advancement has sequentially introduced a range of factors that now increase the complexity of IOL selection post cataract surgery. Traditional training has mainly focused on SER, with correction of regular astigmatism via toric IOLs still considered a premium service in many countries to reduce the need for spectacle use.[21,22] As a secondary consideration, surgeons may examine total corneal spherical aberrations when deciding on the use of extended depth of focus IOLs.[23,24] When considering an IOL, these factors are typically considered in a linear manner. Pinhole optics introduces for the first time the potential to minimize corneal HOAs,[25–29] which can improve visual acuity and image quality.[6–8] As such, prioritizing HOA reduction is an important aspect of optimizing vision post cataract surgery and should be considered early in the IOL selection process. This represents a paradigm shift from traditional teaching patterns. In the author's experience, eyes with HOA > 0.700 µm (measured on Pentacam) benefit the most from pinhole optics and can be considered a clinical guideline to help choose an appropriate IOL for highly aberrated eyes.

IOL power calculations in eyes with irregular corneas are challenging. The availability of biometry devices based on newer technologies, such as Scheimpflug imaging and SS-OCT, has allowed the measurement of both the anterior and posterior aspects of the cornea to estimate its total power, and may improve the IOL power calculations in eyes with corneal comorbidities.[30] However, in our study using keratometry measurements from both the IOLMaster 700 (K and TK) and Pentacam (SimK and TCPRK), along with five different IOL power formulas from a smaller subset of eyes, we found comparable prediction accuracy. The trimmed mean SEQ-PE was similar for all 10 prediction errors, with no statistically significant difference in the precision and absolute SEQ-PE between the IOL formulas tested. However, we note that the refractive prediction accuracy was assessed on a smaller subset of 20 eyes, which might not be sufficient to achieve statistical significance. As such, future studies with a larger sample size are required to validate the refractive prediction accuracy of various IOL formulas using biometry measurements from IOLMaster 700 and Pentacam. In the absence of a clearly superior formula, it would be advantageous clinically to assess these patients using multiple formulas and measurement devices to minimize the risk of prediction error and subsequent refractive surprises.

The principles of pinhole optics result in neutralization of a proportion of both higher-order as well as lower-order aberrations (sphere and cylinder). However, as the IC-8 IOL is not manufactured in a toric form, larger quantities of regular astigmatism cannot be adequately corrected with this lens. Thus, the visual gain from the IC-8 IOL pinhole optics can be refined with correction of any residual refractive error to achieve a higher level of glasses independence or to reduce the size of the glasses prescription for patient ease and comfort, even in the context of abnormal corneas. This study separately reports the largest cohort of patients with secondary sulcus-based piggyback IOLs inserted after IC-8 implantation (n = 11 eyes). Within our cohort, 27.3% of patients with piggyback-supplemented IC-8 IOL insertion achieved a postoperative UDVA of 6/6 or better. We suggest targeting close to emmetropia in eyes with astigmatism below 3 D. In eyes with higher levels of astigmatism, where contact lenses cannot be used and the refractive goal of minimizing glasses reliance is desired, a piggyback IOL may be used and an appropriate myopic target should be targeted to permit successful astigmatism correction.

The major limitations of the study are its relatively small sample size and short follow-up period, which reflect the niche nature of surgery in patients with significantly abnormal corneas. Further studies with larger sample sizes and longer follow-up periods or pooled data from multiple sites would be beneficial to enhance the understanding of how best to use pinhole optics in this specialized patient population. Furthermore, we did not assess IOL power calculators specifically designed for keratoconus, as the patients included had diverse corneal pathologies. Assessment of additional parameters, such as defocus curve, contrast sensitivity, optical quality indices, patient-reported visual symptoms, etc., in future studies may provide additional insights into the benefits of this small-aperture IOL in compromised corneas.

Conclusion

In this exploratory study, the implantation of the small-aperture IC-8 IOL in the niche population of cataract patients with preexisting corneal comorbidities yielded good visual and refractive outcomes. In patients with high residual refractive error, performing secondary piggyback IOL implantation following IC-8 IOL may be a successful strategy. Further studies are required to validate the outcomes. We suggest clinical guidelines be explored for the use of the IC-8 IOL in this challenging cohort of patients.

Abbreviations

UDVA, uncorrected distance visual acuity; SER, spherical equivalent refraction; IOL, intraocular lens; HOAs, higher-order aberrations; K, standard keratometry; TK, total keratometry; TCRP, total corneal refractive power; QID, four times a day; D, diopters; SD, standard deviation; MAE, mean absolute prediction error; logMAR, logarithm of the minimum angle of resolution; SEQ-PE, spherical equivalent prediction error.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author (Chameen Samarawickrama) upon reasonable request.

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Disclosure

The authors have no potential conflicts of interest to disclose.

References

1. Chalkiadaki E, Gartaganis PS, Ntravalias T, Giannakis I, Manousakis E, Karmiris E. Agreement in anterior segment measurements between swept-source and Scheimpflug-based optical biometries in keratoconic eyes: a pilot study. *Ther Adv Ophthalmol*. 2022;14:25158414211063283. doi:10.1177/25158414211063283
2. Applegate RA, Hilmantel G, Howland HC. Corneal aberrations increase with the magnitude of radial keratotomy refractive correction. *Optom Vis Sci*. 1996;73(9):585–589. doi:10.1002/j.1538-9235.1996.tb04527.x
3. Maeda N, Nakagawa T, Kosaki R, et al. Higher-order aberrations of anterior and posterior corneal surfaces in patients with keratectasia after LASIK. *Invest Ophthalmol Vis Sci*. 2014;55(6):3905–3911. doi:10.1167/iovs.14-14391
4. McCormick GJ, Porter J, Cox IG, MacRae S. Higher-order aberrations in eyes with irregular corneas after laser refractive surgery. *Ophthalmology*. 2005;112(10):1699–1709. doi:10.1016/j.ophtha.2005.04.022
5. De Bernardo M, Cione F, Capasso L, Coppola A, Rosa N. A formula to improve the reliability of optical axial length measurement in IOL power calculation. *Sci Rep*. 2022;12(1):18845. doi:10.1038/s41598-022-23665-0
6. Goto S, Maeda N. Corneal topography for intraocular lens selection in refractive cataract surgery. *Ophthalmology*. 2021;128(11):e142–e152.
7. Wang L, Koch DD. Intraocular lens power calculations in eyes with previous corneal refractive surgery: review and expert opinion. *Ophthalmology*. 2021;128(11):e121–e131.
8. Schröder S, Eppig T, Liu W, Schrecker J, Langenbucher A. Keratoconic eyes with stable corneal tomography could benefit more from custom intraocular lens design than normal eyes. *Sci Rep*. 2019;9(1):3479.
9. Toyama N, Kuwabara N, Ogata M, Mori Y, Minami K, Miyata K. Refractive tolerance in the use of monofocal intraocular lenses enhanced with new aspheric design. *Graefes Arch Clin Exp Ophthalmol*. 2025;263:1605–1611. doi:10.1007/s00417-025-06762-4
10. Kim WS, Park IK, Chun YS. Quantitative analysis of functional changes caused by pinhole glasses. *Invest Ophthalmol Vis Sci*. 2014;55(10):6679–6685. doi:10.1167/iovs.14-14801
11. Barnett V, Barsam A, Than J, Srinivasan S. Small-aperture intraocular lens combined with secondary piggyback intraocular lens during cataract surgery after previous radial keratotomy. *J Cataract Refract Surg*. 2018;44(8):1042–1045. doi:10.1016/j.jcrs.2018.06.005
12. Dick HB. The Lens: IC-8. CRST Global; 2017. Available from: https://crstodayeurope.com/articles/2017-jan/the-lens-ic-8/. Accessed May 23, 2025.
13. The IC-8 IOL: big advantages through small apertures. The Ophthalmologist; 2019. Available from: https://theophthalmologist.com/issues/2019/articles/sep/the-ic-8-iol-big-advantages-through-small-apertures. Accessed May 23, 2025.

14. Kan-Tor Y, Abulafia A, Zadok D, et al. Spherical equivalent prediction analysis in intraocular lens power calculations using Eyetemis: a comprehensive approach. *J Cataract Refract Surg*. 2024;50(11):1128–1134. doi:10.1097/j.jcrs.0000000000001518
15. Dienes L, Kranitz K, Juhasz E, et al. Evaluation of intereye corneal asymmetry in patients with keratoconus. A scheimpflug imaging study. *PLoS One*. 2014;9(10):e108882. doi:10.1371/journal.pone.0108882
16. Franco F, Branchetti M, Vicchio L, et al. Implantation of a small aperture intraocular lens in eyes with irregular corneas and higher order aberrations. *J Ophthalmic Vis Res*. 2022;17(3):317–323. doi:10.18502/jovr.v17i3.11568
17. Shajari M, Mackert MJ, Langer J, et al. Safety and efficacy of a small-aperture capsular bag–fixated intraocular lens in eyes with severe corneal irregularities. *J Cataract Refract Surg*. 2020;46(2):188–192. doi:10.1097/j.jcrs.0000000000000045
18. Langer J, Shajari M, Kreutzer T, Priglinger S, Mayer WJ, Mackert MJ. Predictability of refractive outcome of a small-aperture intraocular lens in eyes with irregular corneal astigmatism. *J Refract Surg*. 2021;37(5):312–317. doi:10.3928/1081597X-20210222-03
19. Ang RE. Visual performance of a small-aperture intraocular lens: first comparison of results after contralateral and bilateral implantation. *J Refract Surg*. 2020;36(1):12–19. doi:10.3928/1081597X-20191114-01
20. Dick HB, Elling M, Schultz T. Binocular and monocular implantation of small-aperture intraocular lenses in cataract surgery. *J Refract Surg*. 2018;34(9):629–631. doi:10.3928/1081597X-20180716-02
21. Al-Mohtaseb Z, Steigleman WA, Pantanelli SM, et al. Toric monofocal intraocular lenses for the correction of astigmatism during cataract surgery: a report by the American Academy of Ophthalmology. *Ophthalmology*. 2024;131(3):383–392. doi:10.1016/j.ophtha.2023.10.010
22. Kessel L, Andresen J, Tendal B, Erngaard D, Flesner P, Hjortdal J. Toric intraocular lenses in the correction of astigmatism during cataract surgery: a systematic review and meta-analysis. *Ophthalmology*. 2016;123(2):275–286. doi:10.1016/j.ophtha.2015.10.002
23. Kozhaya K, Kenny PI, Esfandiari S, Wang L, Weikert MP, Koch DD. Effect of spherical aberration on visual acuity and depth of focus in pseudophakic eyes. *J Cataract Refract Surg*. 2024;50(1):24–29. doi:10.1097/j.jcrs.0000000000001314
24. Lago CM, de Castro A, Marcos S. Computational simulation of the optical performance of an EDOF intraocular lens in post-LASIK eyes. *J Cataract Refract Surg*. 2023;49(11):1153–1159. doi:10.1097/j.jcrs.0000000000001260
25. Schultz T, Dick HB. Small-aperture intraocular lens implantation in a patient with an irregular cornea. *J Refract Surg*. 2016;32(10):706–708. doi:10.3928/1081597X-20160721-01
26. Ang RET, Araneta MMQ, Cruz EM. Review of surgical devices using small aperture optics. *Taiwan J Ophthalmol*. 2022;12(3):282–294. doi:10.4103/tjo.tjo_45_21
27. Ezzeldin M, Steinberg J, Frings A, Linke S. Small-aperture intraocular lens implantation in a patient with cataract and keratoconus. *JCRS Online Case Rep*. 2020;8(2):e00005. doi:10.1097/j.jcro.0000000000000005
28. Leccisotti A. Refractive lens exchange in keratoconus. *J Cataract Refract Surg*. 2006;32(5):742–746. doi:10.1016/j.jcrs.2006.01.063
29. van den Berg RM, van den Berg AB, Maia Rocha K, et al. Prediction of the small aperture intraocular lens on visual acuity in patients with keratoconus. *J Cataract Refract Surg*. 2024;50(9):930–935. doi:10.1097/j.jcrs.0000000000001480
30. Wendelstein JA, Hoffmann PC, Hoffer KJ, et al. Differences between keratometry and total keratometry measurements in a large dataset obtained with a modern swept source optical coherence tomography biometer. *Am J Ophthalmol*. 2024;260:102–114. doi:10.1016/j.ajo.2023.12.003