Intraocular lens power calculation after incisional and thermal keratorefractive surgery

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Purpose: To evaluate the efficacy of corneal topography in determining the central corneal refractive power in intraocular lens (IOL) power calculations after incisional and thermal keratorefractive surgery.

Setting: Oregon Eye Institute, Eugene, Oregon, USA.

Methods: This retrospective review comprised 20 eyes (14 patients) that had cataract extraction with IOL implantation or refractive lens exchange after radial keratotomy, hexagonal keratotomy, or laser thermal keratoplasty. The effective refractive power (EffRP) of the Holladay Diagnostic Summary on the EyeSys Corneal Analysis System was used to determine the central corneal refractive power, which was input into the Holladay 2 IOL calculation formula.

Results: Eighty percent of eyes achieved a postoperative spherical equivalent refraction within ±0.50 diopter of emmetropia.

Conclusion: The use of the EffRP increases the likelihood of an acceptable refractive outcome after cataract or refractive lens exchange surgery in eyes with a history of keratorefractive surgery.

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Intraocular lens (IOL) power calculations for cataract and refractive lens exchange surgery have become much more precise with the current theoretical generation of formulas and newer biometry devices.[1] Intraocular lens power calculation remains a challenge in eyes with previous keratorefractive surgery, however. The difficulty is accurately determining the corneal refractive power (K.J. Hoffer, MD, "Intraocular Lens Power Calculation in Radial Keratotomy Eyes," Phaco & Foldables, 1994, 7[3], page 6).[2,3]

In a normal cornea, standard keratometry and computed corneal topography are accurate in measuring 4 sample points to determine the steepest and flattest meridians of the cornea, yielding accurate values for the central corneal power. In irregular corneas, such as those that have had radial keratotomy (RK), laser thermal keratoplasty (LTK), hexagonal keratotomy (HK), penetrating keratoplasty, photorefractive keratectomy (PRK), or laser in situ keratomileusis (LASIK), the 4 sample points are not sufficient to provide an accurate estimate of the center corneal refractive power.[4]

Traditionally, 3 methods have been used to calculate the corneal refractive power in these eyes.[5] They include the historical method, the hard contact lens method, and values derived from standard keratometry or corneal topography. The historical method remains limited by its reliance on the availability of refractive data before the keratorefractive surgery. The contact lens method is not applicable in patients with significantly reduced visual acuity.[6] The use of simulated or actual keratometry values almost invariably leads to a hyperopic refractive surprise.[7]

It has been suggested that using the average central corneal power rather than topography-derived kera-

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tometry improves IOL power calculation accuracy after corneal refractive surgery.[8] The effective refractive power (EffRP, Holladay Diagnostic Summary, EyeSys Topographer) is the refractive power of the corneal surface within the central 3.0 mm pupil zone, taking into account the Stiles-Crawford effect. This value is commonly known as the spheroequivalent power of the cornea within the 3.0 mm pupil zone. The EffRP differs from simulated keratometry values given by topographers. The simulated K-readings that the standard topography map gives are only the points along the 3.0 mm pupil perimeter, not the entire zone. As with standard keratometry, these 2 meridians are forced to be 90 degrees apart. The higher the discrepancy between the mean simulated K-readings and the EffRP, the higher the degree of variability in the results of the IOL calculations.[2]

Aramberri[9] reports the advantages of using a double-K method to calculate IOL power in eyes that have had keratorefractive surgery. Holladay recognized this concept and used it in the development of the Holladay 2 IOL power calculation formula in 1996.[10] The Holladay 2 formula (Holladay IOL Consultant) uses the corneal power value for a vergence formula to calculate the refractive power of the eye and to aid in determining the effective lens position (ELP). The formula uses 7 variables to estimate the ELP including keratometry, axial length (AL), horizontal white-to-white (WTW) measurement, anterior chamber depth, phakic lens thickness, patient age, and current refraction.

The Holladay 2 program permits the use of the EffRP as an alternative to keratometry (Alt K) for the vergence calculation. For ELP calculation, the program uses the K-value entered as the pre-refractive-surgery K or, if it is unknown, 43.86, which is the mean of the human population (Jack Holladay, personal communication, February 2004).

Patients and Methods

This retrospective analysis included all patients at the Oregon Eye Institute who had cataract or refractive lens exchange surgery after incisional or thermal keratorefractive surgery and in whom the EffRP and Holladay 2 IOL calculation formula were used to determine IOL power. Between February 23, 2000, and October 28, 2002, 20 eyes met these criteria. Fourteen eyes had previous RK; 3 eyes, HK; and 3 eyes, LTK with the Sunrise Sun1000 laser (Sunrise Technologies).

A complete preoperative ophthalmic examination was performed in all cases. Axial length was measured with the IOLMaster (Carl Zeiss Meditec). The protocol allowed up to a 0.15 mm variation within 10 axial length measurements in 1 eye and up to a 0.20 mm variation between the 2 eyes, unless explained by anisometropia. The signal-to-noise ratio had to be 1.6 or better, and a tall, sharp "Chrysler Building" shaped peak was preferred. If any criterion was not met, the measurements were repeated with immersion ultrasonography (Axis II, Quantel Medical). The corneal WTW distance was measured with a Holladay-Godwin gauge in the initial 14 eyes and with new frame grabber software on the IOLMaster in the final 6 eyes.

Phakic lens thickness was estimated as 4 plus the patient's age divided by 100 (eg, a 67-year-old patient's lens thickness was estimated as 4.67) or determined by immersion ultrasonography. The Holladay 2 formula was used for all IOL power calculations. "Previous RK" was set to "yes," and the EffRP value from the Holladay Diagnostic Summary was input in the "Alt K" area. This procedure instructs the formula to use the EffRP value in place of standard keratometry for the vergence calculation. In no case was the pre-refractive-surgery keratometry known, so the formula used 43.86 as the default to determine the ELP. The Alt K radio button was highlighted, and the EffRP value was printed on the report as a confirmation that the formula had used it in the calculation. In every case, the targeted postoperative refraction was emmetropia.

Preoperative astigmatism was addressed at the time of cataract or lens exchange surgery by limbal relaxing incisions performed with a Force blade (Mastel Precision Surgical Instruments) as described by Gills and Gayton[11] and Nichamin (L. Nichamin, MD, "Refining AK May Enhance Your Cataract Procedure," Ocular Surgery News, August 15, 1993, pages 81–82). In general, with-the-rule corneal astigmatism of 1.00 diopter (D) or greater and against-the-rule corneal astigmatism of 0.75 D or greater was considered appropriate for correction.

The surgical technique, including clear corneal cataract extraction with topical anesthesia and the use of power modulations in phacoemulsification, has been described.[12] Eight eyes (5 patients) received an Array® SA40 multifocal IOL (AMO); 5 eyes (3 patients), an AQ2010V IOL (Staar Surgical); both eyes of 1 patient, a CLRFLXB IOL (AMO); both eyes of 1 patient, an SI-40 IOL (AMO); and 1 eye of 1 patient each, a CeeOn® Edge 911A (Pfizer), Tecnis® Z9000 (Pfizer), or Collamer CC4204BF (Staar Surgical) IOL. The deviation of the achieved postoperative spherical equivalent (SE) from the desired postoperative goal in each eye was determined. Each group of keratorefractive patients was also analyzed separately.

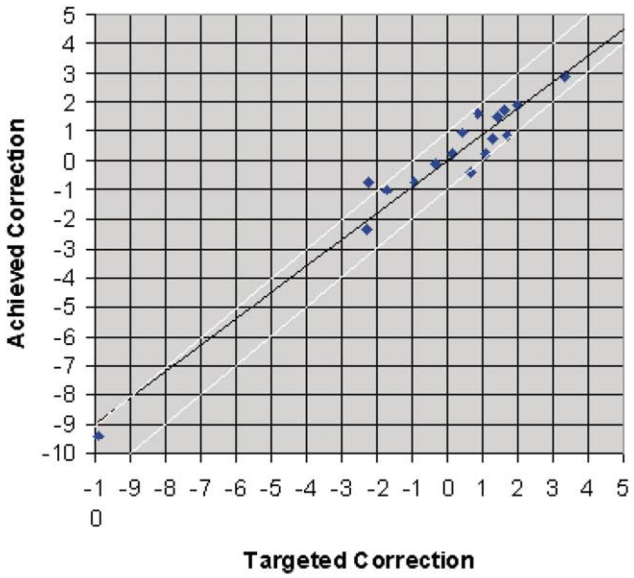

Figure 1. (Packer) Targeted correction in SE calculated by the Holladay 2 formula compared with the achieved postoperative SE correction. Linear regression analysis (y = 0.9266x + 0.1233) demonstrated a slightly hyperopic trend (◆ = targeted versus achieved SE; — = linear [targeted versus achieved SE]).

The differences between the EffRP value and the corneal refractive power derived from the corneal topographer and autokeratometer were also analyzed. All data were placed in an Excel spreadsheet, and statistical analyses were performed.

Results

In the RK group, the number of radial incisions ranged from 4 to 20, with most eyes having 8 incisions. Fifty percent of these patients had astigmatic keratotomy in addition to RK. For all eyes, the mean duration from IOL surgery to the last postoperative refraction was 6.73 months (range 1 to 24 months). The RK group had the longest follow-up, a mean of 9.25 months (range 2.5 to 24 months).

The mean deviation from the calculated postoperative refractive goal in all eyes was 0.13 D ± 0.62 (SD) (range −1.49 to 1.03 D). The mean difference from the postoperative refractive goal was 0.27 ± 0.51 D in the RK group, −0.07 ± 0.44 D in the LTK group, and −0.32 ± 1.10 D in the HK group. Figure 1 shows the targeted versus the achieved SE correction. The following linear regression equation was fitted to the data: Achieved correction = 0.9266 (targeted correction) + 0.1233 D. The results show a slightly hyperopic trend in achieved SE correction. All eyes had a postoperative refraction within ±1.50 D of emmetropia, and 80% were within ±0.50 D (Figure 2).

The mean difference between standard automated keratometry readings (IOLMaster) and the EffRP values in all eyes was 0.01 ± 0.66 D (range −1.50 to 2.00 D) (Figure 3). The mean difference was 0.12 ± 0.65 D (range 0.47 to 2.00 D) in the RK group, 0.05 ± 0.29 D (range −1.50 to 0.24 D) in the LTK group, and 0.48 ± 0.91 D (range −0.26 to 0.28 D) in the HK group.

The mean difference between standard simulated keratometry readings and the topography and EffRP values in all eyes was −0.85 ± 0.73 D (range −2.28 to 0.31 D). The mean difference was −1.03 ± 0.74 D (range −2.28 to −0.19 D) in the RK group, −0.01 ± 0.28 D (range −1.08 to −0.50 D) in the LTK group, and −0.84 ± 0.30 D (range −0.13 to 0.31 D) in the HK group.

The mean AL in all eyes was 24.78 ± 1.54 mm (range 22.31 to 27.96 mm). The mean AL was 25.38 ± 1.40 mm (range 23.04 to 27.96 mm) in the RK group, 23.21 ± 1.26 mm (range 22.31 to 24.65 mm) in the LTK group, and 23.57 ± 0.43 mm (range 23.08 to 23.82 mm) in the HK group. No significant correlation between AL and the postoperative SE was found (Pearson correlation coefficient = 0.08).

The eye with a preoperative SE refraction of −9.88 D was an outlier and had unusual features. The patient presented 22 years after "failed" RK in the eye and never had surgery in the fellow eye. No other history was available. The fellow unoperated eye had an SE of −4.86 D with keratometry of 42.82 × 44.34@98 and an AL of 25.13 mm. The preoperative best corrected visual acuity (BCVA) in the operated eye was 20/30 with −10.75 +1.75 × 33. Keratometry in the operated eye was 41.31 × 42.67@64, yielding a mean K-value of 41.99; simulated keratometry was 41.36 × 42.55@70. The calculated EffRP was 41.90 D, and the AL was 26.59 mm. Examination revealed moderate nuclear sclerosis. The Holladay 2 formula predicted a postoperative SE refraction of −0.02 D. The eye achieved a final BCVA of 20/20 with +0.25 +0.75 × 55, indicating a predictive error of 0.64 D.

Discussion

The determination of IOL power after keratorefractive surgery remains a challenge for cataract and refrac-

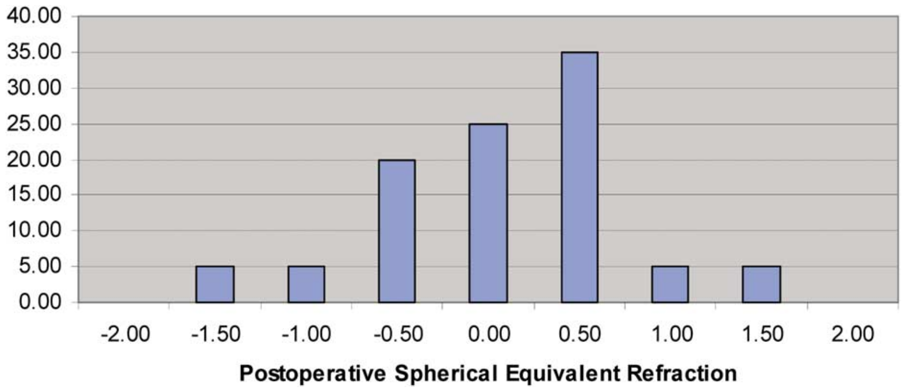

Figure 2. (Packer) The frequency distribution of eyes (%) determined by the postoperative SE refraction.

tive surgeons. Using a combination of measured and calculated K-values with the historical and contact lens methods, as well as a myopic target refraction, Chen et al.[7] achieved a postoperative refractive outcome within ±0.50 D of emmetropia in 29.2% of 24 eyes with a history of RK. They suggest that "corneal power values that involve more central regions of the cornea, such as the effective refractive power in the Holladay diagnostic summary of the EyeSys Corneal Analysis System, would be more accurate K-readings in post-RK eyes." Our results tend to support that conclusion.

Accurate biometry also plays an important role in IOL power determination. The use of partial coherence interferometry (IOLMaster) for AL measurement improves the predictive value of postoperative refraction[13] and has an accuracy equivalent to that of immersion ultrasound.[14]

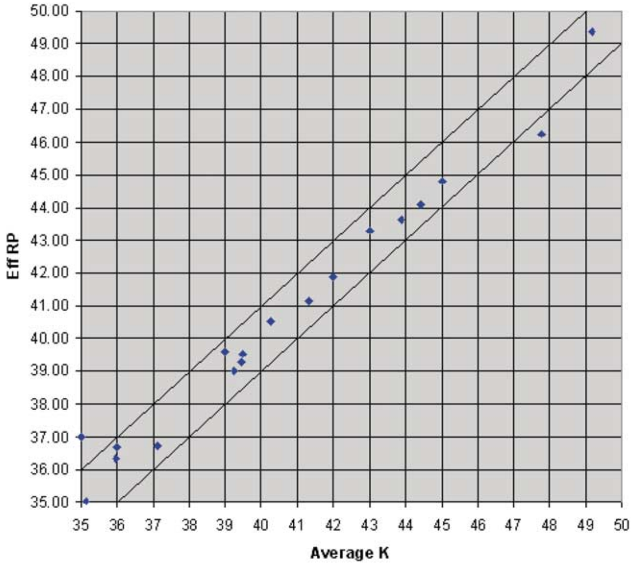

Figure 3. (Packer) The average keratometry reading (IOLMaster) compared with the EffRP determined by the Holladay Diagnostic Summary. Although the mean difference was small, the range of differences was broad (−1.50 to 2.00 D). Equivalency lines show the range ±1.0 D.

The difference between simulated keratometry and the EffRP was smaller in the LTK group than in the incisional keratorefractive surgery groups. A possible explanation for this difference is that the LTK corneas regressed after treatment and returned to a less distorted anatomy.

The IOL calculation formula plays a critical role in obtaining improved outcomes. The Holladay 2 formula is designed to improve determination of the final ELP by considering disparities in the relative size of the anterior and posterior segments of the eye. To accomplish this goal, the formula incorporates the corneal WTW measurement and the phakic lens thickness and uses keratometry (or EffRP) values to determine corneal power and predict the ELP. Use of the Holladay 2 formula has increased the accuracy of our IOL power calculations.[15]

Our study was limited to eyes that had incisional and thermal keratorefractive surgery. Ongoing research will help determine the most effective methods of calculating IOL power in eyes that have had lamellar keratorefractive surgery (eg, PRK or LASIK). Further modification is necessary in these situations because of the inaccuracy of the standardized values of the index of refraction.[16]

As part of informed consent, we continue to tell our patients that IOL calculations after keratorefractive surgery remain a challenge and that refractive surprises can occur. We explain that further surgery (eg, placement of a piggyback IOL) may be necessary to enhance uncorrected visual acuity. We defer secondary procedures until a full 3 months postoperatively and document refractive stability before proceeding.

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