

Use of the Posterior/Anterior Corneal Curvature Radii Ratio to Improve the Accuracy of Intraocular Lens Power Calculation: Eom's Adjustment Method

Mingue Kim, Youngsub Eom, Hwa Lee, Young-Woo Suh, Jong Suk Song, and Hyo Myung Kim

Department of Ophthalmology, Korea University College of Medicine, Seoul, South Korea

Correspondence: Youngsub Eom, Department of Ophthalmology, Ansan Hospital, Korea University College of Medicine, 123, Jeokgeum-ro, Danwon-gu, Ansan-si, Gyeonggi-do 15355, South Korea; hippotate@hanmail.net.

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PURPOSE. To evaluate the accuracy of IOL power calculation using adjusted corneal power according to the posterior/anterior corneal curvature radii ratio.

METHODS. Nine hundred twenty-eight eyes from 928 reference subjects and 158 eyes from 158 cataract patients who underwent phacoemulsification surgery were enrolled. Adjusted corneal power of cataract patients was calculated using the fictitious refractive index that was obtained from the geometric mean posterior/anterior corneal curvature radii ratio of reference subjects and adjusted anterior and predicted posterior corneal curvature radii from conventional keratometry (K) using the posterior/anterior corneal curvature radii ratio. The median absolute error (MedAE) based on the adjusted corneal power was compared with that based on conventional K in the Haigis and SRK/T formulae.

RESULTS. The geometric mean posterior/anterior corneal curvature radii ratio was 0.808, and the fictitious refractive index of the cornea for a single Scheimpflug camera was 1.3275. The mean difference between adjusted corneal power and conventional K was 0.05 diopter (D). The MedAE based on adjusted corneal power (0.31 D in the Haigis formula and 0.32 D in the SRK/T formula) was significantly smaller than that based on conventional K (0.41 D and 0.40 D, respectively; $P < 0.001$ and $P < 0.001$, respectively). The percentage of eyes with refractive prediction error within ± 0.50 D calculated using adjusted corneal power (74.7%) was significantly greater than that obtained using conventional K (62.7%) in the Haigis formula ($P = 0.029$).

CONCLUSIONS. IOL power calculation using adjusted corneal power according to the posterior/anterior corneal curvature radii ratio provided more accurate refractive outcomes than calculation using conventional K.

Keywords: intraocular lens, calculation, corneal power, posterior corneal radius, cataract

IOL power calculation comprises three main parts: measurement of corneal power, estimation of effective lens position, and measurement of axial length (AL).¹⁻³ Of these three components, corneal power can be obtained from corneal thickness and anterior and posterior corneal curvature radii. However, in the past, clinical data regarding the posterior corneal curvature radius were not available. Thus, corneal refractive power was traditionally estimated from anterior corneal measurements, keratometry (K), using a fictitious refractive index of the cornea under the assumption that the posterior/anterior corneal curvature radii ratio is constant.⁴ Conventional K has become the gold standard for corneal power in IOL power calculation of cataract surgery.

Scheimpflug tomography, an optical system for anterior segment analysis, provides both anterior and posterior corneal measurements as well as corneal thickness. As clinical data have become available on the variability of the posterior corneal curvature radius, there have been efforts to improve the accuracy of IOL power calculation using posterior corneal measurements.⁵⁻⁷ Tamaoki et al.⁵ demonstrated that IOL power calculation using real corneal power values obtained from both the anterior and posterior corneal curvature radii improved refractive outcomes in eyes with posterior keratoconus. In

contrast, there was no improvement in the accuracy of IOL power calculation in normal eyes when corneal power measurements from a Scheimpflug camera were applied directly.⁸

We hypothesized that if conventional K can be adjusted according to the posterior/anterior corneal curvature radii ratio without changing the mean value of the entire data set, the adjusted corneal power could reduce the refractive prediction error created by the assumption that the posterior/anterior corneal curvature radii ratio is constant in IOL power calculation. This study introduces a method for adjusting conventional K according to the posterior/anterior corneal curvature radii ratio without changing the mean value of the entire data set. The aim of this study was to evaluate the accuracy of IOL power calculation using adjusted corneal power according to the posterior/anterior corneal curvature radii ratio.

MATERIALS AND METHODS

Study Population

This retrospective cross-sectional study included 928 eyes of 928 reference subjects and 158 eyes of 158 cataract patients.



The Institutional Review Board of Korea University Ansan Hospital, Gyeonggi, Korea, approved this study. All research and data collection adhered to the tenets of the Declaration of Helsinki.

Electronic medical records of all subjects who underwent measurement with a single Scheimpflug camera (Pentacam; Oculus Optikgeräte, Wetzlar, Germany) at our institution between May 1, 2009, and January 31, 2015, were reviewed.⁹ Reference subjects were selected based on the results of a single Scheimpflug examination as previously described.⁹ Exclusion criteria included (1) age younger than 30 years, (2) a history of previous ocular surgery, (3) presence of corneal disease (such as keratoconus) or other corneal pathology that could affect Scheimpflug measurement, or (4) use of a contact lens within 3 weeks prior to measurement.⁹

One hundred fifty-eight consecutive patients who underwent uncomplicated phacoemulsification with implantation of an IOL (Tecnis ZCB00 1-Piece; Abbott Medical Optics, Inc., Santa Ana, CA, USA) at our institution between March 1, 2013, and October 31, 2016, were enrolled. Patients with preoperative measurements from a single Scheimpflug camera with good-quality states (quality okay mark displayed on Pentacam maps) and with a best-corrected visual acuity (BCVA) $\geq 20/40$ in the operated eye after cataract surgery were included. Eyes with a history of previous ocular surgery (e.g., penetrating keratoplasty or refractive surgery), corneal diseases such as keratoconus, corneal pathologies that could affect Scheimpflug measurements, traumatic cataract, sulcus fixated IOLs, IOL exchanges, or postoperative complications were excluded.

Patient Examination

In 928 reference subjects, anterior and posterior corneal curvature radii and central corneal thickness were measured using a single Scheimpflug camera. In 158 cataract patients, preoperative K, anterior chamber depth (ACD), and AL were measured using an optical biometer (IOLMaster 500, version 7.3; Carl Zeiss Meditec, Jena, Germany). In addition, preoperative anterior and posterior corneal curvature radii were measured using a single Scheimpflug camera, and the true net power and total corneal refractive power of the 1.0- to 6.0-mm apex zone were extracted from the power distribution report.¹⁰ Postoperative uncorrected distance visual acuity, BCVA, objective refraction measured with an autorefractor/keratometer (KR-8100; Topcon, Tokyo, Japan), and subjective refraction were measured at visits between 4 and 8 weeks after cataract surgery.

Surgical Technique

All phacoemulsification with IOL implantation procedures were performed under topical anesthesia with 0.5% proparacaine hydrochloride (Paracaine; Hanmi Pharm, Seoul, Korea) by one of three experienced surgeons. A 2.75-mm clear corneal incision was made, and a continuous curvilinear capsulorhexis slightly smaller than the IOL optic size was created with a 26-gauge needle and capsulorhexis forceps. A standard phacoemulsification technique was used, and the IOL was inserted into the capsular bag using an injector system.

Main Outcome Measures

Fictitious Refractive Index of the Cornea for a Single Scheimpflug Camera. Single Scheimpflug measurements of 928 reference subjects were obtained. The geometric mean posterior/anterior corneal curvature radii ratio, mean anterior corneal curvature radius, mean central corneal thickness, thick lens formula, and thin lens formula were used to calculate the

fictitious refractive index of the cornea for a single Scheimpflug camera as follows²:

$$D_A = \frac{(n_{cornea} - 1) \times 1000}{r_{cornea}} \quad (1)$$

$$D_P = \frac{(n_{aqueous} - n_{cornea}) \times 1000}{r_{cornea} \times R_{PA}} \quad (2)$$

$$D_{Total} = D_A + D_P - \frac{T}{n_{cornea} \times 1000} \times D_A \times D_P \quad (3)$$

$$n_c = \frac{D_{Total} \times r_{cornea}}{1000} + 1 \quad (4)$$

where D_A is the dioptric power of the anterior corneal surface, n_{cornea} is the refractive index of the cornea (1.376), r_{cornea} is the mean anterior corneal curvature radius, D_P is the dioptric power of the posterior corneal surface, $n_{aqueous}$ is the refractive index of the aqueous (1.336), R_{PA} is the geometric mean posterior/anterior corneal curvature radii ratio, D_{Total} is the dioptric power of the total cornea, T is the mean central corneal thickness, and n_c is the fictitious refractive index of the cornea for a single Scheimpflug camera.

Adjustment of Conventional K. In 158 cataract patients, the adjusted anterior corneal curvature radius and the predicted posterior corneal curvature radius were calculated using the fictitious refractive index of the cornea for a single Scheimpflug camera, K measurements of the IOLMaster, and the posterior/anterior corneal curvature radii ratio as follows:

$$r_A = \frac{(n_c - 1) \times 1000}{D_{IOLMaster}} \quad (5)$$

$$r_P = r_A \times R_{PA} \quad (6)$$

where r_A is the adjusted anterior corneal curvature radius, n_c is the fictitious refractive index of the cornea for a single Scheimpflug camera, $D_{IOLMaster}$ is the dioptric power of K measurements of the IOLMaster, r_P is the predicted posterior corneal curvature radius, and R_{PA} is the posterior/anterior corneal curvature radii ratio.

Adjusted corneal power was calculated using a thick lens formula based on the adjusted anterior corneal curvature radius, predicted posterior corneal curvature radius, refractive indices of cornea and aqueous humor (1.376 and 1.336, respectively), and central corneal thickness.⁴

Optimization of Haigis Constants and the SRK/T A-Constant. The data-adjusted a_0 , a_1 , and a_2 constants for the Haigis formula were calculated with linear regression analysis using the back-calculated effective lens position in order to obtain zero mean arithmetic error in IOL power prediction.¹¹ The back-calculated effective lens position was defined as the postoperatively calculated effective lens position based on preoperative K, AL, implanted IOL power, and postoperative refraction.^{1,11,12} The Haigis constant optimization Excel spreadsheet (Microsoft, Inc., Redmond, WA, USA) was used to calculate the data-adjusted SRK/T A-constant.¹³

Refractive Prediction Error. The median absolute error (MedAE) was defined as the median absolute value of the refractive prediction error. The refractive prediction error was defined as the difference between the refractive spherical equivalent observed 4 to 8 weeks after surgery and the preoperative predicted refraction determined using the Haigis and SRK/T formulae (refractive prediction error = postoperative spherical equivalent – preoperative predicted refraction).

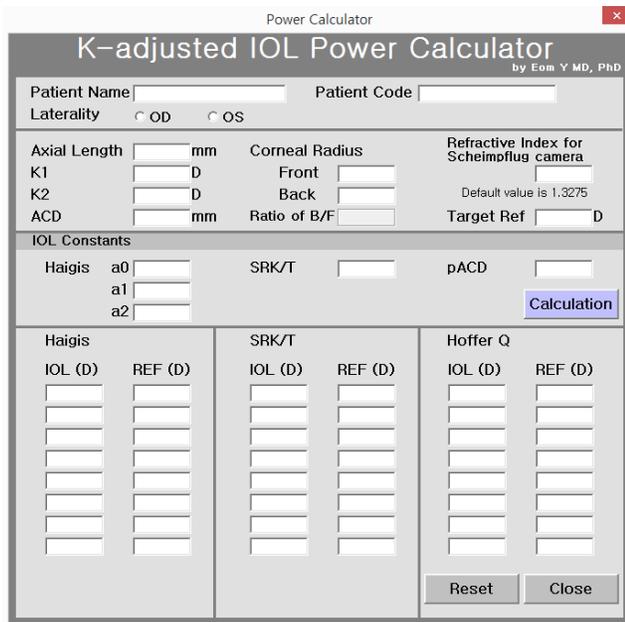


FIGURE 1. The K-adjusted IOL power calculator developed for this study to improve refractive outcomes using adjusted corneal power according to the posterior/anterior corneal curvature radii ratio.

IOL power calculations were completed using three methods. One method employed preoperative K measured with the IOLMaster according to the conventional keratometer method using a refractive index of 1.3315. Another method used adjusted corneal power with the posterior/anterior corneal curvature radii ratio. The third method used the true net power and total corneal refractive power of the 1.0- to 6.0-mm apex zone of Pentacam.

Patients were divided into two groups according to the lower (25th) and upper (75th) quartiles of the posterior/anterior corneal curvature radii ratio: the middle 50% of the data group, and the lower and upper 25% of the data group. The effects of using adjusted corneal power on the accuracy of IOL power calculation were compared between two subgroups.

IOL Power Calculator Using Adjusted Corneal Power

Excel (Microsoft, Inc.) was used to develop a K-adjusted IOL power calculator (Supplementary Material; and an online calculator, available in the public domain at <http://www.eomy.kr/kadjiolcalc>).^{9,11,14} This calculator enables easy calculation of the predicted refraction and IOL power using the Haigis, Hoffer Q, and SRK/T formulae with adjusted corneal power based on the posterior/anterior corneal curvature radii ratio (Fig. 1).

Statistical Analysis

Descriptive statistics for all patient data were obtained using statistical software (Statistical Package for Social Sciences (SPSS), version 21.0; IBM Corp., Armonk, NY, USA). Linear regression analyses were performed to evaluate the relationship between the posterior/anterior corneal curvature radii ratio and refractive prediction error. Wilcoxon signed-rank tests were conducted to compare MedAE, and paired *t*-tests were performed to compare mean absolute error. χ -Square tests were performed to determine whether there was a

TABLE 1. Clinical Characteristics of Cataract Patients and Their Eyes in a Study of IOL Power Calculation Using the Posterior/Anterior Corneal Curvature Radii Ratio (*n* = 158)

Parameter	Mean (SD)	Range
Age, y	68.5 (11.0)	30-88
Sex		
Male, <i>n</i> (%)	69 (43.7)	
Female, <i>n</i> (%)	89 (56.3)	
Laterality		
Right eye, <i>n</i> (%)	71 (44.9)	
Left eye, <i>n</i> (%)	87 (55.1)	
Keratometry, D*	44.30 (1.72)	39.10-50.68
ACD, mm*	3.10 (0.43)	2.14-4.43
AL, mm*	23.43 (1.19)	20.48-27.66
IOL power, D	21.8 (2.7)	11.0-27.0
Anterior corneal radius of curvature, mm†	7.62 (0.30)	6.88-8.42
Posterior corneal radius of curvature, mm†	6.21 (0.26)	5.44-6.88
Ratio _{PA} †	0.815 (0.026)	0.700-0.877

Ratio_{PA}, posterior/anterior corneal curvature radii ratio. Data are presented as mean (SD) except for sex and laterality, which are presented as *n* (%).

* K, ACD, and AL measured by IOLMaster.

† Anterior and posterior corneal curvature radii measured by a single Scheimpflug camera.

statistically significant difference in the ratio of refractive prediction error. A post hoc power analysis using the χ -square tests option of G*power (version 3.1.9.2; Franz Paul, Kiel, Germany) was conducted to determine study power. *P* values less than 0.05 were considered statistically significant.

RESULTS

Of 928 reference subjects, mean age was 52.7 ± 11.8 years (range, 30-89 years), and there were 484 males (52.2%) and 466 left eyes (50.2%).⁹ The geometric mean posterior/anterior corneal curvature radii ratio was 0.808. Mean anterior corneal curvature radius was 7.71 mm, and mean central corneal thickness was 0.565 mm. Based on these results, the fictitious refractive index of the cornea for a single Scheimpflug camera was calculated as 1.3275. Of 158 cataract patients, the mean age of subjects was 68.5 ± 11.0 years (range, 30-88 years). There were 89 females (56.3%) and 87 left eyes (55.1%). The mean adjusted corneal power was 44.35 ± 1.78 diopter (D), and the mean difference between adjusted corneal power and conventional K was 0.05 ± 0.21 D. Preoperative K, ACD, and AL measured via IOLMaster and anterior and posterior corneal curvature radii using a single Scheimpflug camera are shown in Table 1.

In spite of IOL constant optimization, the refractive prediction error derived from the use of conventional K became more myopic as the posterior/anterior corneal curvature radii ratio increased in both the Haigis and SRK/T formulae (Figs. 2A, 2B); however, no correlation and/or a decreased correlation was observed between the refractive prediction error and the posterior/anterior corneal curvature radii ratio when adjusted corneal power was used in the IOL power calculation (Figs. 2C, 2D).

Table 2 shows MedAE and mean refractive prediction error as determined by two different methods, one using adjusted corneal power, the other using conventional K. The MedAE predicted using the adjusted corneal power (0.31 D in the Haigis formula and 0.32 D in the SRK/T formula) was significantly smaller than that predicted using conventional K (0.41 D in the Haigis formula and 0.40 D in the SRK/T formula;

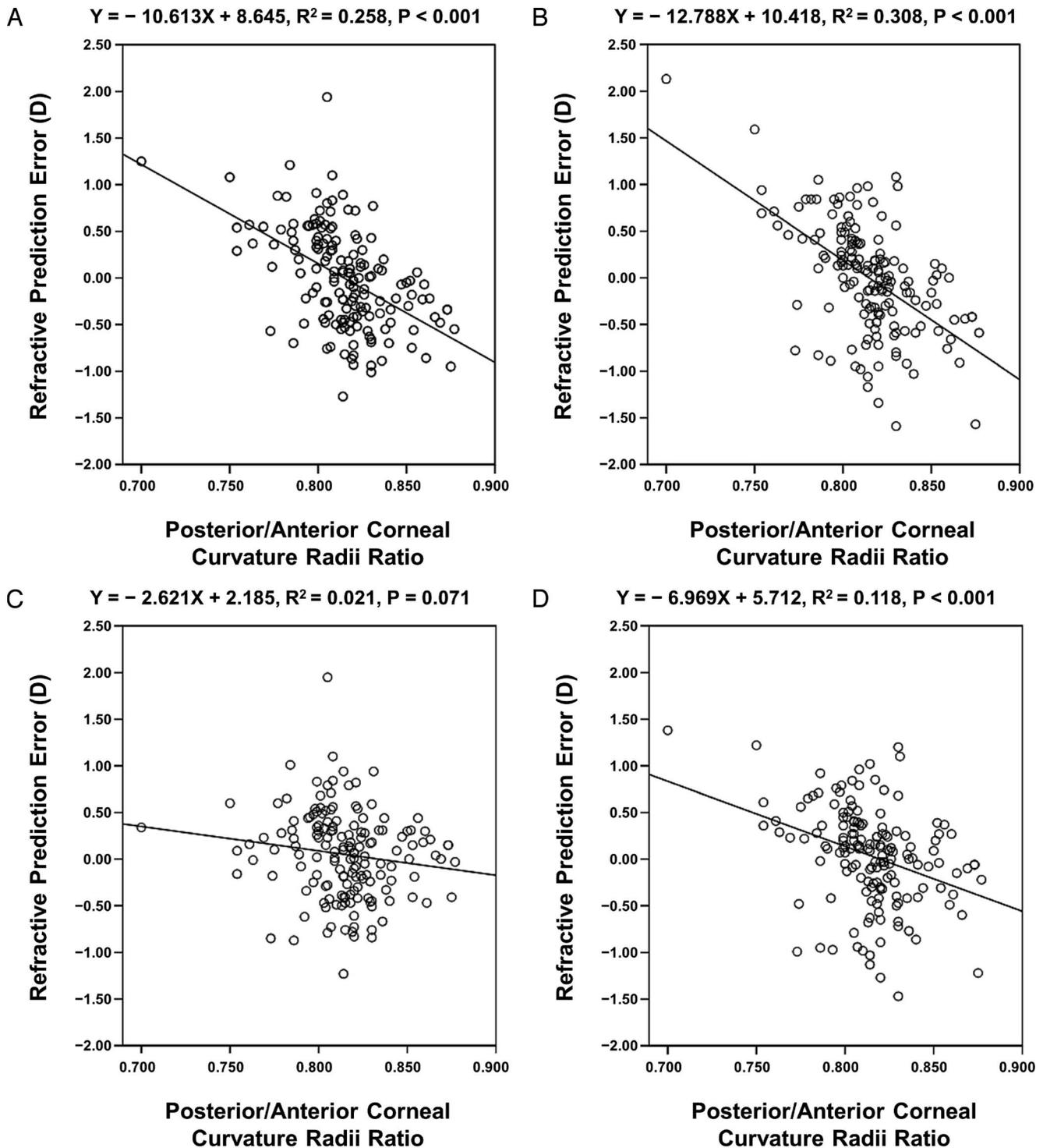


FIGURE 2. Linear regression analysis of the relationship between the posterior/anterior corneal curvature radii ratio and the refractive prediction error after optimization of IOL constants in the Haigis and SRK/T formulae. (A, B) IOL power calculation using conventional K; (C, D) IOL power calculation using adjusted corneal power according to the posterior/anterior corneal curvature radii ratio; (A, C) the Haigis formula; (B, D) the SRK/T formula.

$P < 0.001$ and $P < 0.001$, respectively). The percentage of eyes that achieved a postoperative refractive prediction error within ± 0.50 D from the preoperative predicted refraction was 62.7%, when conventional K was used in the Haigis formula. This percentage improved significantly to 74.7% when adjusted corneal power was applied to the Haigis formula ($P = 0.029$).

In a post hoc power analysis, the calculated effect size from the percentage of eyes within ± 0.50 D of the refractive prediction error was 0.248. The effect size of 0.248 and α of 0.05 with 158 patients led to a power of 0.88.

All MedAEs predicted using the true net power and total corneal refractive power were significantly greater than that

TABLE 2. Comparison of MedAE and Mean Refractive Prediction Error Calculated Using Conventional K and Adjusted Corneal Power According to the Posterior/Anterior Corneal Curvature Radii Ratio in the Haigis and SRK/T Formulae ($n = 158$)

	Conventional K	Adjusted Corneal Power	P Value
Haigis formula			
MedAE, D*	0.41 (0.20:0.57)	0.31 (0.17:0.51)	<0.001‡
MAE, D†	0.44 (0.31)	0.37 (0.29)	<0.001§
RE, D (range)	0.00 (−1.27 to 1.94)	0.05 (−1.23 to 1.95)	
±0.25 D, <i>n</i> (%)	51 (32.3)	63 (39.9)	
±0.50 D, <i>n</i> (%)	99 (62.7)	118 (74.7)	0.029
±0.75 D, <i>n</i> (%)	135 (85.4)	139 (88.0)	
>±1.00 D, <i>n</i> (%)	7 (4.4)	4 (2.5)	
SRK/T formula			
MedAE, D*	0.40 (0.16:0.70)	0.32 (0.14:0.60)	<0.001‡
MAE, D†	0.46 (0.37)	0.41 (0.33)	<0.001§
RE, D (range)	0.00 (−1.59 to 2.13)	0.03 (−1.47 to 1.38)	
±0.25 D, <i>n</i> (%)	57 (36.1)	65 (41.1)	
±0.50 D, <i>n</i> (%)	97 (61.4)	112 (70.9)	0.096
±0.75 D, <i>n</i> (%)	122 (77.2)	132 (83.5)	
>±1.00 D, <i>n</i> (%)	10 (6.3)	10 (6.3)	

MAE, mean absolute error; RE, mean refractive prediction error.

* Values are presented as median (interquartile range).

† Values are presented as mean (SD).

‡ Wilcoxon signed-rank test.

§ Paired *t*-test.

|| χ -square test.

predicted using conventional K in the Haigis formula (all $P < 0.05$; Fig. 3). In the SRK/T formula, all MedAEs predicted using the true net power and total corneal refractive power were significantly greater than that predicted using conventional K, except the true net power and total corneal refractive power of the 2.0-, 3.0-, and 4.0-mm apex zone (Fig. 4).

In subgroup analysis, there were no significant differences in MedAE and the percentage of eyes with refractive prediction error within ± 0.50 D calculated using conventional K and adjusted corneal power in the middle 50% of the data group. In contrast, MedAE predicted using adjusted corneal power (0.31 D in the Haigis formula and 0.38 D in the SRK/T formula) was significantly smaller than that predicted using conventional K (0.44 D in the Haigis formula and 0.52 D in the SRK/T formula; $P < 0.001$ and $P < 0.001$, respectively) in the upper and lower 25% of the data group. In addition, the percentage of eyes with refractive prediction error within ± 0.50 D calculated using adjusted corneal power was significantly greater than that obtained using conventional K in both the Haigis and SRK/T formulae in the upper and lower 25% of the data group (Tables 3, 4).

DISCUSSION

This study suggests a method for adjusting conventional K according to the posterior/anterior corneal curvature radii ratio without changing the mean value of the entire data set and calculated IOL power using this adjusted corneal power. The results of this study showed that IOL power calculation using the adjusted corneal power obtained through our method provides a more accurate estimate of refractive outcomes than IOL power calculation using conventional K. In addition, this study introduced the K-adjusted IOL power calculator. Thus, the user can easily calculate IOL power and can predict postoperative refraction using this K-adjusted IOL power calculator in order to apply the posterior/anterior corneal curvature radii ratio to conventional K in IOL power calculation.

In this study, refractive prediction error was significantly correlated with the posterior/anterior corneal curvature radii ratio when conventional K was used, while there was no association or a decreased correlation between the refractive prediction error and the posterior/anterior corneal curvature radii ratio when adjusted corneal power was used. This indicates that the bias in refractive prediction error derived from the use of conventional K could be eliminated by using adjusted corneal power. Consistent with our results, Miyata et al.¹⁵ demonstrated a significant association between the refractive prediction error and posterior corneal curvature when single Scheimpflug imaging was not included in IOL power calculation.

Similar to this study's method and findings, previous studies introduced a theoretical variable keratometric index according to the anterior corneal curvature radius for normal eyes^{16,17} and demonstrated that using the variable keratometric index could improve refractive outcomes after multifocal IOL implantation.^{18,19} IOL power calculation using adjusted corneal power calculated with the variable keratometric index also improved refractive outcomes in eyes with a history of previous refractive corneal surgery after cataract surgery.²⁰⁻²²

There were no improvements in refractive outcomes when we applied the true net power and total corneal refractive power from Pentacam directly to IOL power calculation despite IOL constant optimization; instead, outcomes were worse in many cases. In line with this study, previous studies also found no superiority using the corneal power derived from both the anterior and posterior corneal measurements of a single Scheimpflug camera relative to using simulated K in IOL power calculation for normal eyes.^{6-8,15} Whang et al.²³ found that K readings from the IOLMaster are appropriate for IOL power calculation, but K readings from other devices are not. In addition, the true net power map and refractive power map at various zones and rings of the single Scheimpflug camera were significantly different from the K reading from the IOLMaster.⁶ K readings are usually taken from a 3.0- or 2.5-mm-diameter midperipheral area, but not from the most important central area.

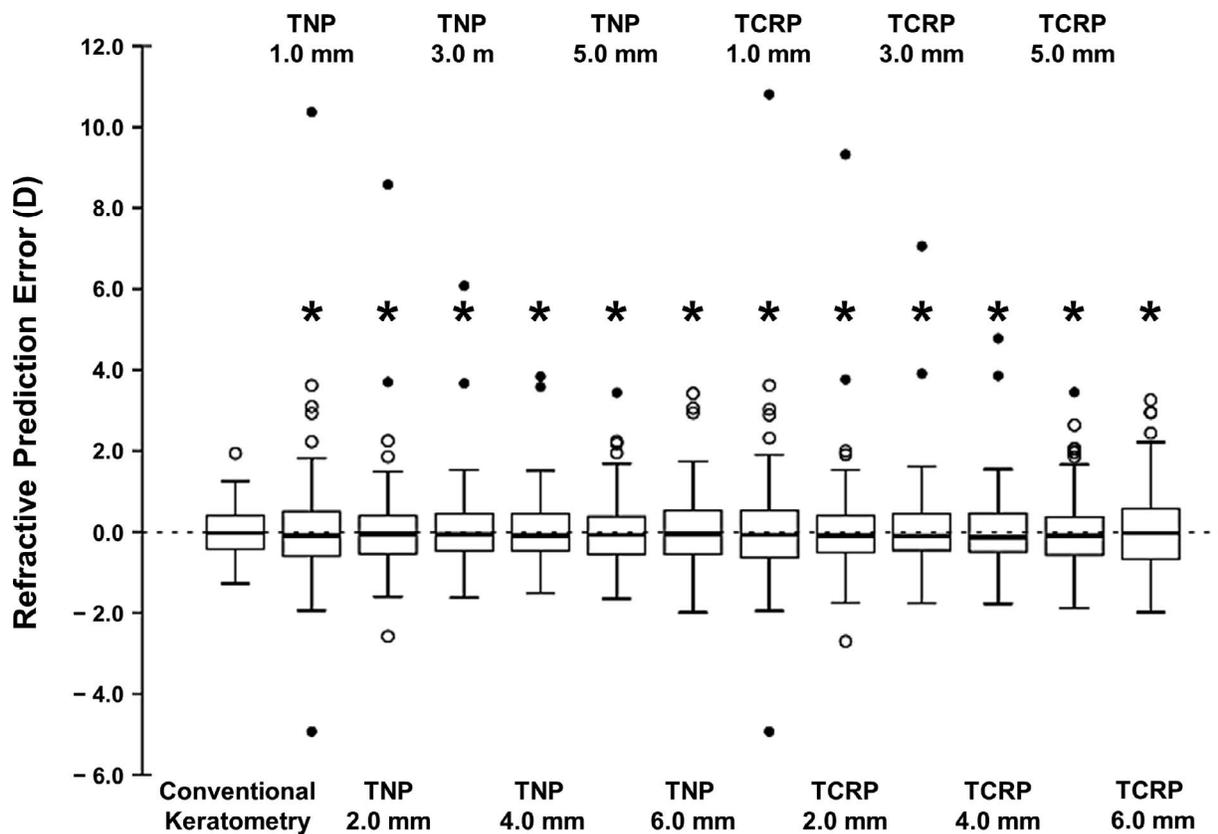


FIGURE 3. Refractive prediction error calculated using conventional K and the true net power (TNP) and total corneal refractive power (TCRP) of Pentacam in the Haigis formula ($n = 158$). An asterisk indicates a significant difference (P value < 0.05) compared with conventional K by the Wilcoxon signed-rank test.

Ray tracing is the gold standard method for calculating the path of rays in lenses and optical systems, and previous studies have used ray tracing in IOL power calculation.²⁴⁻²⁶ Ray-tracing IOL power calculations in normal eyes showed comparable accuracy compared to the conventional formula,^{24,25} although the refractive outcomes obtained by applying the true net power and total corneal refractive power to IOL power calculation were worse than those obtained using conventional K in this study. In addition, in eyes with prior myopic ablation, ray-tracing IOL power calculation provided accurate refractive outcomes similar to those in eyes without prior surgery.²⁶ Ray-tracing IOL power calculation does not use the fictitious refractive index for corneal power calculation.²⁶ On the other hand, the method used in this study relies on the introduced fictitious refractive index of the cornea for a single Scheimpflug camera to adjust IOLMaster K according to the posterior/anterior corneal curvature radii ratio. Therefore, the refractive outcomes from ray-tracing IOL power calculation are more accurate than the method used in this study. However, devices that perform ray-tracing IOL power calculation are not available in all eye clinics, and many ophthalmologists are most familiar with conventional formulae. Thus, we sought to reduce error caused by the conventional method by creating a method that would be useful in clinics where IOL power calculation via optical ray tracing are not available.

IOL constants used in IOL power calculation formulae are optimized for conventional K because conventional K is the gold-standard biometry in IOL power calculation. In order to avoid altering the IOL constants of various formulae, this study introduced a method that adjusts conventional K without changing the mean value for the entire data set. When optimized IOL constants were applied to IOL power calculation,

a nearly zero mean arithmetic error was obtained for IOL power prediction with not only conventional K but also with adjusted corneal power. As a result, the accuracy of IOL power calculation could be improved using adjusted corneal power based on our method with original IOL constants derived from conventional K.

Although the accuracy of IOL power calculation significantly improved when using adjusted corneal power, the magnitude of improvement in MedAE (0.10 D in the Haigis formula and 0.08 D in the SRK/T formula) may not have clinical relevance. Although modern IOL power calculation formulae provide similarly excellent refractive outcomes in eyes with average AL, refractive outcomes become less accurate in eyes that deviate from average AL.^{27,28} Similarly, refractive outcomes might become less accurate in eyes that deviate from the average posterior/anterior corneal curvature radii ratio. In fact, the magnitude of improvement in MedAE using adjusted corneal power increased up to 0.13 D in the Haigis formula and 0.14 D in the SRK/T formula in the upper and lower 25% of data when patients were divided into two groups according to the lower (25th) and upper quartile (75th) of the posterior/anterior corneal curvature radii ratio. In contrast, there was no improvement in MedAE in the middle 50% of the data. Consistent with this study, direct application of corneal power derived from both the anterior and posterior corneal measurements to IOL power calculation improved refractive outcomes in eyes with posterior keratoconus that deviated from the average posterior/anterior corneal curvature radii ratio⁵ but not in normal eyes.^{6,7,15} Thus, IOL power calculation using the adjusted corneal power developed in this study might have clinical benefit, especially in eyes that deviate from the average posterior/anterior corneal curvature radii ratio.

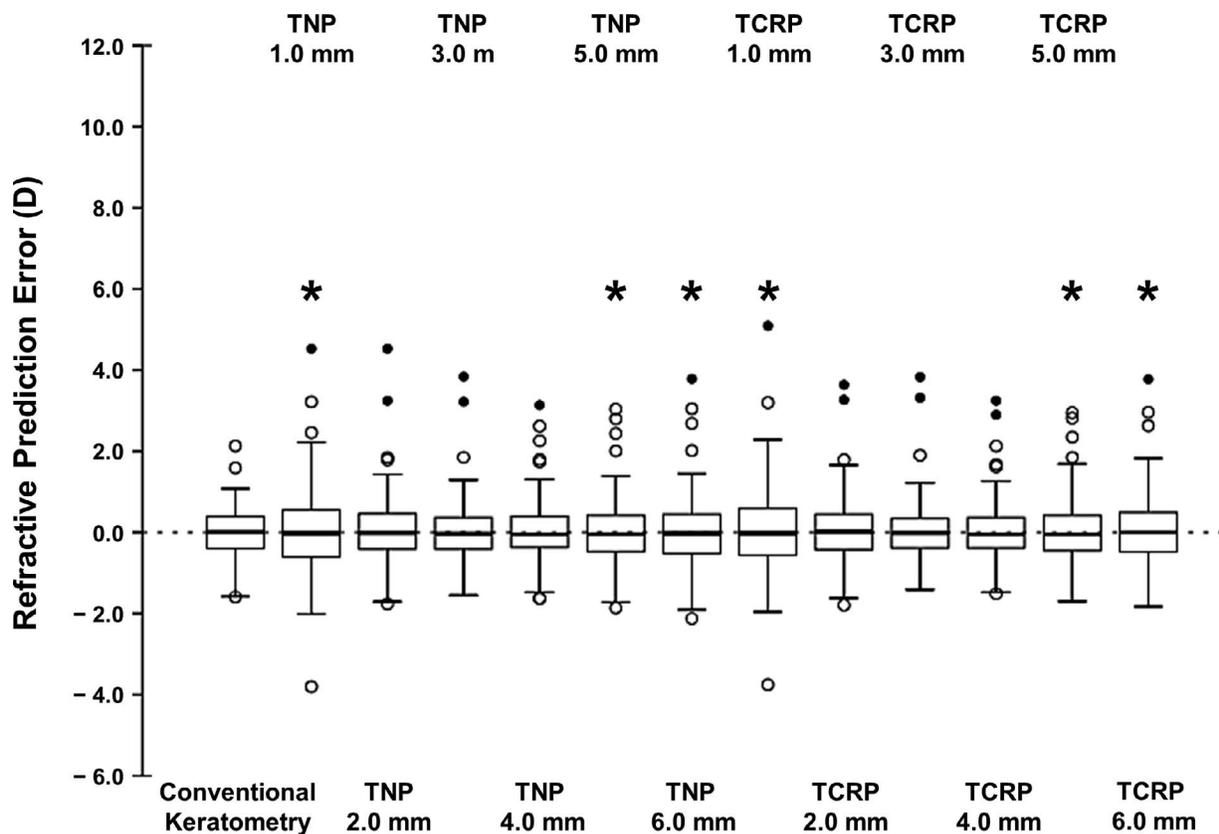


FIGURE 4. Refractive prediction error calculated using conventional K and the TNP and TCRP of Pentacam in the SRK/T formula ($n = 158$). An asterisk indicates a significant difference (P value < 0.05) compared with conventional K by the Wilcoxon signed-rank test.

There are some limitations to this study. First, our method was retrospectively tested in 158 cataract eyes, although our reference refractive index for the cornea was obtained via single Scheimpflug camera data from 928 reference subjects.

Second, this study used a single acquisition by a single Scheimpflug camera to adjust corneal power. There is the possibility of error occurring when using a single acquisition by a single Scheimpflug measurement, even though this study

TABLE 3. Comparison of MedAE and RE Based on the Posterior/Anterior Corneal Curvature Radii Ratio Between Calculations Using Conventional K and Those Using Adjusted Corneal Power in the Haigis Formula

	Conventional K	Adjusted Corneal Power	P Value
Ratio _{PA} ≤ Q1 or > Q3 ($n = 79$)			
MedAE, D*	0.44 (0.22:0.63)	0.31 (0.17:0.48)	<0.001‡
MAE, D†	0.46 (0.29)	0.35 (0.24)	<0.001§
RE, D (range)	0.04 (-1.01 to 1.25)	0.09 (-0.87 to 1.01)	
±0.25 D, n (%)	22 (27.8)	34 (43.0)	
±0.50 D, n (%)	44 (55.7)	61 (77.2)	0.007
±0.75 D, n (%)	67 (84.8)	72 (91.1)	
>±1.00 D, n (%)	4 (5.1)	1 (1.3)	
Q1 < Ratio _{PA} ≤ Q3 ($n = 79$)			
MedAE, D*	0.36 (0.18:0.55)	0.34 (0.17:0.53)	0.126‡
MAE, D†	0.41 (0.33)	0.40 (0.32)	0.130§
RE, D (range)	-0.05 (-1.27 to 1.94)	0.01 (-1.23 to 1.95)	
±0.25 D, n (%)	29 (36.7)	29 (36.7)	
±0.50 D, n (%)	55 (69.6)	57 (72.2)	0.861
±0.75 D, n (%)	68 (86.1)	67 (84.8)	
>±1.00 D, n (%)	3 (3.8)	3 (3.8)	

Q1, lower quartile (25th) of Ratio_{PA}; Q3, upper quartile (75th) of Ratio_{PA}.

* Values are presented as median (interquartile range).

† Values are presented as mean (SD).

‡ Wilcoxon signed-rank test.

§ Paired t -test.

|| χ -square test.

TABLE 4. Comparison of MedAE and RE Based on the Posterior/Anterior Corneal Curvature Radii Ratio Between Calculations Using Conventional K and Those Using Adjusted Corneal Power in the SRK/T Formula

	Conventional K	Adjusted Corneal Power	P Value
Ratio _{PA} ≤ Q1 or > Q3 (n = 79)			
MedAE, D*	0.52 (0.21:0.80)	0.38 (0.14:0.67)	<0.001‡
MAE, D†	0.55 (0.41)	0.45 (0.35)	<0.001§
RE, D (range)	0.04 (−1.59 to 2.13)	0.07 (−1.47 to 1.38)	
±0.25 D, n (%)	23 (29.1)	28 (35.4)	
±0.50 D, n (%)	39 (49.4)	53 (67.1)	0.036
±0.75 D, n (%)	55 (69.6)	65 (82.3)	
>±1.00 D, n (%)	7 (8.9)	6 (7.6)	
Q1 < Ratio _{PA} ≤ Q3 (n = 79)			
MedAE, D*	0.30 (0.13:0.55)	0.27 (0.12:0.52)	0.112‡
MAE, D†	0.38 (0.31)	0.37 (0.31)	0.116§
RE, D (range)	−0.04 (−1.34 to 0.98)	−0.00 (−1.27 to 1.02)	
±0.25 D, n (%)	34 (43.0)	37 (46.8)	
±0.50 D, n (%)	58 (73.4)	59 (74.7)	>0.999
±0.75 D, n (%)	67 (84.8)	67 (84.8)	
>±1.00 D, n (%)	3 (3.8)	4 (5.1)	

* Values are presented as median (interquartile range).

† Values are presented as mean (SD).

‡ Wilcoxon signed-rank test.

§ Paired *t*-test.

|| χ -square test.

used scans with good-quality states and Pentacam measurements of both anterior and posterior corneal curvature radii showed good repeatability and reliability.^{9,29,30} Thus, a prospective study with a large number of cataract eyes that have multiple measurements of a single Scheimpflug camera will be needed to address whether IOL power calculation using adjusted corneal power based on the posterior/anterior corneal curvature radii ratio is superior to that using conventional K.

In conclusion, IOL power calculation using adjusted corneal power based on the posterior/anterior corneal curvature radii ratio might more accurately predict postoperative refraction than that using conventional K. To apply posterior corneal measurement to IOL power calculation, the posterior/anterior corneal curvature radii ratio can be used in the K-adjusted IOL power calculator developed in this study.

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