Ratio of Axial Length to Corneal Radius in Japanese Patients and Accuracy of Intraocular Lens Power Calculation Based on Biometric Data

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• PURPOSE: To evaluate the features of the axial length-to-corneal radius (AL/CR) ratio in Japanese patients with cataracts and to determine the accuracy of intraocular lens (IOL) power calculation formulas according to the AL/CR features and the axial length (AL).
• DESIGN: Retrospective observational case series.
• METHODS: Setting was a clinical practice. Patient population was a total of 1,135 eyes (1,135 patients) with cataracts. Observation procedures included measurement of the AL and corenal radius (CR) by optical biometry and evaluation of the refractive outcomes by using the SRK/T, Holladay 1, Hoffer Q, Haigis, and Barrett Universal II formulas. Main outcome measurements were the features of the AL/CR ratio and the accuracy of IOL power calculations based on the AL/CR ratio and the AL.
• RESULTS: The mean AL/CR ratio was 3.15 ± 0.19. Significant weak negative correlations were observed between the spherical equivalent (SE) and AL ($r = -0.7489$; $P < .001$) and between the SE and AL/CR ratio ($r = -0.8069$; $P < .001$); no correlation was found between the SE and CR ($r = 0.0208$, $P = .483$). For medium ALs and high AL/CR ratios, the SRK/T formula performed less accurately. For long ALs and high AL/CR ratios, the Holladay 1 and Hoffer Q formulas performed less accurately. The Barrett Universal II formula performed well across a range of ALs and AL/CR ratios.
• CONCLUSIONS: The AL/CR ratio explained the total variation in the SE better than the AL alone. Surgeons should pay attention to the selection of IOL power calculation formulas in eyes with high AL/CR ratios. (Am J Ophthalmol 2020;218:320–329.

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Cataract surgeries are both rehabilitative and refractive procedures. With modern surgical techniques, patients' expectations for perfect postoperative vision are increasing day by day. Partial coherence interferometry has increased the precision of the preoperative measurements, leading to improved postoperative refractive results.[1,2] Postoperative refractive errors depend mainly on 4 factors: corneal power, axial length (AL), intraocular lens (IOL) type, and postoperative anterior chamber depth (ACD).[3–5] Popular third-generation formulas (ie, the Hoffer Q,[6] the SRK/T,[7] and the Holladay 1)[8] calculate the theoretical effective lens position (ELP) using the AL and corneal power. The newer fourth- and fifth-generation formulas, Haigis[1] and Barrett Universal II,[9] respectively, include additional parameters for calculating the ELP, including the preoperative ACD in the Haigis formula and lens thickness; ACD; and the corneal white-to-white value in the Barrett Universal II.

Modern IOL calculation formulas show similarly accurate refractive outcomes in eyes with normal ALs.[10–12] However, among the wide range of available IOL power formulas, none is completely accurate in all scenarios. Considering that each formula determines the ELP in different ways based on the input variables, certain formulas should be more accurate under specific conditions related to the input variables used, such as the AL and corneal keratometry reading. Recently, 3 new methods of IOL power selection, the Ladas Super Formula,[13] the FullMonte IOL method,[14] and the Hill-Radial Basis Function method,[15] have been proposed. These methods predict the refractive outcomes by considering the particular combination of AL and keratometry or by pattern recognition. However, the prediction errors using these new methods have not surpassed those of the conventional methods.[16]

Refractive errors, which are related closely to visual function, vary among populations.[17–23] In addition, the optimized lens constants for IOL calculation differ according to race.[24] Therefore, the refractive outcomes of

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cataract surgeries in previous reports from Western countries may not be applicable to Asian eyes.

Grosvenor[25] first reported an association between the AL and the axial length-to-corneal radius (AL/CR) ratio and the refractive status. The AL/CR ratio then was found to be related more closely to refraction than the AL or CR alone.[26–32] He and colleagues[26] reported that the AL/CR ratio generally can determine the refractive status of the human eye and described the shape of the globe. Therefore, this study hypothesized that the AL and the AL/CR ratio may play important roles in the inaccuracy of the IOL power calculations.

The first aim of the current study was to evaluate the AL/CR ratio features of patients with cataracts in Japan and the relationship between the preoperative spherical equivalent (SE) refraction and the preoperative measurements of the AL, CR, and AL/CR ratio. The second aim was to investigate the accuracy of the IOL power calculations according to the AL/CR ratio features and the AL by using 5 IOL power calculation formulas (ie, the SRK/T, the Holladay 1, the Hoffer Q, the Haigis, and the Barrett Universal II formulas).

METHODS

A RETROSPECTIVE CHART REVIEW WAS PERFORMED OF PAtients who underwent uneventful sutureless phacoemulsification cataract surgery with in-the-bag implantation of an AcrySof IQ SN60WF IOL (Alcon Laboratories, Inc., Fort Worth, Texas) through a limbal or clear corneal incision of 2.0- to 2.4-mm at the Hayashi Eye Hospital. Seven surgeons (K.H., K.Y., K.H., T.Y., S.M., T.S., and H.S.) performed all surgeries between February 2017 and January 2019. All patients underwent preoperative biometric measurements using a swept-source optical coherence tomography device (IOLMaster 700, Carl Zeiss Meditec, Jena, Germany). If patients underwent bilateral surgeries, the study eye was selected randomly. The exclusion criteria were eyes with a history of previous corneal or intraocular surgeries, any corneal disease, and a postoperative best-corrected visual acuity less than 0.8 (20/25) for any reason. In addition, 2 patients with AL exceeding 30 mm (ALs of 30.08 and 31.6 mm) also were excluded because of the extremely small number of cases. All patients provided written informed consent before the surgeries, and opt-out consent was used to participate in this study. The Institutional Review Board of Hayashi Eye Hospital, Fukuoka, Japan, approved this study.

Preoperatively, the IOL powers were calculated using the SRK/T, Holladay 1, Hoffer Q, Haigis, and Barrett Universal II formulas. Data were collected from the partial coherence interferometry device and from the electronic medical records. Subjective refraction was performed in all patients 2 months after surgery. The prediction error then was calculated as the actual postoperative SE minus the refractive result predicted by each formula. Thus, a positive prediction error indicated a refractive outcome that was more hyperopic than predicted. The IOL constants for the Zeiss IOLMaster from the User Group for Laser Interference Biometry online tables[33] were used (IOL constant A of 119.0 for the SRK/T formula; surgeon factor 1.84 for the Holladay 1 formula; personalized ACD of 5.64 for the Hoffer Q formula; a0 of −0.769 and a1 of 0.234 and a2 of 0.217 for the Haigis formula; and lens factor 1.88 for the Barrett Universal II formula).

The mean prediction error (ME), the median absolute prediction error (MedAE), and the mean absolute prediction error were calculated for each formula. The percentages of eyes with a prediction error of ±0.50 diopter (D) were calculated for each formula. The eyes were divided into 9 subgroups according to the AL (short, <22.0 mm; medium, ≥22.0-<26.0 mm; long, ≥26.0 mm) and the AL/CR ratio depending on the 10th and 90th percentiles (<2.95, ≥2.95, and <3.43, ≥3.43, respectively).

Statistical analyses were performed using the SPSS version 22 software (IBM, Armonk, New York) for Microsoft (Redmond, Washington) and JMP Pro version 19 (SAS Institute, Cary, North Carolina). Because the AL and AL/CR ratio were not distributed normally, the Mann-Whitney *U* test was used to compare the unpaired samples. The associations among the SE and AL, CR, or AL/CR ratio were examined using correlation analyses, and the Z-test was used to compare distributions. The Friedman test with a Bonferroni correction was used to compare the prediction errors with the 5 IOL power calculation formulas in each subgroup. The percentages of eyes within the ±0.50 D limit of the target refraction among the formulas were assessed using the Cochran Q test with a Bonferroni correction. The Bonferroni correction was used for multiple comparisons. Statistical significance was set at a *P* value <.05.

RESULTS

THE STUDY SAMPLE CONSISTED OF 1,135 EYES (568 RIGHT eyes) of 1,135 patients (684 women). The mean patient age at the time of surgery was 73.1 ± 7.8 years old (range, 43-93 years old). The mean AL was 24.00 mm (range, 21.12-29.73 mm). The mean CR was 7.63 mm (range, 6.79-8.40 mm).

• AL/CR RATIO AND RELATIONSHIPS AMONG SE AND AL, CR, AND AL/CR RATIO: The AL/CR ratio exhibited a non-normal distribution (median, 3.10; range, 2.74-3.91). For men and women, respectively, the mean ALs were 24.51 ± 1.50 and 23.65 ± 1.45 mm; the mean CRs were 7.70 ± 0.24 and 7.58 ± 0.25; and the mean AL/CR ratios

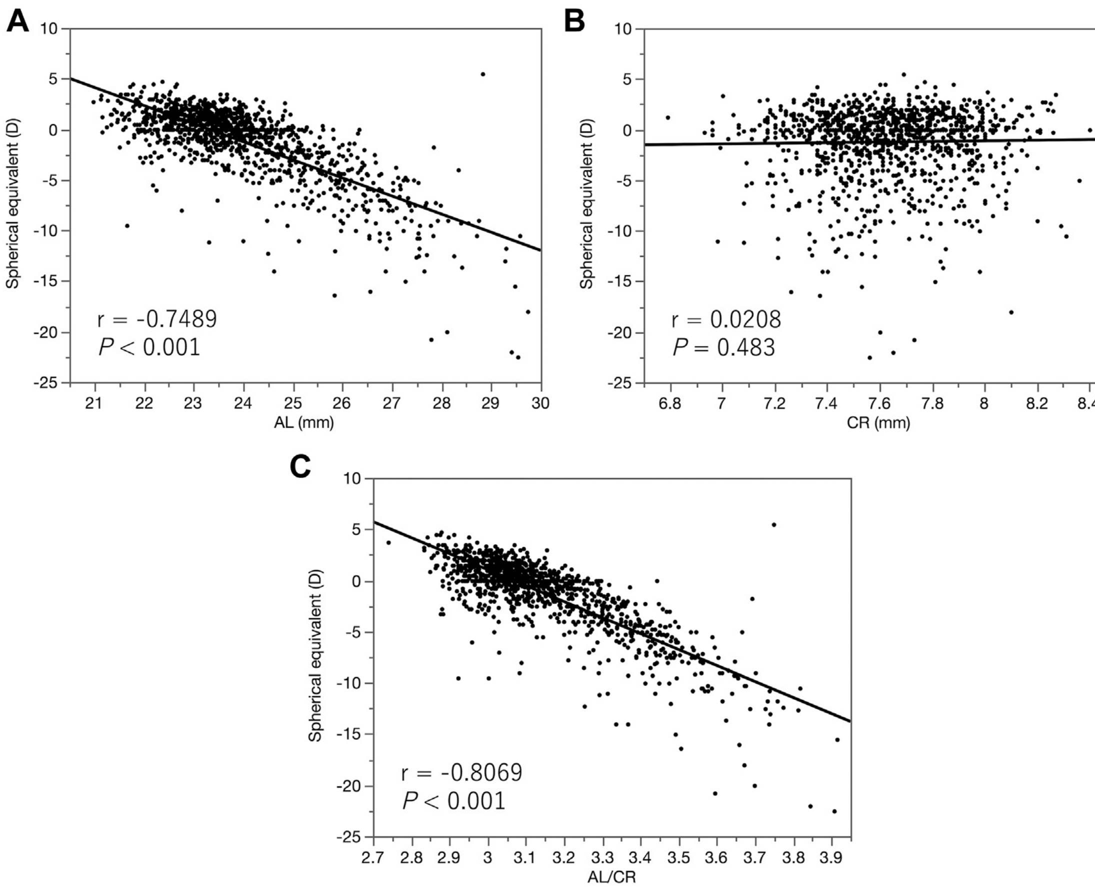

FIGURE 1. A: Scatterplosts of AL and shperical equivalent; B: Scatterplots of CR and sperical equivalent; C: Scatterplots of AL/CR and spherical equivalent; AL = axial length; AL/CR ratio = axial length-to-corneal radius ratio; CR = corneal radius; D = diopters.

were 3.18 ± 0.19 and 3.12 ± 0.18. All differences reached significance ($P < .05$ for all comparisons).

Distributions of the SE and AL, CR, and AL/CR ratio are shown in Figure 1. Significantly weak negative relationships were observed between the SE and AL (r = −0.7489; $P < .001$) and between the SE and AL/CR ratio (r = −0.8069; $P < .001$), both of which reached significance ($P < .001$). No correlation was found between the SE and CR (r = 0.0208; $P = .483$).

• **ACCURACY OF IOL POWER CALCULATIONS ACCORDING TO THE AL AND AL/CR RATIO:** For analytical purposes, the patients were divided into 9 groups according to the AL and AL/CR ratio (Table 1). Figure 2 shows the distributions of the numerical prediction errors in each subgroup. In groups 1 and 4, the Hoffer Q formula had significantly ($P < .05$) negative numerical errors compared with the other 4 formulas (MEs, −0.24 D and -0.19 D, respectively, in groups 1 and 4). In group 2, the Hoffer Q formula also had a significantly ($P < .05$) negative numerical error (ME, −0.20 D) compared with the Holladay 1, Haigis, and Barrett Universal II formulas, whereas the Haigis formula had a significantly ($P < .05$) positive numerical error (ME, 0.20 D) compared with the other 4 formulas. In group 6, the SRK/T formula had a significantly ($P < .001$) negative numerical error (ME, −0.49 D) compared with the Hoffer Q, Haigis, and Barrett Universal II formulas. The Hoffer Q formula had a significantly ($P < .001$) positive numerical error (ME, 0.33 D) compared with the SRK/T, Holladay 1, and Barrett Universal II formulas. In group 8, the Holladay 1 formula had a significantly ($P < .001$) positive numerical error (ME, 0.28 D) compared with the other 4 formulas. In group 9, the Holladay 1 and Hoffer Q formulas had significantly ($P < .001$) positive numerical errors compared with the other 3 formulas (MEs, −0.43 D and 0.43 D, respectively).

Table 2 shows the MedAEs and mean absolute prediction errors of each formula plotted according to the AL and AL/CR ratio subgroups. In groups 1, 2, 4, 5, and 8, no significant differences were seen among the formulas. In group 6, the MedAE of the SRK/T formula was significantly ($P < .05$) larger than those of the Holladay 1 and Barrett Universal II formulas. The MedAE of the Hoffer Q formula was significantly ($P < .05$) larger than those of the Holladay 1 formula. In group 9, the MedAE of the Holladay 1 formula was significantly ($P < .05$) larger

TABLE 1. Nine Subgroups According to the AL and AL/CR (10th and 90th Percentiles)

	Low AL/CR (AL/CR <2.95)	Moderate AL/CR (2.95 ≤AL/CR <3.43)	High AL/CR (3.43 ≤ AL/CR)
Short AL (AL < 22.0 mm)	Group 1 (n = 29; 2.5%)	Group 2 (n = 33; 2.9%)	Group 3 (n = 0)
Medium AL (22.0 ≤ AL < 26.0 mm)	Group 4 (n = 84; 7.4%)	Group 5 (n = 832; 73.3%)	Group 6 (n = 26; 2.3%)
Long AL (26.0 mm ≤ AL< 30.0 mm)	Group 7 (n = 0)	Group 8 (n = 44; 3.9%)	Group 9 (n = 87; 7.7%)

AL = axial length; AL/CR = axial length to corneal radius ratio; CR = corneal radius.

than those of the SRK/T, Haigis, and Barrett Universal II formulas, and the MedAE of the Hoffer Q formula was significantly ($P < .05$) larger than those of the SRK/T, Haigis, and Barrett Universal II formulas.

The percentages of eyes within the ±0.50-D and ±1.00-D errors are shown in Table 3. For eyes with a short AL (groups 1 and 2), no significant differences were seen. In groups 4 and 5, no significant differences were seen, whereas in group 6, the SRK/T formula produced a significantly ($P < .05$) smaller percentage of eyes within a ±0.50-D error than the Barrett Universal II formula. In group 8, the Holladay 1 formula produced a significantly ($P < .05$) smaller percentage of eyes within a ±0.50-D error than the Haigis and Barrett Universal II formulas. In group 9, the Holladay 1 formula produced a significantly ($P < .05$) smaller percentage of eyes within a ±0.50-D error than the Haigis and Barrett Universal II formulas. Further, the Hoffer Q formula produced a significantly ($P < .05$) smaller percentage of eyes within a ± 0.50-D error than the SRK/T, Haigis, and Barrett Universal II formulas.

DISCUSSION

TO THE BEST OF THE AUTHORS' KNOWLEDGE, THIS IS THE first study of the AL/CR ratio and the accuracy of IOL power calculations based on the AL and AL/CR ratio using one IOL model in Japan.

• **AL/CR RATIO AND RELATIONSHIPS AMONG THE SE AND AL, CR, AND AL/CR RATIO:** The distributions of the AL/CR ratio have been reported in different populations and age groups[31,34–41] and the AL/CR ratios for myopia were between 2.9 and 3.1 and less than 2.9 for emmetropia and hyperopia.[26,27,42–46] Table 4 summarizes the other studies. In the current report, the CR was approximately the same as that in those previous reports, and women had significantly steeper corneal curvature values,[43] whereas the current AL was longer than those reported previously. Therefore, the mean AL/CR ratio became the highest. This difference may be due to the higher prevalence of myopia in Japan.[22,23] Myopia is one of the most common ocular disorders in schoolchildren, and the prevalence of myopia has been reported to be high in East Asia.[47,48] In the future, because this tendency may intensify, it is important to improve the accuracy of refractive calculations in eyes with a high AL/CR ratio.

In the current study, the correlation coefficient of the AL/CR ratio with the SE was greater than that of the AL with the SE; therefore, the AL/CR ratio may explain the total variation in the SE better than the AL alone. This trend also has been reported previously,[26,38] and the current results agreed with them.

• **ACCURACY OF IOL POWER CALCULATIONS ACCORDING TO AL AND AL/CR RATIO:** Previous studies have reported that the Barrett Universal II formula provided better results than the SRK/T, Haigis, Hoffer Q, and Holladay 1 formulas.[12,29,30] The current results showed that the Barrett Universal II formulas performed well across a range of ALs and AL/CR ratios. The third-generation formulas, including the SRK/T, Hoffer Q, and Holladay 1, were less accurate than the Haigis and Barrett Universal II formulas in eyes with medium and long ALs with high AL/CR ratios. In eyes with low and medium AL/CR ratios, the third-generation formulas were similarly as accurate as the Haigis and Barrett Universal II formulas regardless of the ALs.

Norrby[4] reported that the preoperative estimation of the postoperative IOL position, postoperative refraction determination, and preoperative AL measurement were the largest contributors of error.

The refractive outcomes for hyperopic patients with short ALs are less accurate, with prediction errors increasing with increasing hyperopia.[49] This occurs because of difficulties in calculating the true ELP position, because the anterior segment in short eyes is not proportional to the AL.[50] Because higher IOL powers are needed for emmetropia as a result of the shorter ALs, any inaccuracy in the ELP has an exaggerated effect. Consistent with previous studies,[12,51,52] the current results did not identify significant differences among the formulas, including the Barrett Universal II formula in short eyes. Moreover, previous studies have reported that the Hoffer Q formula produced slightly myopic refractive errors.[12,51,52] Shrivastava and colleagues[52] reported that the Haigis formula produced slightly hyperopic refractive errors. The current findings agreed well with those reported previously.

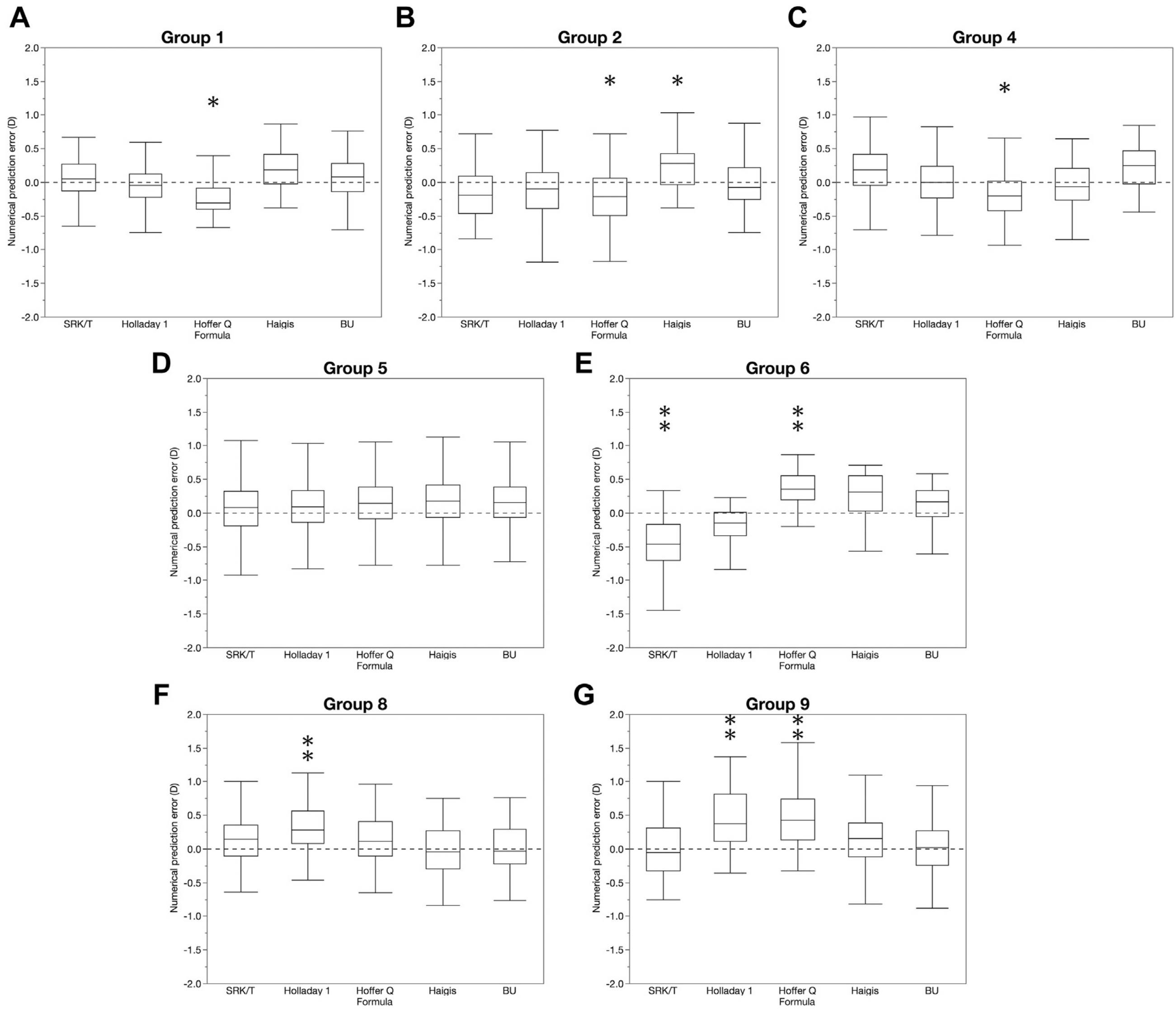

FIGURE 2. Distribution of the numerical prediction error in refraction with the 5 intraocular lens power calculation formulas for 7 subgroups. A: Group 1; B: Group 2; C: Group 4; D: Group 5; E: Group 6; F: Group 8; G: Group 9. *Significant ($P < .05$) differences were compared with other formulas. **Significant ($P < .001$) differences were compared with other formulas.AL = axial length; CR = corneal radius; AL/CR ratio = axial length-to-corneal radius ratio; BU = Barrett Universal II; D = diopters.

In eyes with normal ALs and high AL/CR ratios, the SRK/T formula had a strong tendency toward myopic results. Reitblat and colleagues[53] reported that the IOL power calculations for eyes with steep corneas yielded myopic prediction errors with the SRK/T formula. Melles and colleagues[54] reported that the SRK/T formula tended to overestimate the IOL power in eyes with steep corneas. The current study found that, in steep corneas with medium ALs, a high degree of myopia was predicted, whereas steep corneas with long ALs were not predicted to have as high a degree of myopia. Sheard and colleagues[55] reported a systemic error arising from the equations used to predict the corneal height when using the SRK/T formula. In eyes with normal ALs and high AL/CR ratios, the corneas are relatively steep; therefore, the corneal height and ELP lengthened, which may cause the myopic trend with the SRK/T formula associated with normal ALs and high AL/CR ratios. Moreover, the SRK/T formula defined the AL (corrected), W (corneal diameter), and corneal height as follows[7]:

- If AL $\leqq$ 24.2 mm, AL (corrected) = AL
- If AL >24.2 mm, the AL (corrected) = $-3.446 + 1.715 \times \text{AL} - 0.0237 \times \text{AL}^2$
- $\text{W} = -5.41 + 0.58413 \times \text{AL (corrected)} + 0.098 \times \text{K}$
- Corneal height $= \text{CR} - \sqrt{(\text{CR}^2 - \text{W}^2/4)}$

TABLE 2. Median and Mean Absolute Errors for All Formulas and Groups

Group	AL	AL/CR	n	S (D)	Holla (D)	Hoff (D)	Ha (D)	BU (D)	*P* Value
1	Short	Low	29	0.20 (0.26 ± 0.26[a])	0.20 (0.26 ± 0.25[a])	0.34 (0.36 ± 0.26[a])	0.26 (0.38 ± 0.35[a])	0.19 (0.32 ± 0.31[a])	NS
2		Moderate	33	0.24 (0.35 ± 0.31[a])	0.22 (0.31 ± 0.26[a])	0.26 (0.34 ± 0.30[a])	0.34 (0.35 ± 0.25[a])	0.23 (0.30 ± 0.26[a])	NS
3		High	0	NA	NA	NA	NA	NA	NA
4	Medium	Low	84	0.25 (0.31 ± 0.24[a])	0.23 (0.26 ± 0.21[a])	0.28 (0.32 ± 0.23[a])	0.24 (0.29 ± 0.23[a])	0.30 (0.33 ± 0.24[a])	NS
5		Moderate	832	0.26 (0.33 ± 0.27[a])	0.25 (0.31 ± 0.26[a])	0.26 (0.33 ± 0.27[a])	0.27 (0.34 ± 0.29[a])	0.26 (0.32 ± 0.28[a])	NS
6		High	26	0.46 (0.50 ± 0.36[a])	0.21 (0.28 ± 0.26[a])	0.44 (0.40 ± 0.21[a])	0.38 (0.36 ± 0.23[a])	0.28 (0.26 ± 0.17[a])	S vs. BU and Holla ($P < .05$ for all comparisons) Hoff vs. Holla ($P < .05$)
7	Long	Low	0	NA	NA	NA	NA	NA	NA
8		Moderate	44	0.29 (0.33 ± 0.25[a])	0.39 (0.40 ± 0.29[a])	0.25 (0.32 ± 0.27[a])	0.27 (0.31 ± 0.26[a])	0.22 (0.31 ± 0.25[a])	NS
9		High	87	0.31 (0.35 ± 0.26[a])	0.40 (0.50 ± 0.38[a])	0.43 (0.49 ± 0.36[a])	0.27 (0.34 ± 0.28[a])	0.25 (0.31 ± 0.25[a])	Holla vs. S, Ha and BU ($P < .05$ for all comparisons) Hoff vs. S, Ha and BU ($P < .05$ for all comparisons)

AL = axial length; AL/CR = axial length length-to to-corneal radius ratio; BU = Barrett Universal II; D = diopters; Ha = Haigis; Hoff = Hoffer Q; Holla = Holladay 1; NA = not applicable; NS = not significant; S = SRK/T.

[a]Values in parentheses indicate means ± SD.

TABLE 3. Percentage of Eyes with a Refractive Prediction Error within ±0.50 D and ±1.00 D

Group	AL	AL/CR	No.	S (%)	Holla (%)	Hoff (%)	Ha (%)	BU (%)	*P* Value
Within ±0.50 D									
1	Short	Low	29	86.2	82.8	79.3	75.9	75.9	.565[a]
2		Moderate	33	75.8	81.8	69.7	78.8	84.8	.391[a]
3		High	0	NA	NA	NA	NA	NA	NA
4	Medium	Low	84	78.6	84.5	81.0	83.3	79.8	.722[a]
5		Moderate	832	78.2	81.6	79.4	78.0	80.4	.679[a]
6		High	26	53.8	80.8	61.5	69.2	88.5	S vs BU ($P < .05$)
7	Long	Low	0	NA	NA	NA	NA	NA	NA
8		Moderate	44	79.5	61.4	77.3	84.1	84.1	Holla vs. Ha and BU ($P < .05$ for all comparisons)
9		High	87	75.9	60.9	55.2	79.3	83.9	Holla vs. Ha and BU ($P < .05$ for all comparisons) Hoff vs. S, Ha and BU ($P < .05$ for all comparisons)
Within ± 1.00 D									
1	Short	Low	29	96.6	96.6	96.6	93.1	96.6	.856
2		Moderate	33	97.0	97.0	97.0	97.0	97.0	1.000[a]
3		High	0	NA	NA	NA	NA	NA	NA
4	Medium	Low	84	100	100	98.8	98.8	100	.406[a]
5		Moderate	832	97.8	98.1	97.1	96.0	97.1	.841[a]
6		High	26	92.3	96.2	100	100	100	.171[a]
7	Long	Low	0	NA	NA	NA	NA	NA	NA
8		Moderate	44	95.5	95.5	97.7	97.7	97.7	.788[a]
9		High	87	75.9	60.9	55.2	79.3	83.9	Holla vs. S and Ha ($P < .05$ for all comparisons) Holla vs. BU ($P < .001$) Hoff vs. BU ($P < .05$)

AL = axial length; AL/CR = axial length length-to to-corneal radius ratio; BU = Barrett Universal II; D = diopters; Ha = Haigis; Hoff = Hoffer Q; Holla = Holladay 1; NA = not applicable; NS = not significant; S = SRK/T.
[a]Values are means ± SD.

Therefore, the longer the AL becomes, the longer the difference between the AL and the AL (corrected) for the SRK/T formula becomes. It suggests that for medium ALs and high AL/CR ratios, the AL (corrected) may be calculated as not being so short and the corneal height may not be canceled by the AL (corrected).

Calculating the IOL powers in highly myopic eyes also remains a challenge that often leads to unexpected postoperative hyperopia.[12,26–30,56] In eyes with long ALs, both the Holladay 1 and Hoffer Q formulas exhibited a hyperopic trend. Several studies have reported the same result.[12,27–30] Zhang and colleagues[57] reported that in eyes with long ALs (over 29 mm), the SRK/T formula had a lower MedAE than the Haigis formula. In the current study, there were no significant differences between the SRK/T and Haigis formulas in eyes with long ALs. We found that in the subgroups with medium AL/CR ratios, the Holladay 1 formula was less accurate, whereas the Hoffer Q formula was as accurate as other formulas. The following reasons may explain this. In eyes with long ALs with medium AL/CR ratios, there are great variations in the postoperative ACDs with the Holladay 1 formula, whereas the postoperative ACD with the Hoffer Q formula is constant (6.5). The Holladay 1 formula uses the Pythagorean theorem to calculate the ELP, similar to the SRK formula, and it is possible that the difference in the method of calculating the postoperative ACD may cause a prediction error.

In other words, the third-generation formulas (Hoffer Q, SRK-T, and Holladay 1) are less accurate in eyes with medium and long ALs with high AL/CR ratios possibly because these formulas calculate the ELP or postoperative ACD obtained from the AL and the corneal power. In eyes with long ALs with high AL/CR ratios, the ELP for the SRK/T formula becomes longer than those for the Holladay 1 and Hoffer Q formulas, because the AL for the SRK/T formula is corrected in eyes with long ALs. Therefore, the SRK/T formula was accurate in long ALs with high AL/CR ratios.

The current study had some limitations. First, the study sample did not include eyes with short ALs with high AL/CR ratios or long ALs with low AL/CR ratios. In this study, the definitions of short and long ALs were based on a

TABLE 4. Studies Reporting AL, CR, and AL/CR

Origin Study	N	Mean ± SD Age (y) or Age Range	AL/CR Ratio or Mean ± SD Ratio	Mean AL or Mean ± SD AL (mm)	Mean CR or Mean ± SD CR (mm)
Myanmar[35]	1,498	56.2 ± 11.5	2.99	22.76 ± 1.05[a]	7.6 ± 0.50[a]
Jordan[34]	1,093	17-40	3.00 ± 0.13[a]	23.13 ± 1.00[a]	7.7 ± 0.30[a]
Iran[37]	4,820	40-64	3.03	23.14	7.63
China[40]	3,728	69.5 ± 8.05[a] (29-88)	3.03 ± 0.12[a]	23.04 ± 1.49[a]	–
China[39]	1,717	40-84	3.04	23.23 ± 1.17[a]	7.6 ± 0.27[a]
Nigeria[38]	350	34.8 ± 11.2[a] (18-60)	3.04 ± 0.10[a]	23.78 ± 0.91[a]	7.8 ± 0.28[a]
Spain[31]	583	20.32 ± 2.82[a]	3.05 ± 0.14[a]	23.61 ± 1.05[a]	7.7 ± 0.25[a]
India[36]	2,785	57.8 ± 10.1[a] (40-83)	3.08 ± 0.13[a]	23.45 ± 1.10[a]	7.61 ± 0.26[a]
China[41]	6,099	62.56 ± 8.00[a] (50-96)	3.08 ± 1.07[a]	23.53 ± 1.34[a]	–
Current study	1,135	73.1 ± 7.78[a] (43-93)	3.15 ± 0.19[a]	24.00 ± 1.53[a]	7.6 ± 0.25[a]

AL = axial length; AL/CR = axial length to corneal radius ratio; CR = corneal radius; SD = standard deviation.
[a]These values are means ± SD (if they were mentioned in the original article).

previous study,[58] and the AL/CR ratio values were divided depending on the 10th and 90th percentiles. Therefore, the number of peripheral subgroups was inevitably small. In addition, the authors believe this trend is reasonable because the AL/CR ratios tend to become high in myopic eyes and vice versa, as shown in the current study. However, despite these small numbers, significant differences were found in groups 6, 8, and 9, which are meaningful. Second, the study sample did not include short eyes (AL, <21.0 mm) or very long eyes (AL, >30.0 mm).

In conclusion, the mean AL/CR ratio in Japan was the highest compared with previously published data from other countries. The AL/CR ratio explains the total variation in the SE better than the AL alone. The SRK/T formula performed less accurately in eyes with medium ALs with high AL/CR ratios. Furthermore, the Holladay 1 and Hoffer Q formulas performed less accurately in eyes with long ALs with high AL/CR ratios. The Barrett Universal II formulas performed well across a range of ALs and AL/CR ratios. Surgeons should pay attention to the selection of IOL power calculation formulas in eyes with high AL/CR ratios.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

MIKI KAMIKAWATOKO OMOTO: CONCEPTUALIZATION, Methodology, Software, Writing - original draft. **Hidemasa Torii:** Writing - review & editing. **Ken Hayashi:** Data curation, Writing - review & editing. **Masahiko Ayaki:** Writing - review & editing. **Kazuo Tsubota:** Writing - review & editing. **Kazuno Negishi:** Conceptualization, Methodology, Writing - review & editing, Supervision.

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