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Research article

Comparative accuracy of intraocular lens power calculation formulas when targeting myopia

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A B S T R A C T

Purpose: This study aims to compare the accuracies of intraocular lens (IOL) power calculation formulas when targeting myopia versus emmetropia.
Methods: A total of 450 patients were included, with 225 patients targeting emmetropia and 225 patients aiming for approximately −2.0 diopters of myopia. This retrospective analysis utilized data from a single eye of each patient, with preoperative biometric measurements obtained using the IOL Master 700. The study considered established formulas such as Haigis, Hoffer Q, Holladay 1, Holladay 2, and SRK/T, as well as modern formulas including Barrett Universal II, Cooke K6, EVO 2.0, Hill-RBF, Hoffer QST, Kane, Olsen, and PEARL-DGS. Statistical analyses, including Friedman test and post hoc analysis, were employed to compare the accuracy of each IOL power calculation formula between the two groups. Additionally, a multiple regression analysis was conducted to identify variables influencing the accuracy of intraocular lens power calculation formulas.
Results: In targeting myopia, all IOL formulas tended to exhibit a greater refractive error compared to when targeting emmetropic eyes. Notably, the Haigis, SRK/T, and Holladay 2 formulas were found to be highly influenced by this trend, while the modern formulas were less affected.
Conclusion: The accuracy of IOL power calculation formulas diminishes when targeting myopia in comparison to emmetropia. However, the modern formulas appear less susceptible to this trend. Consequently, when aiming for myopia, the use of the modern formulas is recommended for enhanced accuracy in IOL power calculation.

1. Introduction

Cataract surgery currently stands as the most frequently performed surgical procedure globally [1]. Recent clinical outcomes following cataract surgery indicate significant improvement owing to the heightened precision of modern biometry and the advancement of state-of-the-art intraocular lens (IOL) power calculation formulas. Approximately 70–80 % of eyes undergoing cataract surgery report a prediction error within 0.5 diopters (D), highlighting the remarkable success of the procedure [2–6]. Consequently, patient expectations post-surgery are notably high.

Patients undergoing cataract surgery have the option to select their desired postoperative target refraction. For individuals with pre-existing myopia, many express a preference for maintaining some degree of myopia post-surgery to facilitate near-field activities comfortably. This residual myopia post-cataract surgery can also serve as a strategy to mitigate the risk of hyperopic surprises that may arise postoperatively [7]. Currently, a target refraction of about −2.0 D is generally accepted for myopia correction after cataract surgery [8,9].

While numerous studies have assessed the accuracy of IOL calculation formulas, the majority have focused on cases targeting

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emmetropic eyes [3,5,6,10,11]. Surprisingly, few studies have investigated the accuracy of IOL formulas specifically targeting myopia [12–17]. Recent research suggests that targeting myopic eyes may result in lower accuracy compared to emmetropic eyes. Turnbull and colleagues conducted a paired-eye study on 88 patients (176 eyes) employing a monovision strategy during cataract surgery, revealing slightly lower accuracy in the group targeting −1.25 D myopia compared to those targeting emmetropic eyes [17]. Similarly, Sakai and associates found a myopic trend in the refraction after cataract surgery in 50 eyes with axial lengths between 24.5 mm and 26.0 mm when targeting −2.0 to −3.0 D myopia, as opposed to cases where emmetropia was the target [16].

Previous studies, albeit insightful, often featured small sample sizes of fewer than 100 patients. Notably, studies with sample sizes exceeding 100 patients have yet to be reported. Consequently, we designed the present study with a larger sample size, considering only one eye per patient to eliminate confounding variables. Employing robust statistical analyses and incorporating the modern IOL calculation formulas, the objective of this study was to compare the accuracies of IOL power calculation formulas when targeting myopia versus emmetropia.

2. Materials and methods

The Institutional Review Board (IRB) of Seoul St. Mary's Hospital, the Catholic University of Korea, approved this study (IRB No. KC21RASI0806) and waived the requirement for informed consent due to the retrospective nature of the investigation. The study adhered to the principles of the Declaration of Helsinki. A retrospective review encompassing all cataract surgeries performed by a single experienced surgeon (H.S–K.) at Seoul St. Mary's Hospital from 2019 to 2021 was undertaken. The study methodology aligned with the editorial recommendations for IOL studies provided by the American Journal of Ophthalmology and the Journal of Cataract and Refractive Surgery [18,19]. Inclusion criteria comprised: (1) uneventful cataract surgery with a clear corneal incision, utilizing the ARTIS® PL E IOL (Cristalens Industrie, Lannion, France); (2) axial length between 22.0 mm and 26.0 mm; and (3) postoperative target refraction set at emmetropia (between 0 and -0.50 D) or myopia (between −1.75 and −2.25 D). Preoperative biometry employed the IOL Master 700 (software version 1.50; Carl Zeiss Meditec, AG, Jena, Germany). Subjective manifest refraction was conducted by one of the orthoptists during the follow-up visit, averaging 1 month post-surgery. Exclusion criteria comprised: corneal diseases (keratoconus, ectasia, pterygium, or previous trauma); ocular diseases (pseudoexfoliation syndrome, macular degeneration, glaucoma); previous ophthalmic operations (laser vision correction, vitrectomy, pterygium surgery, penetrating glaucoma surgery, or scleral buckling procedures); intraoperative or postoperative complications; or postoperative corrected distance visual acuity worse than 6/9. Additionally, enrollment was limited to one eye per patient to avoid compounding effects. The entire dataset (N = 450) was categorized into two subgroups: the emmetropia group (N = 225) and the myopia group (N = 225).

Preoperative distance best-corrected visual acuity (DCVA) was evaluated using Snellen charts, and routine anterior and posterior segment examinations were conducted. Topographic Scheimpflug corneal topography (Oculus Pentacam, Wetzler, Germany) was employed to screen for irregular astigmatism, serving as an exclusion criterion. Optical biometry with the IOL Master 700 (Carl Zeiss Meditec, AG, Jena, Germany) was performed for all patients, ensuring measurement repeatability by evaluating parameters twice by an experienced technician. An intra-rater repeatability test using the intraclass correlation coefficient (ICC) was conducted, with an ICC greater than 0.8 considered excellent repeatability. The prediction error (PE) for each eye with each formula was calculated by subtracting the predicted postoperative refraction from the achieved refraction value.

The following IOL power calculation formulas were used: Barrett Universal II, Cooke K6, EVO 2.0, Haigis, Hill-RBF, Hoffer Q, Hoffer QST, Holladay 1, Holladay 2, Kane, Olsen (standalone), PEARL-DGS, and SRK/T.

IOL constants were optimized to nullify the arithmetic mean error (ME) for each formula across the entire dataset, encompassing both emmetropia and myopia groups, following the methodology outlined in the editorial by Wang and associates [19]. This optimization entailed adjusting the error upwards or downwards to minimize all MEs as closely as possible to zero. The ME values obtained through this optimization process were subsequently utilized in all subsequent calculations. Constant optimization for SRK/T, Hoffer Q, and Holladay 1 was performed using Excel (Microsoft, Redmond, WA, USA). For the unpublished formulas such as Barrett, Cooke K6, EVO 2.0, Hill-RBF, Kane, and PEARL-DGS, constant optimization was conducted according to the methodology described by Gatinel et al. [20] For the Holladay 2 formula, constant optimization was performed using proprietary software (HicSoap Professional Edition, version 2023.1231 Holladay Consulting, Inc., Bellaire). For the Haigis formula, back-calculation was performed to compute the optimized *d* value, followed by triple optimization through multiple linear regression. The anterior chamber depth constant and *C*-constant for the Olsen formula were calculated using values provided by the PhacoOptics software (version 1.10.100.2038; IOL Innovations Aps). For the Hoffer QST, constant optimization was performed using an Excel file available on the official website (https://hofferqst.com, accessed on January 30, 2024).

Mean absolute error (MAE), median absolute error (MedAE), standard deviation (SD) of the absolute error, and the proportion of eyes within a PE of ±0.25 D, ±0.50 D, ±0.75 D, and ±1.00 D, respectively, were calculated for the entire group and the two subgroups: emmetropia and myopia.

Statistical analysis adhered to Ophthalmology recommendations [21]. A sample size calculation was performed to detect a difference of half the standard deviation of differences in prediction errors between groups. With a significance level of 5 % and a test power of 80 %, 282 eyes (141 eyes per group) were deemed necessary. The unpaired *t*-test was employed to compare the difference in absolute error between emmetropia and myopia groups for each formula, and it was also used to assess the disparity in mean prediction errors between groups with K readings steeper than 43.75 and those with K readings flatter than 43.75. The Cochran's Q test compared proportions of eyes achieving within ±0.25, ±0.50, ±0.75, and ±1.00 D postoperatively. Differences in mean absolute error between formulas were assessed using the nonparametric Friedman test, and post hoc analysis employed the Wilcoxon signed-rank test. Multiple regression analysis was conducted to predict variables related to prediction error in the entire patient group. All calculations utilized Excel (Microsoft, Redmond, WA, USA) or SPSS software (version 22.0, SPSS Inc., Chicago, IL, USA). Results were deemed statistically significant when the P-value was less than 0.05.

3. Results

A total of 450 eyes from 450 patients were enrolled in this study, with 225 eyes targeting emmetropia and 225 eyes targeting myopia. Supplementary Table 1 presents the baseline demographics of the two groups, revealing no statistically significant differences in demographic or biometric data between them. The implanted IOL power was significantly higher in the myopic group ($P = 0.020$).

3.1. 1) Accuracy of the IOL formulas

The Hoffer QST formula showed the lowest MAE at 0.366, which was statistically significantly lower than the MAE of the Haigis, Hoffer Q, Holladay 1, Holladay 2, and SRK/T formulas ($P < 0.05$). Additionally, the modern formulas (Barrett, K6, EVO 2.0, Hill-RBF, Hoffer QST, Kane, Olsen, PEARL-DGS) generally demonstrated relatively lower MAE values compared to the Haigis, Hoffer Q, Holladay 1, Holladay 2, and SRK/T formulas (Fig. 1A and Table 1).

3.2. 2) Comparison between the emmetropic and the myopic subgroups

Comparing the two target subgroups, the emmetropic subgroup exhibited a trend towards more accurate results compared to the myopic target subgroup. This trend was confirmed by a few statistically significant differences.

Specifically, the myopic subgroup displayed a significantly higher MAE than the emmetropic subgroup in the Holladay 2 formula ($P = 0.018$). For the Haigis formula, the percentage of prediction error (PE) within ±0.25 diopters or ±0.50 diopters was significantly lower in the myopic group ($P = 0.047$ or $P = 0.042$, respectively). The Holladay 2 formula showed a significantly lower percentage of PE within ±0.75 or ±1.00 diopters in the myopic group ($P = 0.011$ or $P = 0.004$, respectively). Additionally, in the SRK/T formula, the percentage of PE within ±0.50 diopters was significantly lower in the myopic group ($P = 0.043$) (Fig. 1A and B, 2, and Table 1).

3.3. 3) Comparisons within the myopic subgroup

Within the myopic group, the Holladay 2 formula yielded a significantly higher MAE than all other formulas, except for the Haigis formula ($P < 0.05$).

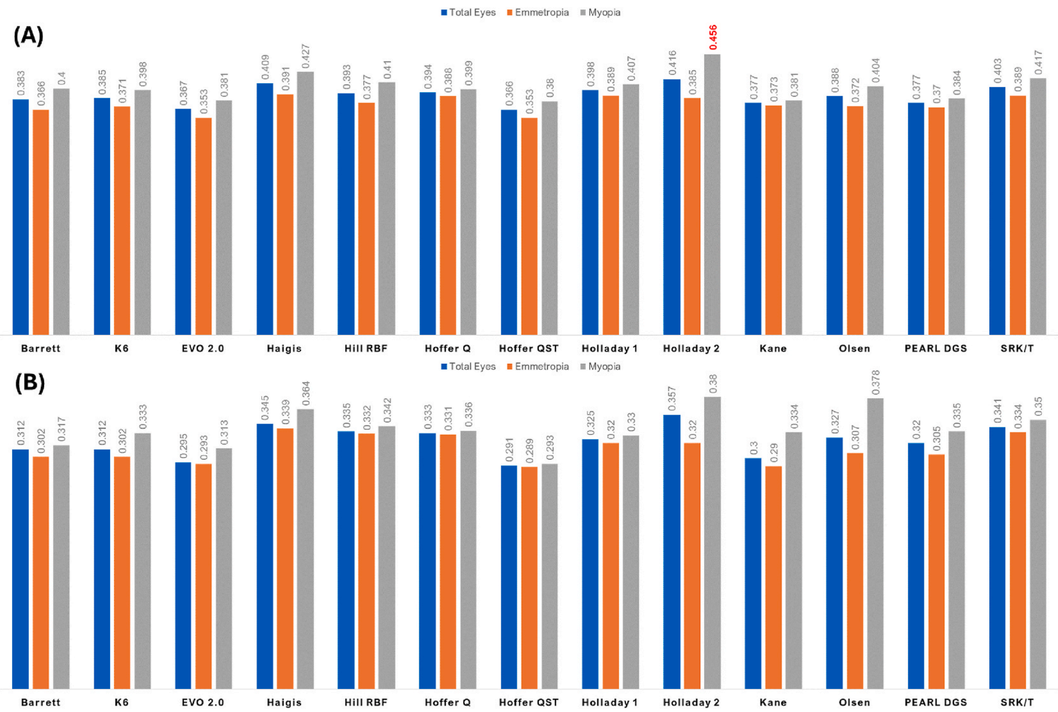

Fig. 1. (A) Mean absolute error of each intraocular lens calculation formula comparing the emmetropic and myopic target subgroups. (B) Median absolute error of each intraocular lens calculation formula comparing the emmetropic and myopic target subgroups. Statistically significant differences ($P < 0.05$) are highlighted with red labels. Unit: diopters. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Accuracy of each intraocular lens calculation formula for emmetropic and myopic targets.

Formula	All eyes (N = 450)	Emmetropia (N = 225)	Myopia (N = 225)	P-value (emmetropia vs. myopia)
Barrett Universal II				
ME	0.00	0.01	−0.01	
MAE	0.383	0.366	0.400	0.225
MedAE	0.312	0.302	0.317	
SD	0.295	0.279	0.310	
±0.25D	43.80 %	45.30 %	42.20 %	0.284
±0.50D	70.70 %	72.40 %	68.90 %	0.234
±0.75D	87.80 %	88.40 %	87.10 %	0.397
±1.00D	97.30 %	98.70 %	96.00 %	0.070
Cooke K6				
ME	0.00	0.02	−0.02	
MAE	0.385	0.371	0.398	0.350
MedAE	0.312	0.302	0.333	
SD	0.306	0.291	0.320	
±0.25D	43.11 %	44.00 %	42.22 %	0.317
±0.50D	70.89 %	74.22 %	67.56 %	0.074
±0.75D	87.80 %	88.44 %	87.11 %	0.335
±1.00D	96.89 %	97.78 %	96.00 %	0.139
EVO 2.0				
ME	0.00	0.01	−0.01	
MAE	0.367	0.353	0.381	0.262
MedAE	0.295	0.293	0.313	
SD	0.268	0.258	0.277	
±0.25D	44.89 %	46.67 %	43.10 %	0.197
±0.50D	73.50 %	75.56 %	71.56 %	0.168
±0.75D	89.70 %	90.22 %	89.33 %	0.380
±1.00D	98.20 %	98.67 %	97.78 %	0.238
Haigis				
ME	0.00	0.01	−0.01	
MAE	0.409	0.391	0.427	0.220
MedAE	0.345	0.339	0.364	
SD	0.306	0.303	0.309	
±0.25D	36.00 %	40.00 %	32.00 %	**0.047***
±0.50D	68.40 %	72.40 %	64.40 %	**0.042***
±0.75D	86.40 %	87.60 %	85.30 %	0.291
±1.00D	94.70 %	96.00 %	93.30 %	0.147
Hill RBF				
ME	0.00	0.03	−0.03	
MAE	0.393	0.377	0.410	0.221
MedAE	0.335	0.332	0.342	
SD	0.288	0.281	0.295	
±0.25D	42.22 %	43.56 %	40.89 %	0.283
±0.50D	70.00 %	72.44 %	67.56 %	0.152
±0.75D	89.55 %	90.22 %	88.89 %	0.380
±1.00D	97.10 %	98.22 %	96.00 %	0.139
Hoffer Q				
ME	0.00	0.05	−0.05	
MAE	0.394	0.388	0.399	0.698
MedAE	0.333	0.331	0.336	
SD	0.312	0.310	0.315	
±0.25D	40.20 %	40.40 %	40.00 %	0.500
±0.50D	69.10 %	71.60 %	66.70 %	0.154
±0.75D	86.00 %	86.70 %	85.30 %	0.393
±1.00D	94.70 %	96.00 %	93.30 %	0.147
Hoffer QST				
ME	0.00	0.02	−0.02	
MAE	0.366	0.353	0.380	0.306
MedAE	0.291	0.289	0.293	
SD	0.274	0.266	0.282	
±0.25D	45.78 %	47.11 %	44.44 %	0.285
±0.50D	75.56 %	76.00 %	75.11 %	0.413
±0.75D	90.00 %	91.11 %	88.89 %	0.216
±1.00D	98.44 %	98.67 %	98.22 %	0.352
Holladay 1				
ME	0.00	0.08	−0.08	
MAE	0.398	0.389	0.407	0.523
MedAE	0.325	0.320	0.330	
SD	0.299	0.300	0.298	

(*continued on next page*)

Table 1 (*continued*)

Formula	All eyes (N = 450)	Emmetropia (N = 225)	Myopia (N = 225)	P-value (emmetropia vs. myopia)
±0.25D	38.90 %	41.30 %	36.40 %	0.167
±0.50D	68.90 %	71.10 %	66.70 %	0.180
±0.75D	85.10 %	86.20 %	84.00 %	0.298
±1.00D	94.90 %	96.40 %	93.30 %	0.099
Holladay 2				
ME	0.00	0.07	−0.07	
MAE	0.416	0.385	0.456	**0.018***
MedAE	0.357	0.320	0.380	
SD	0.315	0.285	0.342	
±0.25D	35.80 %	39.10 %	32.40 %	0.084
±0.50D	68.90 %	72.40 %	65.30 %	0.063
±0.75D	85.30 %	89.30 %	81.30 %	**0.011***
±1.00D	94.20 %	97.30 %	91.10 %	**0.004***
Kane				
ME	0.00	0.07	−0.07	
MAE	0.377	0.373	0.381	0.775
MedAE	0.300	0.290	0.334	
SD	0.292	0.287	0.298	
±0.25D	44.00 %	45.80 %	42.20 %	0.170
±0.50D	72.20 %	73.30 %	71.10 %	0.460
±0.75D	88.20 %	89.30 %	87.10 %	0.440
±1.00D	97.80 %	98.70 %	96.90 %	0.250
Olsen				
ME	0.02	0.03	−0.01	
MAE	0.388	0.372	0.404	0.224
MedAE	0.327	0.307	0.378	
SD	0.286	0.278	0.294	
±0.25D	43.55 %	44.00 %	43.11 %	0.462
±0.50D	70.67 %	73.78 %	67.56 %	0.074
±0.75D	87.33 %	88.00 %	86.67 %	0.335
±1.00D	96.67 %	96.89 %	96.44 %	0.396
PEARL DGS				
ME	0.00	0.01	−0.01	
MAE	0.377	0.370	0.384	0.601
MedAE	0.320	0.305	0.335	
SD	0.284	0.279	0.290	
±0.25D	44.60 %	45.70 %	43.5 %	0.318
±0.50D	71.3 %	73.30 %	69.30 %	0.174
±0.75D	89.10 %	89.30 %	88.89 %	0.440
±1.00D	97.10 %	97.30 %	96.89 %	0.389
SRK/T				
ME	0.00	0.11	−0.11	
MAE	0.403	0.389	0.417	0.333
MedAE	0.341	0.334	0.350	
SD	0.312	0.300	0.323	
±0.25D	40.40 %	41.30 %	39.60 %	0.387
±0.50D	68.00 %	72.00 %	64.00 %	**0.043***
±0.75D	85.10 %	87.60 %	82.70 %	0.093
±1.00D	95.80 %	97.30 %	94.20 %	0.079

ME = mean error, MAE = mean absolute error, MedAE = median absolute error, SD = standard deviation, D = diopter, *Statistically significant.

3.4. 4) Mean prediction error according to K-readings within the myopic subgroup

Table 2 presents results by dividing the myopic group data based on keratometry values. In the case of SRK/T, when the K-reading was less than 43.75, there was a slight hyperopic shift. Conversely, when it was 43.75 or more, there was a myopic shift. For the Haigis formula, when the K-reading was less than 43.75, a myopic shift was observed, while a hyperopic shift occurred when it was 43.75 or more.

3.5. 5) Multiple regression analyses

Multiple regression analysis was conducted to examine how prediction error could be affected by each formula based on preoperative biometric values. Using data from subjects in this study with axial lengths of 24.5 mm or more (top 25 %), relationships of prediction error with axial length, keratometry, and preoperative refractive target were explored for each formula. Table 3 displays multiple regression equations for each intraocular lens formula. The regression equations estimated by each of the five formulas exhibited no multicollinearity. R-squared values, indicating explanatory power, ranged from 0.243 to 0.502. The prediction error demonstrated a positive correlation with the preoperative refractive target in all five formulas, signifying that the myopic shift targeted

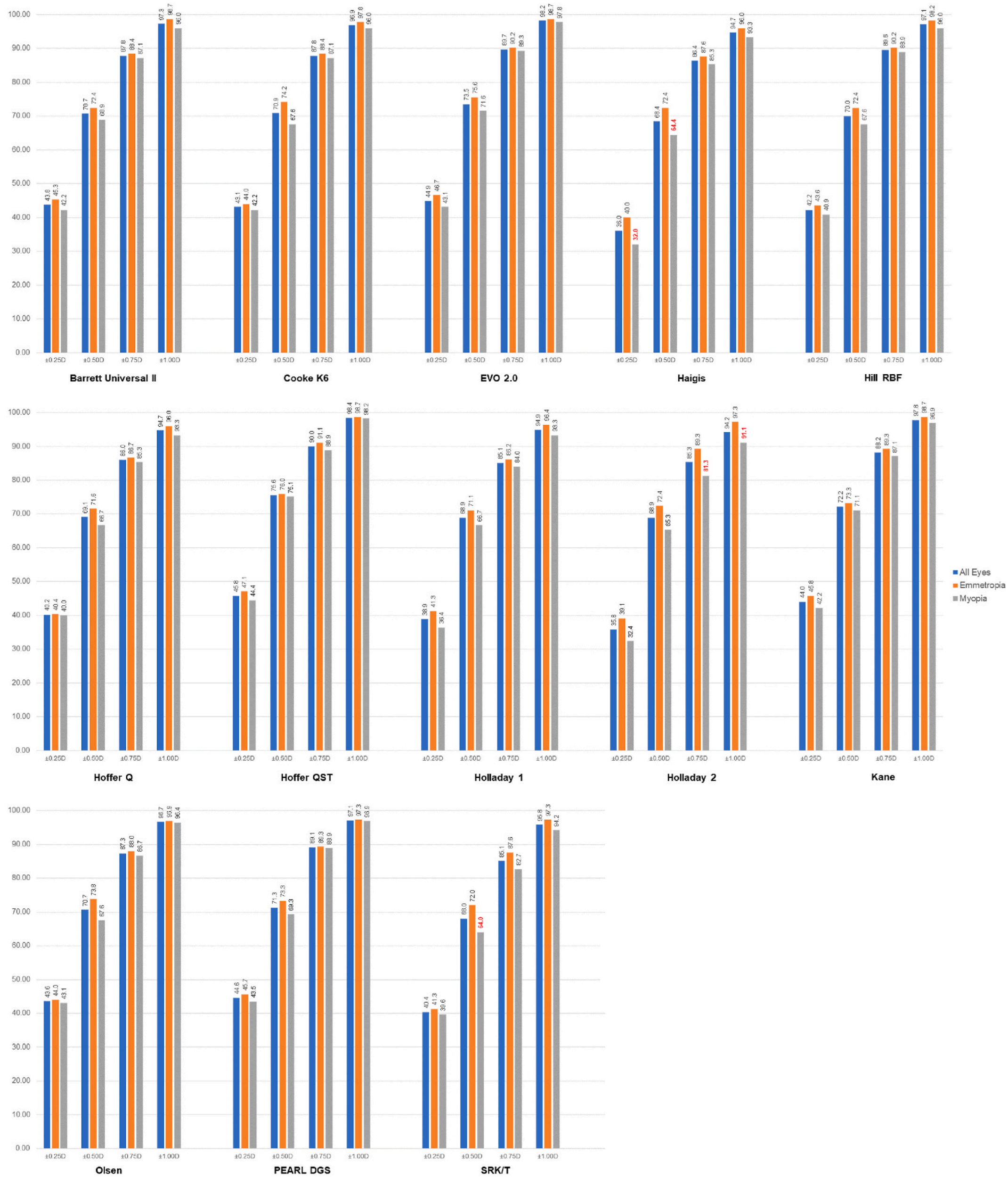

Fig. 2. Relative accuracy of each intraocular lens calculation formula comparing the percentage of emmetropic and myopic target subgroups within ±0.25 D, ±0.50D, ±0.75D, and ±1.00D of target refraction. Statistically significant differences ($P < 0.05$) are highlighted with red labels. Unit: diopters. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

as the refraction correlated positively with the prediction error. Notably, no statistically significant regression formula was derived for the Barrett, Cooke K6, EVO 2.0, Hill-RBF, Hoffer QST, Kane, Olsen, and PEARL-DGS.

4. Discussion

This study revealed that the emmetropic target subgroup showed a trend towards more accurate results compared to the myopic target subgroup. The significance of our study lies in its inclusion of a relatively large sample size and the comparison of clinical outcomes using the modern IOL power calculation formulas.

It has been reported in several studies that modern IOL formulas (such as Barrett Universal II, Cooke K6, EVO 2.0, Hill-RBF, Hoffer QST, Kane, Olsen, and PEARL-DGS) generally have higher accuracy compared to earlier formulas like SRK/T, Holladay 1, and Hoffer Q [3–6,10,22,23]. Our study corroborated this finding. In our investigation, the range of PE within ±0.5D was 68.0–72.7 %, similar to

Table 2
Mean prediction error according to keratometry values in the myopia group.

Formula	Mean keratometry <43.75 D (N = 67)	Mean keratometry ≥43.75 D (N = 158)	P-value
Barrett	0.003	−0.045	0.498
Cooke K6	−0.047	−0.013	0.579
EVO	0.040	−0.036	0.391
Haigis	−0.105	0.031	0.045*
Hill-RBF	−0.052	−0.022	0.612
Hoffer Q	−0.078	−0.032	0.539
Hoffer QST	−0.018	−0.020	0.929
Holladay 1	−0.037	−0.096	0.423
Holladay 2	0.018	−0.113	0.093
Kane	−0.050	−0.075	0.722
Olsen	−0.015	−0.014	0.904
PEARL DGS	−0.012	−0.016	0.847
SRK/T	0.036	−0.170	<0.01*

D = diopter, *Statistically significant.

Table 3
Multiple regression equations for each intraocular lens formula.

Formulas	Multiple regression equations	R^2	*P*-value	Multicollinearity
Haigis	PE = −7.034 + 0.130AXL +0.085K + 0.051PRE	0.243	P < 0.001	(−)
Hoffer Q	PE = −11.821 + 0.254AXL + 0.128K + 0.152PRE	0.457	P < 0.001	(−)
Holladay 1	PE = −6.817 + 0.290AXL - 0.012K + 0.094PRE	0.502	P < 0.001	(−)
Holladay 2	PE = −7.606 + 0.227AXL + 0.044K + 0.104PRE	0.353	P < 0.001	(−)
SRK/T	PE = −0.263 + 0.171AXL - 0.092K + 0.137PRE	0.272	P < 0.001	(−)

PE = prediction error, AXL = axial length, K = keratometry, PRE = preoperative refractive target.

Darcy and associates' report but relatively lower than Turnbull and associates' findings [4,17]. Recent prospective studies have shown that the accuracy of modern IOL formulas has significantly improved, with some formulas achieving a prediction error within 0.5D in up to 90 % of cases [22,23].

In this study, the accuracies of the Haigis, Holladay 2, and SRK/T formulas were observed to be relatively lower in the group targeting myopia of about −2.00 D compared to the group targeting emmetropic eyes. Surprisingly, there has been limited research on the topic of decreased accuracy of IOL formulas when targeting myopia [12–17]. Turnbull and associates conducted a study involving a total of 176 eyes and found that the accuracy of SRK/T and Haigis formulas might be slightly lower when targeting about −1.25D myopic eyes compared to that when targeting emmetropic eyes. Furthermore, they reported that the Barrett Universal II formula demonstrated accurate results even for the myopic target group [17]. Sakai and associates noted that the SRK/T, Holladay 1, Hoffer Q, and Holladay 2 formulas exhibited a statistically significant tendency to become relatively more myopic when targeting intentional myopia (−2.0 to −3.0 D) than when targeting emmetropia [16]. Specifically, they reported a statistically significant myopic trend with the SRK/T and Holladay 2 formulas [16]. Consistent with these findings, Geggel's study indicated that the Haigis formula was less accurate when targeting −1.0D myopia compared to targeting emmetropia [14]. These results align closely with the observations made in our study.

Our study unveiled that prediction errors of the SRK/T and Haigis formulas exhibited opposite directions when the K-reading was less than or greater than 43.75 in the myopic target group. Consistent with our findings, previous studies have also highlighted the potential impact of the K reading value on the accuracy of the SRK/T formula and the Haigis formula during cataract surgery targeting myopia [12,13]. Dalto and associates reported a significant hyperopic shift in the mean prediction error of the SRK/T formula when the K reading was flatter than 43.75, while the Haigis formula displayed a notable myopic shift [13]. Similarly, Cooke and associates observed that prediction errors of SRK/T and Haigis formulas predicted oppositely when the K reading was flatter than 43.75 or steeper, respectively [12]. Dalto and associates suggested the possibility that gender could be a contributing factor to the observed errors, as the prediction error of the SRK/T and Haigis formulas was more pronounced for females with flatter corneas, longer axial lengths, and deeper anterior chambers [13]. However, in our study, preoperative biometry, including gender, did not exhibit statistically significant differences between the two groups. According to the Kaiser study, SRK/T demonstrated a hyperopic shift as the cornea flattened, while the Haigis formula displayed a myopic shift as the cornea became steeper, based on a K reading of approximately 44.0 D [6]. These results collectively suggest that, when targeting myopia, the prediction error is likely to be larger due to the higher IOL power required, providing a potential explanation for the observed outcomes in our study.

The Holladay 2 formula calculates the effective lens position by taking into account seven variables: axial length, keratometry, anterior chamber depth, white-to-white, lens thickness, preoperative refraction, and age [24]. In the current study, preoperative refraction was intentionally excluded from the Holladay 2 formula. This decision was based on findings from a study by Cooke and Cooke, which indicated that the Holladay 2 formula, when excluding preoperative refraction, yielded superior results compared to its inclusive counterpart [3]. Consequently, it can be inferred that the exclusion of preoperative refraction did not exert a significant impact on the study's outcomes. In alignment with the observations of Sakai and associates, our study also identified a noteworthy myopic trend with the Holladay 2 formula when performing cataract surgery targeted towards myopia [16]. The relatively lower accuracy of the Holladay 2 formula in our study may be attributed to the absence of Wang-Koch adjustment [25] for cases with axial lengths of 24.0 mm or more. To enhance our understanding, further investigations are warranted to compare clinical outcomes using the Holladay 2 formula, specifically incorporating axial length adjustments. This would contribute valuable insights into refining the application of the Holladay 2 formula, especially in cases where axial length extends beyond 24.0 mm.

In this study, we conducted a comparison of biometric values between the two groups (emmetropia and myopia groups), ensuring that there were no statistically significant differences. However, it is well-established in the field of IOL power calculation that preoperative biometric values, such as axial length and keratometry, have a profound impact, with substantial influence on the accuracy of these formulas [5]. Consequently, we performed multiple regression analysis to explore how the prediction error could be influenced by each formula based on the manipulation of these variables. Our findings indicated that when the axial length was 24.5 mm or more, the prediction error exhibited a myopic shift as the preoperative target refraction became more myopic, except for the modern formulas. This observation was consistent with the results of a study by Sakai and associates [16]. Additionally, the Swedish National Cataract Register Study, involving 17,056 eyes, reported that when myopia was targeted, the actual prediction error was more myopic than the preoperative goal [26]. In contrast, a study by Cooke and associates, which included cases with axial lengths ranging from 23.62 mm to 28.11 mm, showed that only the SRK/T formula demonstrated a tendency to become more myopic when targeting myopia with the Barrett, Haigis, Hoffer Q, Holladay 1, and SRK/T formulas [12]. Based on our findings, we recommend the use of the modern IOL formulas when targeting myopia, especially when the axial length is 24.5 mm or more. However, if utilizing the Haigis, Hoffer Q, Holladay 1, Holladay 2, or SRK/T formulas, it is crucial to be mindful of the possibility of a more myopic shift than the intended myopic target.

A limitation of this study is the relatively suboptimal refractive outcomes for each formula compared to previous studies. One possible reason for this result could be measurement errors arising from multiple optometrists performing postoperative refraction assessments. As a retrospective study, our analysis is based on previously recorded data, which limits our ability to precisely determine who performed the refractions and the methods used. To overcome this limitation, future research should adopt a prospective design with strict protocols for measuring postoperative refraction. Standardizing the measurement distance for visual acuity is also important. According to Simpson and Chairman, 6 m is appropriate, and refractions measured at a distance of 4 m can be converted to 6 m by adding −0.08 D to the spherical equivalent value [27].

The study's strength lies in the comprehensive analysis of a relatively large number of subjects compared to previous investigations. Additionally, the study exclusively considered outcomes from a single monofocal IOL cataract surgery performed by a lone surgeon. This approach served to eliminate confounding factors, with the further refinement of including only one randomly selected eye per patient.

In conclusion, this study revealed that the emmetropic target subgroup exhibited a tendency toward more accurate results compared to the myopic target subgroup. Specifically, for the SRK/T, Haigis, and Holladay 2 formulas, the accuracy was significantly reduced when myopic eyes were targeted in contrast to emmetropic eyes. Conversely, the accuracies of the modern formulas appeared to be less affected even when myopic eyes were the target. It is noteworthy that when the axial length is 24.5 mm or more, there is a potential for a myopic shift from the intended target refraction, particularly when using the SRK/T, Haigis, Hoffer Q, Holladay 1, and Holladay 2 formulas. Therefore, in cases where myopia is the target, it is advisable to employ the modern IOL power formulas.

What was known.

- Previous studies with a limited number of patients have suggested that the prediction error tends to be larger when targeting myopia compared to targeting emmetropia.

What this study adds

- In this study, which included a relatively large number of patients, the prediction error was found to be larger when targeting myopia compared to targeting emmetropia.
- The modern formulas exhibited lesser susceptibility to this phenomenon. Conversely, the SRK/T, Haigis, and Holladay 2 formulas were more significantly affected.
- It is advisable to consider the potential for a myopic shift from the intended target refraction when utilizing the SRK/T, Haigis, Hoffer Q, Holladay 1, and Holladay 2 formulas, particularly when the axial length exceeds 24.5 mm.

Data availability statement

Data included in article/supp. material/referenced in article.

Ethics declarations

The Institutional Review Board (IRB) of Seoul St. Mary's Hospital, the Catholic University of Korea, approved this study (IRB No. KC21RASI0806) and waived the requirement for informed consent due to the retrospective nature of the investigation. The study adhered to the principles of the Declaration of Helsinki.

CRediT authorship contribution statement

Soonwon Yang: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Chanjoon Park:** Data curation. **Yong-Soo Byun:** Supervision, Methodology. **So-Hyang Chung:** Supervision, Methodology. **Hyun Seung Kim:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e33339.

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