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Full Length Article

Comparison of the accuracy of six intraocular lens power calculation methods in post-myopic-LASIK eyes

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ABSTRACT

Objectives: To compare the accuracy of six intraocular lens (IOL) power calculation methods in post-myopic-LASIK eyes.

Methods: Post-myopic-LASIK patients scheduled for cataract surgery were enrolled. Mean error (ME), mean absolute error (MAE), and median absolute error (MedAE) of ASCRS (ASCRS-Max, ASCRS-Average, ASCRS-Min), EVO 2.0, Pearl-DGS, Barrett True-K no-history, Shammas-PL, and Haigis-L were compared. The ASCRS method employed four formulas, including Shammas-PL, Haigis-L, Potvin-Hill Pentacam, and Barrett True-K no-history. Trueness, precision, and accuracy indices were evaluated by comparing trimmed-mean values with heteroscedasticity adjustment. Subgroup analyses were performed based on K value, axial length (AL), and corneal decentered ablation, respectively. Factors influencing prediction errors were analyzed.

Results: Totally, 87 eyes were analyzed. ASCRS-Min had the lowest MAE (0.79 D) and MedAE (0.62 D), followed by EVO 2.0, Pearl-DGS, and Barrett True-K no-history. It also had the highest percentage of absolute errors within 1.00 D. All methods outperformed ASCRS-Max in accuracy indices, and ASCRS-Min and EVO 2.0 showed superior accuracy indices compared to Shammas-PL and Haigis-L. In the subgroups of lower K value, longer AL, and larger decentration of ablation zone, ASCRS-Min, EVO 2.0, Pearl-DGS, and Barrett True-K no-history generated statistically lower MedAEs than ASCRS-Max. The accuracy of Shammas-PL was associated with AL; the accuracy of Haigis-L was associated with K value and AL; no other significant associations were found.

Conclusions: Generally, ASCRS-Min, EVO 2.0, Pearl-DGS, and Barrett True-K no-history achieve relatively better accuracy than the other methods, which might be considered as first choices for IOL power calculation in post-myopic-LASIK eyes.

1. Introdution

Laser-assisted in situ keratomileusis (LASIK) for myopia, which relies on corneal reshaping by ablation, has evolved over decades.[1] Many patients who underwent this procedure are now reaching the age where cataracts typically develop.[2] However, their eyes exhibit distinct differences in anterior corneal curvature and corneal thickness compared to virgin eyes. These surgical changes alter the physiological anatomical parameters and disrupt the normal relationship between the anterior and posterior corneal surfaces, which poses significant challenges for surgeons when calculating intraocular lens (IOL) power using conventional formulas.[3,4]

Current evidence indicates that IOL power prediction accuracy remains suboptimal in post-myopic-LASIK eyes.[5] In recent years, multiple new formulas, including EVO 2.0, Pearl-DGS, Barrett True-K no-history, Shammas-PL, and Haigis-L, have been developed,[6–8] which demonstrate enhanced accuracy in post-myopic-LASIK eyes. Additionally, as a web-based platform enabling parallel computation across multiple formulas with generation of maximum, average, and minimum IOL power values, the ASCRS post-refractive IOL calculator has also emerged as a valuable tool for post-myopic-LASIK eyes.[9,10]

Given that no single formula has demonstrated consistent superiority in post-myopic-LASIK eyes, research supports the strategies of evaluating several formulas comprehensively, such as utilizing ASCRS online calculator.[11] Furthermore, it is generally believed by cataract surgeons that the ASCRS-Average is much more reliable than ASCRS-Max and ASCRS-Min.[12] However, this perspective requires rigorous validation.

Therefore, this study aimed to compare the accuracy of six IOL power

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calculation methods tailored for post-myopic-LASIK eyes, including ASCRS (ASCRS-Max, ASCRS-Average, ASCRS-Min), EVO 2.0, Pearl-DGS, Barrett True-K no-history, Shammas-PL, and Haigis-L, and to optimize postoperative refractive outcomes.

2. Methods

2.1. Ethics statement

This prospective case series study was approved (2023110) by the Institutional Review Board of Eye and ENT Hospital, Fudan University, and was conducted as part of the Shanghai High Myopia Study registered at ClinicalTrials.gov (NCT03062085). All procedures adhered to the tenets of the Declaration of Helsinki. Each patient in this study completed an informed consent form prior to enrollment.

2.2. Patients

Post-myopic-LASIK patients scheduled for phacoemulsification with IOL implantation at Eye and ENT Hospital, Fudan University, between December 2021 and November 2023, were consecutively recruited. Exclusion criteria comprised: (1) ophthalmic pathologies potentially impacting postoperative refractive outcomes (including but not limited to corneal abnormalities, glaucoma, strabismus, zonular weakness, uveitis, and severe retinopathies); (2) history of ocular trauma or non-refractive ocular surgeries; and (3) significant intraoperative/postoperative complications (e.g., posterior capsular rupture). Eyes with postoperative best corrected visual acuity (BCVA) worse than 6/9 were also excluded. For bilateral cases, one eye was randomly selected. The final analysis included 87 eyes from 87 patients.

2.3. Preoperative and postoperative examinations

All patients completed a standardized preoperative ophthalmic evaluation comprising: visual acuity assessment, slit-lamp biomicroscopy, B-scan ultrasonography, fundoscopic examination, ocular biometry (IOLMaster 700, Carl Zeiss Meditec AG, Jena, Germany), and corneal topography (Pentacam AXL, Oculus Optikgeräte GmbH, Wetzlar, Germany). Manifest refraction was performed by a single certified technician at the 1-month postoperative visit, using a phoropter (NIDEK RT-5100) in a standard 6-m lane to simulate optical infinity. All measurements were taken under constant lighting conditions in the absence of natural daylight. Both logMAR uncorrected (UCVA) and best corrected visual acuity (BCVA) were recorded.

2.4. Standardized surgical protocol

All procedures were performed by a single experienced surgeon (XZ) following a standardized protocol under topical anesthesia. Through a 2.60 mm clear corneal incision, phacoemulsification was performed with subsequent implantation of a foldable IOL (ZEISS CT ASPHINA 409 MP) in the capsular bag. The incisions were hydrated and achieved self-sealing without sutures. Postoperatively, all patients received identical anti-inflammatory regimen.

2.5. IOL power and prediction error calculations

In total, six no-history methods were investigated: ASCRS (ASCRS-Max, ASCRS-Average, ASCRS-Min), EVO 2.0, Pearl-DGS, Barrett True-K no-history, Shammas-PL, and Haigis-L. The measurements obtained from IOLMaster 700 and Pentacam AXL were input into each method for calculation. The following optimized IOL constants for the ZEISS CT ASPHINA 409 MP lens were applied: the Haigis (a0 = 0.6088; a1 = 0.2257; a2 = 0.1389), Holladay 1 (SF = 1.399), and SRK/T (A = 118.336) constants were obtained from the IOLCon website (https://www.iolcon.org), while the platform default constants were used for EVO 2.0 (A-constant = 118.34) and Pearl-DGS (A-constant = 117.95).

For the ASCRS online calculator, the data entry generated IOL power calculations of four formulas, including Shammas-PL, Haigis-L, Potvin-Hill Pentacam, and Barrett True-K no-history.[1,13–16] The maximum, average, and minimum IOL power values of these four formulas were automatically generated. Since the ASCRS calculator does not directly provide the predicted refraction for the implanted IOL power, a systematic iterative approach was employed to manually derive this value.[17] First, a target refraction of 0.00 D was input to generate an initial proposed IOL power (I). Then, an empirical starting value for the target refraction (R) was calculated as given below:

If the implanted IOL power (P) $>$ 14.00 D, R = (P-I)/1.25.

If the implanted IOL power (P) $\leq$14.00 D, R = P-I.

This R value was then input as the new target refraction and iteratively adjusted until the proposed IOL power matched the actual implanted IOL power (P). The final R value was recorded as the predicted postoperative refraction for the ASCRS method. This process was conducted individually for the ASCRS-Max, ASCRS-Average, and ASCRS-Min to derive their respective predicted refractions. For the other methods, the predicted refraction was directly obtained from their respective calculator outputs. Critically, to ensure a standardized comparison, the predicted refraction for each method was calculated for the actual implanted IOL power and then compared to the postoperative refractive outcome in each eye.

The prediction error was defined as the actual postoperative spherical equivalent minus the refraction predicted by each method. The mean error (ME), mean absolute error (MAE), and median absolute error (MedAE) were calculated and compared. Furthermore, trueness, precision, and accuracy indices were obtained and analyzed using the Eyetemis online tool (www.Eyetemis.com), with the "paired spherical equivalent prediction error (SEQ-PE)" option selected. These indices are defined by ISO standards as follows[18]: trueness reflects the closeness of the mean SEQ-PE to the ideal reference value (in this context 0); precision refers to the agreement among individual SEQ-PE observations; and accuracy represents the total deviation from the reference value, combining both systematic (trueness) and random (precision) effects. The outlier-resistant trimmed-mean values of these three ISO categories were evaluated.[19]

Subgroup analyses were performed based on K value, axial length (AL), and corneal decentered ablation, respectively. All the eyes were divided into 2 subgroups according to median K value as follows: K $\leq$ 37.78 D (44 eyes) and K $>$ 37.78 D (43 eyes); they were also divided into 4 subgroups according to AL as follows: AL $<$ 26 mm (15 eyes), AL 26–28 mm (19 eyes), AL 28–30 mm (29 eyes), AL $\geq$30 mm (24 eyes); and they were divided into 2 subgroups according to median decentration of ablation zone as follows: decentration of ablation zone $\leq$ 0.93 mm (44 eyes) and decentration of ablation zone $>$ 0.93 mm (43 eyes). The decentration of ablation zone of each eye was measured manually by Pentacam following the methodology established in our prior investigation.[3] Specifically, on the tangential curvature map, the ablation zone was identified as the area within a fitting circle or ellipse exhibiting a distinct decrease in curvature. Its center (x, y) was defined as the ablation center. To quantify the decentration, the linear distance in millimeters between the corneal vertex (0, 0) and the ablation center was then calculated as $\sqrt{x^2 + y^2}$. All measurements were performed independently by two experienced examiners (QY and WH), and the average value was used for the final analysis.

2.6. Statistical analysis

Statistical analyses were performed by SPSS Statistics 29.0 (IBM, Chicago, USA) and the Eyetemis online tool. Continuous variables were presented as mean ± standard deviation (SD). Preoperative and postoperative visual acuities were compared using paired *t*-test. The differences in MedAEs among the six methods were compared by Friedman

test in the whole sample and subgroups. Statistically significant overall differences were followed by post-hoc pairwise comparison automatically performed by SPSS using its built-in procedure for Friedman test, with *P*-values adjusted using the Bonferroni method. Cochran's Q test was used for the frequency comparison, followed by post-hoc pairwise comparison using McNemar's test with Bonferroni correction. For the ISO indices, the Eyetemis online tool automatically performed comparisons using its built-in robust t-tests: the one-sample test for comparing trueness indices with zero, and the two-sample test for comparing all indices between every two methods. The backward stepwise multivariate linear regression analysis was performed to identify the factors that influenced prediction errors. The factors evaluated included age, gender, eye laterality, K value, AL, anterior chamber depth (ACD), and decentration of ablation zone. A *P*-value less than 0.05 was considered statistically significant.

3. Results

3.1. Patients' characteristics

The study evaluated 87 post-myopic-LASIK eyes of 87 patients. Demographic characteristics of these patients are presented in Table 1. Both UCVA and BCVA of all eyes demonstrated statistically significant improvement at the 1-month postoperative evaluation (paired *t*-test, both $P < 0.001$).

3.2. Prediction errors

The prediction error outcomes, including ME, MAE, and MedAE of each method are tabulated in Table 2. The ME ranged from −1.00 D (ASCRS-Max) to −0.02 D (ASCRS-Min). ASCRS-Min had the lowest MAE (0.79 D), followed by EVO 2.0 (0.86 D), Pearl-DGS (0.88 D), and Barrett True-K no-history (0.90 D). ASCRS-Min also had the lowest MedAE (0.62 D), followed by EVO 2.0 (0.69 D), Pearl-DGS (0.76 D), and Barrett True-K no-history (0.78 D). Friedman test revealed a statistically significant difference among these methods for MedAE ($P < 0.001$), and post-hoc analysis showed that ASCRS-Min, EVO 2.0, Pearl-DGS, and Barrett True-K no-history generated statistically lower MedAEs than ASCRS-Max (all $P < 0.05$).

The box and whisker plots of prediction errors of each method are shown in Fig. 1. All the methods had myopic median prediction errors, and Pearl-DGS had the least myopic median prediction error (−0.17 D), followed by ASCRS-Min (−0.18 D), EVO 2.0 (−0.33 D), and Barrett True-K no-history (−0.55 D). The distribution of absolute prediction errors of each method is shown in Fig. 2. ASCRS-Min had the highest percentage of absolute errors within 0.50 D, followed by Pearl-DGS, EVO 2.0, and Barrett True-K no-history. However, there was no statistically significant difference among these six methods. It also had the highest percentage of absolute errors within 1.00 D (Cochran's Q test, $P < 0.001$), followed by EVO 2.0, Pearl-DGS, ASCRS-Average, and Barrett True-K no-history. All of these methods significantly outperformed ASCRS-Max (McNemar's test with Bonferroni correction, all $P < 0.001$).

Table 1
Demographic data of the patients.

Characteristics	Value
Age (years)	57.2 ± 9.1
Gender (male/female)	20/67
Eye laterality (right/left)	48/39
K (D)	37.92 ± 2.64
Axial length (mm)	28.46 ± 2.35
ACD (mm)	3.29 ± 0.40
Preoperative visual acuity	
UCVA (logMAR)	0.67 ± 0.19
BCVA (logMAR)	0.43 ± 0.21
Postoperative visual acuity	
UCVA (logMAR)	0.32 ± 0.14
BCVA (logMAR)	0.11 ± 0.05

K, corneal curvature (keratometry value); ACD, anterior chamber depth; UCVA, uncorrected visual acuity; BCVA, best corrected visual acuity; logMAR, logarithm of the minimum angle of resolution.

Table 2
ME, MAE, and MedAE of each method.

Method	ME (D) ± SD	MAE (D) ± SD	MedAE (D)
ASCRS-Max	−1.00 ± 1.30	1.29 ± 1.01	1.18
ASCRS-Average	−0.50 ± 1.07	0.94 ± 0.71	0.85
ASCRS-Min	−0.02 ± 1.04	0.79 ± 0.66	0.62
EVO 2.0	−0.25 ± 1.07	0.86 ± 0.68	0.69
Pearl-DGS	−0.09 ± 1.15	0.88 ± 0.74	0.76
Barrett True-K no-history	−0.52 ± 1.00	0.90 ± 0.68	0.78
Shammas-PL	−0.57 ± 1.16	1.03 ± 0.78	0.87
Haigis-L	−0.57 ± 1.29	1.09 ± 0.89	0.97

The trueness, precision, and accuracy indices of each method are detailed in Table 3. For trueness, the trimmed-mean values ranged from −0.97 D (ASCRS-Max) to −0.06 D (ASCRS-Min). All of these values were significantly lower than zero, except for ASCRS-Min ($P = 0.60$) and Pearl-DGS ($P = 0.29$). Furthermore, the trimmed-mean values of ASCRS-Min, Pearl-DGS, EVO 2.0, ASCRS-Average, and Barrett True-K no-history were all significantly closer to zero compared to ASCRS-Max (all $P < 0.01$). For precision, a significant difference was found between ASCRS-Min and Haigis-L ($P < 0.05$). For accuracy, ASCRS-Min had the lowest trimmed-mean value, followed by EVO 2.0, Pearl-DGS, and Barrett True-K no-history. All methods had significantly lower trimmed-mean values than ASCRS-Max. Additionally, the trimmed-mean values of ASCRS-Min and EVO 2.0 were also significantly lower than those of Shammas-PL and Haigis-L (all $P < 0.05$).

3.3. Comparisons of accuracy within different K value subgroups

The mean and median K value of all eyes were 37.92 ± 2.64 D and 37.78 D, respectively. Table 4 shows the MAE and MedAE of each method in the two K value subgroups. In both subgroups, ASCRS-Min had the lowest MAE, followed by EVO 2.0, Pearl-DGS, and Barrett True-K no-history, and the absolute errors of these six methods showed a significant difference (Friedman test, both $P = 0.001$). Specifically, in the subgroup of lower K values (K ≤ 37.78 D), ASCRS-Min, EVO 2.0, Pearl-DGS, and Barrett True-K no-history generated statistically lower MedAEs than ASCRS-Max (all $P < 0.05$). Similarly, in the subgroup of higher K values (K > 37.78 D), ASCRS-Min, EVO 2.0, and Pearl-DGS generated statistically lower MedAEs than ASCRS-Max (all $P < 0.05$). Furthermore, no significant difference among ASCRS-Min, EVO 2.0, Pearl-DGS and Barrett True-K no-history was found in each subgroup. The trueness, precision, and accuracy indices are presented in Supplementary Tables 1 and 2, ASCRS-Min, EVO 2.0, and Pearl-DGS had significantly lower trimmed-mean values for accuracy than ASCRS-Max in the subgroup of lower K values, while only a significant difference between ASCRS-Min and ASCRS-Max was found in the subgroup of higher K values (all $P < 0.05$).

4. Comparisons of accuracy within different AL subgroups

The mean and median AL of all eyes were 28.46 ± 2.35 mm and 28.68 mm, respectively. The MAE and MedAE of each method in the four AL subgroups are shown in Table 5. In each subgroup, ASCRS-Min, EVO 2.0, Pearl-DGS and Barrett True-K no-history ranked among the top four in terms of MAEs numerically. In the subgroups of AL 26–28 mm, 28–30 mm, and ≥ 30 mm, the absolute errors of these six methods showed a significant difference (Friedman test, all $P < 0.05$), and post-hoc analysis showed that ASCRS-Min, EVO 2.0, Pearl-DGS, and Barrett True-K no-history generated statistically lower MedAEs than ASCRS-Max (all $P < 0.05$). Furthermore, no significant difference among

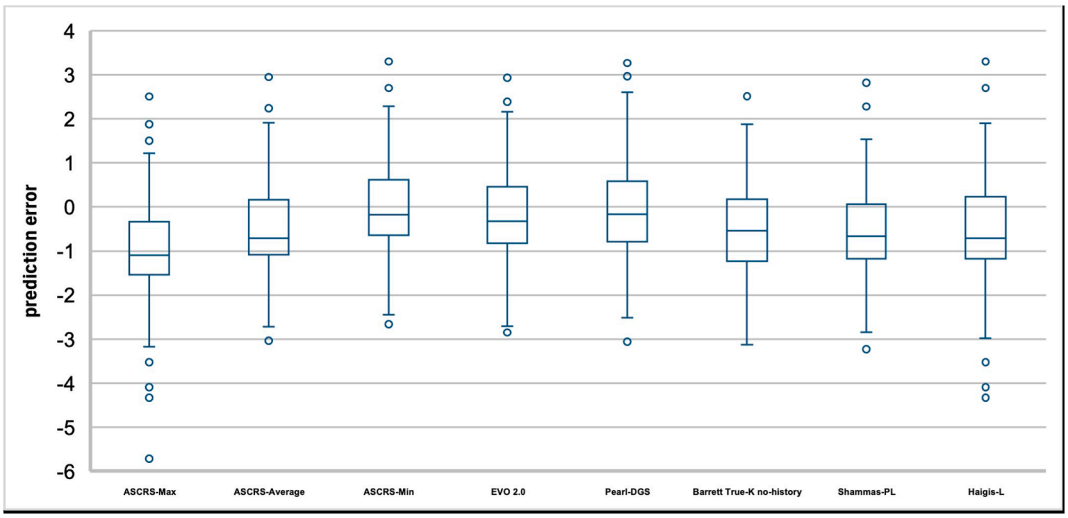


Fig. 1. Box and whisker plots of prediction errors of each method.

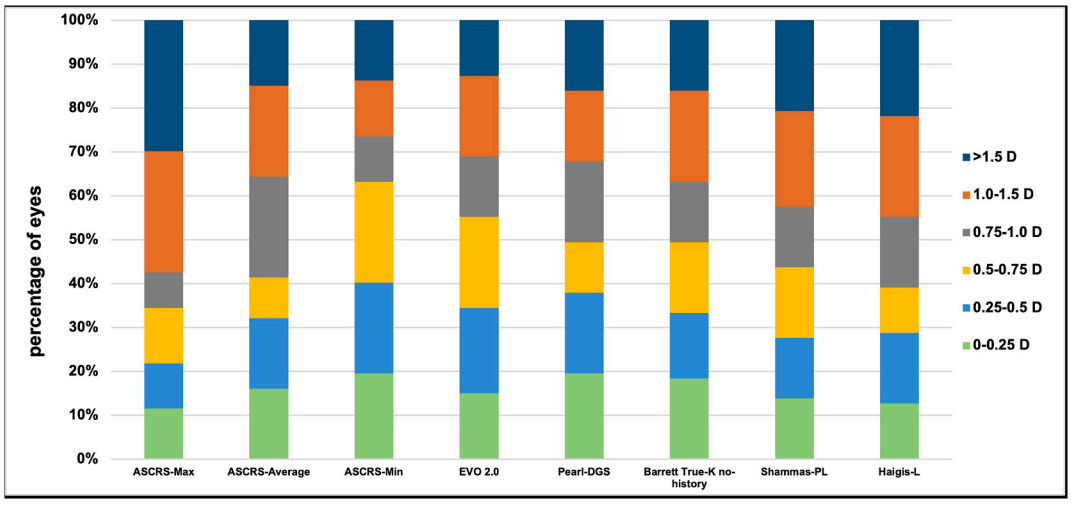


Fig. 2. Distribution of absolute prediction errors of each method.

ASCRS-Min, EVO 2.0, Pearl-DGS and Barrett True-K no-history was found in each subgroup. The trueness, precision, and accuracy indices are presented in Supplementary Tables 3, 4, 5, and 6. ASCRS-Min, EVO 2.0, Pearl-DGS, and Barrett True-K no-history demonstrated significantly lower trimmed-mean values for accuracy than ASCRS-Max in all subgroups except AL $<$ 26 mm (all $P < 0.05$).

4.1. Comparisons of accuracy within different corneal decentered ablation subgroups

The mean and median decentration of ablation zone of all eyes were 1.05 $\pm$ 0.52 mm and 0.93 mm, respectively. The MAE and MedAE of each method in the two corneal decentered ablation subgroups are shown in Table 6. In both subgroups, ASCRS-Min, EVO 2.0, Pearl-DGS and Barrett True-K no-history ranked among the top four in terms of MAEs numerically, and the absolute errors of these six methods showed a significant difference (Friedman test, both $P < 0.05$). Specifically, in the subgroup of smaller decentration of ablation zone ($\leq$ 0.93 mm), post-hoc analysis only revealed that ASCRS-Min generated statistically lower MedAE than ASCRS-Max ($P = 0.035$). And in the subgroup of larger decentration of ablation zone ($>$ 0.93 mm), ASCRS-Min, EVO 2.0, Pearl-DGS, and Barrett True-K no-history generated statistically lower MedAEs than ASCRS-Max and Haigis-L (all $P < 0.05$). Furthermore, no significant difference among ASCRS-Min, EVO 2.0, Pearl-DGS and Barrett True-K no-history was found in each subgroup. The trueness, precision, and accuracy indices are presented in Supplementary Tables 7 and 8 For accuracy, while no significant difference was found among the six methods in the subgroup of smaller decentered ablation, ASCRS-Min, EVO 2.0, Pearl-DGS, and Barrett True-K no-history demonstrated significantly lower trimmed-mean values than ASCRS-Max and Haigis-L in the subgroup of larger decentered ablation (all $P < 0.05$).

4.2. Factors influencing prediction errors

Age, gender, eye laterality, K value, AL, ACD, and decentration of ablation zone were included in the backward stepwise multivariate linear regression analysis for each method. The results showed that the accuracy of Shammas-PL was affected by AL ($\beta = -0.216$, $P = 0.044$); the accuracy of Haigis-L was affected by K value ($\beta = -0.522$, $P < 0.001$) and AL ($\beta = -0.470$, $P = 0.002$); no other significant associations were found for the remaining methods.

5. Discussion

In this study, we compared the accuracy of six methods tailored to calculate IOL power in post-myopic-LASIK eyes: ASCRS (ASCRS-Max,

Table 3
Trueness, precision, and accuracy indices of each method.

Method	tr-mean	Mean	RMS	SD	Min	25%	50%	75%	Max
Trueness (D)									
ASCRS-Max	−0.97	−1.00	1.64	1.30	−5.72	−1.53	−1.09	−0.35	2.51
ASCRS-Average	−0.53	−0.50	1.17	1.07	−3.04	−1.07	−0.71	0.15	2.95
ASCRS-Min	−0.06	−0.02	1.03	1.04	−2.66	−0.63	−0.18	0.60	3.30
EVO 2.0	−0.28	−0.25	1.09	1.07	−2.85	−0.82	−0.33	0.44	2.93
Pearl-DGS	−0.12	−0.09	1.14	1.15	−3.06	−0.79	−0.17	0.57	3.27
Barrett True-K no-history	−0.54	−0.52	1.12	1.00	−3.13	−1.23	−0.55	0.10	2.51
Shammas-PL	−0.60	−0.58	1.30	1.16	−3.23	−1.18	−0.67	0.05	2.82
Haigis-L	−0.57	−0.57	1.40	1.29	−4.33	−1.16	−0.72	0.24	3.30
Precision (D)									
ASCRS-Max	0.79	0.94	1.30	0.90	0.02	0.36	0.60	1.26	4.75
ASCRS-Average	0.71	0.82	1.06	0.68	0.06	0.33	0.63	1.04	3.48
ASCRS-Min	0.69	0.79	1.03	0.67	0.01	0.31	0.61	1.08	3.36
EVO 2.0	0.71	0.81	1.06	0.69	0.02	0.32	0.60	1.11	3.21
Pearl-DGS	0.76	0.86	1.14	0.75	0.00	0.33	0.67	1.13	3.38
Barrett True-K no-history	0.69	0.77	1.00	0.63	0.00	0.31	0.70	1.01	3.05
Shammas-PL	0.75	0.86	1.16	0.78	0.01	0.27	0.64	1.12	3.42
Haigis-L	0.81	0.95	1.28	0.86	0.02	0.39	0.76	1.15	3.87
Accuracy (D)									
ASCRS-Max	1.15	1.29	1.64	1.02	0.02	0.56	1.18	1.58	5.72
ASCRS-Average	0.86	0.94	1.17	0.71	0.02	0.39	0.85	1.33	3.04
ASCRS-Min	0.70	0.79	1.03	0.66	0.02	0.34	0.62	1.02	3.30
EVO 2.0	0.77	0.86	1.10	0.68	0.01	0.37	0.69	1.22	2.93
Pearl-DGS	0.77	0.88	1.14	0.74	0.02	0.34	0.76	1.15	3.27
Barrett True-K no-history	0.82	0.90	1.12	0.68	0.02	0.36	0.78	1.30	3.13
Shammas-PL	0.94	1.04	1.30	0.78	0.02	0.49	0.87	1.37	3.23
Haigis-L	0.96	1.09	1.40	0.89	0.05	0.44	0.97	1.41	4.33

tr-mean, trimmed-mean value; RMS, root mean square; Min, minimal; 25%, first quartile (Q1); 50%, median, second quartile (Q2); 75%, third quartile (Q3); Max, maximal.

Table 4
MAE and MedAE of each method in the two K value subgroups.

Method	K value			
	≤ 37.78 D (44 eyes)		> 37.78 D (43 eyes)	
	MAE (D) ± SD	MedAE (D)	MAE (D) ± SD	MedAE (D)
ASCRS-Max	1.58 ± 1.25	1.30	1.16 ± 0.70	1.16
ASCRS-Average	1.04 ± 0.86	0.89	0.91 ± 0.56	0.86
ASCRS-Min	0.81 ± 0.73	0.62	0.78 ± 0.62	0.64
EVO 2.0	0.96 ± 0.79	0.74	0.81 ± 0.58	0.67
Pearl-DGS	0.98 ± 0.88	0.79	0.82 ± 0.61	0.71
Barrett True-K no-history	0.99 ± 0.76	0.85	0.87 ± 0.62	0.73
Shammas-PL	1.15 ± 0.92	0.87	1.00 ± 0.66	0.89
Haigis-L	1.30 ± 1.12	0.98	0.97 ± 0.59	0.99
P-value	–	0.001	–	0.001

ASCRS-Average, ASCRS-Min), EVO 2.0, Pearl-DGS, Barrett True-K no-history, Shammas-PL, and Haigis-L. The results showed that generally ASCRS-Min, EVO 2.0, Pearl-DGS, and Barrett True-K no-history achieved better accuracy compared to the other methods.

The ASCRS post-refractive IOL calculator is a widely utilized tool that facilitates simultaneous calculation of multiple formulas,[20,21] and ASCRS-Average has been widely adopted as a reference standard in IOL calculation in post-myopic-LASIK eyes. Although ASCRS-Max and ASCRS-Min are also automatically generated, they have remained understudied, because clinical consensus suggests that the average value is more accurate. In most previous studies, ASCRS-Max and ASCRS-Min have not been investigated, and among ASCRS-Max, ASCRS-Average, and ASCRS-Min, there is actually no definitive conclusion regarding which one is the most accurate. Therefore, we decided to include ASCRS-Max and ASCRS-Min in the scope of comparison as well. To the best of our knowledge, this is the first prospective study to systematically compare ASCRS-Max, ASCRS-Average, and ASCRS-Min methods with the latest generation of single formulas tailored for post-myopic-LASIK eyes. In our study, we inputted the data into the ASCRS online calculator, which automatically generated the maximum, average, and minimum IOL power values for four formulas: Shammas-PL, Haigis-L, Potvin-Hill Pentacam, and Barrett True-K no-history. Notably, we observed that ASCRS-Min gave pretty good outcome. We speculated that this was because, as shown in Fig. 1, despite improvements over traditional formulas, some formulas tailored

Table 5
MAE and MedAE of each method in the four AL subgroups.

Method	Axial length							
	< 26 mm (15 eyes)		≥ 26 mm to < 28 mm (19 eyes)		≥ 28 mm to < 30 mm (29 eyes)		≥ 30 mm (24 eyes)	
	MAE (D) ± SD	MedAE (D)	MAE (D) ± SD	MedAE (D)	MAE (D) ± SD	MedAE (D)	MAE (D) ± SD	MedAE (D)
ASCRS-Max	0.88 ± 0.63	0.89	1.24 ± 0.89	1.11	1.43 ± 1.18	1.29	1.50 ± 1.20	1.30
ASCRS-Average	0.66 ± 0.37	0.67	0.93 ± 0.67	0.89	0.99 ± 0.78	0.89	1.16 ± 0.86	1.09
ASCRS-Min	0.58 ± 0.45	0.47	0.74 ± 0.60	0.56	0.87 ± 0.74	0.72	0.95 ± 0.69	0.81
EVO 2.0	0.54 ± 0.30	0.46	0.83 ± 0.64	0.73	0.87 ± 0.57	0.73	1.03 ± 0.87	0.86
Pearl-DGS	0.60 ± 0.47	0.57	0.80 ± 0.61	0.67	0.92 ± 0.68	0.82	1.08 ± 0.97	0.89
Barrett True-K no-history	0.61 ± 0.36	0.56	0.83 ± 0.61	0.73	0.95 ± 0.82	0.78	1.00 ± 0.85	0.82
Shammas-PL	0.76 ± 0.59	0.80	1.01 ± 0.83	0.84	1.12 ± 1.00	1.00	1.29 ± 0.86	1.23
Haigis-L	0.85 ± 0.49	0.81	1.02 ± 0.74	0.93	1.23 ± 0.99	0.99	1.31 ± 1.23	1.16
P-value	–	0.254	–	0.003	–	< 0.001	–	< 0.001

Table 6
MAE and MedAE of each method in the two corneal decentered ablation subgroups.

Method	Decentration of ablation zone			
	≤ 0.93 mm (44 eyes)		> 0.93 mm (43 eyes)	
	MAE (D) ± SD	MedAE (D)	MAE (D) ± SD	MedAE (D)
ASCRS-Max	1.29 ± 0.93	1.13	1.47 ± 1.12	1.28
ASCRS-Average	0.94 ± 0.67	0.88	1.03 ± 0.78	0.88
ASCRS-Min	0.70 ± 0.63	0.49	0.87 ± 0.72	0.66
EVO 2.0	0.79 ± 0.62	0.68	1.00 ± 0.76	0.77
Pearl-DGS	0.79 ± 0.69	0.64	0.99 ± 0.82	0.77
Barrett True-K no-history	0.91 ± 0.65	0.82	0.97 ± 0.75	0.81
Shammas-PL	1.08 ± 0.79	0.87	1.10 ± 0.86	1.00
Haigis-L	1.11 ± 0.92	0.91	1.29 ± 0.94	1.21
P-value	–	0.017	–	< 0.001

for post-myopic-LASIK eyes (such as Barrett True-K no-history, Shammas-PL, and Haigis-L) still exhibited myopic prediction errors. Consequently, in this study, when the calculations on the ASCRS online calculator were limited to these four formulas, selecting the minimum value could effectively minimize these myopic prediction errors.

Previous research has mostly reported that in eyes with previous myopic laser vision correction, Barrett True-K no-history is widely recognized with quite good accuracy.[9,15,22,23] In our study, we found that EVO 2.0 and Pearl-DGS showed no statistically significant difference in accuracy compared to Barrett True-K no-history, and they were even numerically better.

This study has several limitations. First, the analysis was deliberately restricted to a select group of six contemporary no-history methods based on their widespread clinical adoption, algorithmic diversity, and public accessibility, thereby excluding other options. Consequently, our findings may not fully represent the entire spectrum of IOL power calculation methods for post-myopic-LASIK eyes. Furthermore, the excellent accuracy of ASCRS-Min was observed within a subset of only four formulas and may not extend to the full calculator, as incorporating additional or updated formulas could potentially alter the outcomes. Second, though the sample size was moderate compared to previous studies, it may have compromised the statistical power for subgroup analyses, particularly in smaller cohorts such as eyes with AL < 26 mm. Third, the generalizability of our findings may be limited by the single-center design, with all surgeries performed by one surgeon using a specific IOL model. Therefore, the applicability to diverse surgical settings requires further investigation. Finally, the manual measurement of decentered ablation could be susceptible to inter-observer variability. Future studies would benefit from fully automated, standardized software.

In conclusion, our study identified that compared to the other methods, ASCRS-Min, EVO 2.0, Pearl-DGS, and Barrett True-K no-history achieved better accuracy in IOL power calculation in post-myopic-LASIK eyes, especially in the eyes with lower K value, longer AL, and larger decentration of ablation zone. And to our surprise, ASCRS-Min was the most accurate numerically. For routine post-myopic-LASIK eyes, ASCRS-Min, EVO 2.0, Pearl-DGS, and Barrett True-K no-history could all be considered viable options, among which EVO 2.0 and Pearl-DGS offer greater practical convenience due to their web-based accessibility. Based on our findings, if clinical data are limited to the calculation of the above-mentioned four formulas on the ASCRS calculator as evaluated in this study, we recommend the ASCRS-Min method. However, if more extensive data are available to utilize a broader set of formulas, a comprehensive evaluation is advised to guide the final selection.

Study approval

The authors confirm that any aspect of the work covered in this manuscript that involved human patients or animals was conducted with the ethical approval of all relevant bodies and the study was performed in accordance with the Declaration of Helsinki , and the protocol was approved by the Ethics Committee of the Institutional Review Board of Eye and Ear, Nose, and Throat Hospital, Fudan University (approval number: 2023110) and was based on the Shanghai High Myopia Study, which was registered at ClinicalTrials.gov (NCT03062085).

Author contributions

The authors confirm contribution to the paper as follows: XZ conceived the idea and supervised the study. QY analyzed data and wrote the initial and revised versions of the manuscript. WH reviewed the results of data analysis and provided constructive suggestions. XZ and JM were involved in critical revision of manuscript. QY and KC participated in early follow-up work and collected data. All authors reviewed the results and approved the final version of the manuscript.

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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.aopr.2025.10.005.

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