Accuracy of the O Formula Based on OCT and Ray-Tracing for Intraocular Lens Power Prediction

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• PURPOSE: To evaluate the predictive accuracy of the O formula, based on the ray-tracing method, compared with the latest formulas available on the ESCRS website.
• DESIGN: Retrospective consecutive case series at a single center.
• METHODS: Records of consecutive patients who underwent routine cataract surgery implanted with acrylic IOLs between August 2021 and December 2022 were retrospectively reviewed. The prediction accuracy of the O formula was compared with that of the Barrett Universal II (BUII), Emmetropia Verifying Optical 2.0 (EVO), Kane, Pearl-DGS formulas based on the website of ESCRS, and the SRK/T formula. Swept-source optical coherence tomography (SS-OCT)-based biometry and anterior segment SS-OCT were performed preoperatively, and manifest refraction was assessed 1 month postoperatively. Primary outcomes were root-mean-square absolute error (RMSAE), median absolute error (MedAE), and the proportions within ±0.50 D and ±1.00 D.
• RESULTS: A total of 325 eyes (258 patients) were included. The RMSAE of the O formula, BUII, EVO, Kane, Pearl-DGS, and SRK/T were 0.396, 0.468, 0.441, 0.449, 0.550, and 0.425, respectively. In GEE models, mean absolute error was significantly lower with the O formula than with BUII, EVO, Kane, and Pearl-DGS; no difference versus SRK/T was detected. The percentage of eyes within ±0.50 D was 78.7% for the O formula, 71.4% for BUII, 73.6% for EVO, 73.9% for Kane, 61.6% for Pearl-DGS, and 76.3% for SRK/T. The O formula achieved significantly higher percentages of eyes within both ±0.50 D and ±1.00 D of the predicted refraction compared to Pearl-DGS ($P < .001$).
• CONCLUSIONS: The O formula demonstrated high refractive accuracy without A-constant optimization and performs favorably against widely used formulas. It can be used as a fail-safe in IOL power calculation, as it is less susceptible to prediction errors exceeding 1.0 D. (Am J Ophthalmol 2026;281: 109–117. © 2025 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC license (http://creativecommons.org/licenses/by-nc/4.0/))

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INTRODUCTION

Modern cataract surgery is increasingly recognized as a refractive surgery owing to its capacity to accurately predict postoperative refractive outcomes.[1,2] A wide range of intraocular lenses (IOLs) is now available, including extended depth-of-focus (EDOF) lenses and multifocal lenses (or presbyopia-correcting IOLs), providing patients with diverse options.[3] When utilizing premium IOLs, meticulous attention to postoperative refractive outcomes is paramount. To accurately predict postoperative refractive values, it is essential to obtain reproducible and precise preoperative measurements, perform accurate IOL power calculations, and utilize minimally invasive techniques for small-incision cataract surgery.[1,4]

In recent years, numerous IOL power calculation formulas have been developed to improve the accuracy of postoperative refractive outcomes. Several advanced formulas, including the Barrett Universal II (BUII), Cooke K6, Emmetropia Verifying Optical 2.0 (EVO), Hoffer-QST, Hill-RBF, Kane, and Pearl-DGS formulas, have been incorporated into the European Society of Cataract and Refractive Surgery (ESCRS) IOL calculator,[5-8] an online tool designed to assist clinicians in selecting the most appropriate IOL power for cataract surgery patients (available at https://iolcalculator.escrs.org). The ESCRS IOL calculator utilizes scraping software that automatically transmits data to online IOL calculators and displays their results. This approach improves clinical workflow and enables the comparison of refractive outcomes from the modern IOL power calculation formulas.

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Although the predictive accuracy of next-generation formulas has shown significant improvement,[9] it has been demonstrated that adjustments to the A-constant may still be necessary for optimal results.[10] The O formula is independent of A-constants.[11] Instead, the O formula calculates IOL power based on data from a swept-source optical coherence tomography (SS-OCT)–based biometer and anterior segment SS-OCT (AS-SS-OCT) and employs ray-tracing theory. The objective of this study is to assess the accuracy of the O formula in a Japanese cohort by comparing its refractive predictions with those of the most current formulas available on the ESCRS IOL calculator.

METHODS

The study was designed as a retrospective consecutive case series and was approved by the Institutional Review Board of the Miyata Eye Hospital. Written informed consent was obtained from each patient. Each patient was treated in accordance with the tenets of the Declaration of Helsinki. The number of eyes was determined according to the recommendations of Holladay et al., who calculated that the number of eyes required to detect a difference in standard deviation (SD) of 0.02 for P value <.01 is between 300 and 700.[12] Accordingly, a total of 325 eyes of 258 patients who were implanted with the IOL (SY60WF) were included in the study. When both eyes met all inclusion criteria, they were analyzed to achieve the recommended sample size while maintaining consistency in surgical technique and lens type.

The surgical technique comprised a 2.4-mm temporal clear corneal sutureless incision and phacoemulsification after a continuous curvilinear capsulorrhexis in all cases by 1 experienced surgeon (K.M.). All patients were recruited from the Miyata Eye Hospital between August 2021 and December 2022. The exclusion criteria for the study were as follows: corrected distance visual acuity (CDVA) after cataract surgery poorer than 20/30, preoperative or postoperative astigmatism greater than 3.0 D, history of ocular surgery and/or ocular trauma, the presence of a significant ocular comorbidity (eg, ocular surface diseases, keratoconus, and pterygium), unreliable or undetectable preoperative biometry measurements, or a history of intra- or postoperative complications.

All patients underwent routine preoperative and 1-month postoperative ophthalmic examinations, comprising a CDVA measurement using a Landolt C chart, slit-lamp examination, keratometry (K), intraocular pressure measurement, and fundoscopy. Postoperative refraction was performed by experienced certified orthoptists. SS-OCT-based biometer (OA-2000; TOMEY CORPORATION) and AS-SS-OCT (CASIA2; TOMEY CORPORATION) were performed pre- and 1-month postoperatively.

• **PREOPERATIVE PARAMETERS:** The following information was collected in the Excel spreadsheet (Microsoft): age, sex, axial length (AL), K, central corneal thickness (CCT), anterior chamber depth (ACD), crystalline lens thickness (LT), power of the IOL, manifest refraction at 5 m adjusted to 6 m.

Anterior segment parameters measured with AS-SS-OCT were defined as follows. Cross sectional images were obtained by AS-SS-OCT with a horizontal (180°) alignment and were centered on the corneal vertex, which was defined as the cross point of the vertex normal and anterior corneal surface. CCT was defined as the distance between the anterior and posterior corneal surface. The distance between the posterior corneal surface and anterior lens surface was defined as the preoperative aqueous depth (AQD). The definition of LT was the distance between the anterior and posterior lens surface. CCT, AQD, and LT were measured along the vertex normal.[13] Angle-to-angle depth was defined as the perpendicular distance between the posterior corneal surface and a line drawn between the anterior chamber angle recesses on nasal and temporal sides of the horizontal AS-SS-OCT scans.[14] Lens equator (LE) depth was defined as the distance from the posterior surface of the central cornea to the crystalline lens equator line.[15,16] The crystalline lens equator line was determined by 2 meridians of the LE, which was estimated based on an imaginary line connecting the anterior and posterior lens surface. Postoperative IOL depth was measured as the distance between the posterior corneal surface and the anterior IOL surface measured along the vertex normal.

• **INTRAOCULAR LENS POWER CALCULATION:** Biometric parameters were utilized to calculate refractive predictions with the ESCRS IOL calculator. The calculator was accessed several times between November 11, 2023, and December 31, 2023, to collect all the required information. The A-constant used was 118.97, as displayed after selecting the lens in the ESCRS calculator, while SRK/T calculations were performed with the value of 119.33 from the IOL Con database (available at https://iolcon.org/). Refractive prediction for the implanted power of the IOL was input into the Excel spreadsheet. The refractive outcome was adjusted for a 6-meter lane. The prediction error (PE) was obtained as the postoperative manifest refraction minus the predicted refractive values using each formula.

• **OUTCOME MEASURES:** The PE was defined as postoperative manifest refraction minus the predicted refraction for each formula. The absolute error (AE) was the absolute value of PE. Primary outcomes were root-mean-square absolute error (RMSAE), SD, median absolute error (MedAE), and proportions of eyes within ±0.50 D and ±1.00 D as per the recommendations of Holladay et al.[17]

• **STATISTICAL ANALYSIS:** Statistical analysis was performed with JMP Pro version 14.0.0 (SAS Institute Inc.)

TABLE 1. Demographic and Ocular Characteristics (n = 325 Eyes of 258 Patients)

Devices	Characteristic	Mean + SD	Minimum	Maximum
	Age (y)	70.6 ± 10.0	7	90
	Male/Female	139/119	-	-
	IOL power (D)	20.2 ± 3.9	6	28.5
SS-OCT based optical biometer	Axial length (mm)	24.22 ± 1.67	21.15	30.97
	K1 (D)	43.88 ± 1.44	39.89	47.94
(OA-2000)	K2 (D)	44.8 ± 1.48	40.23	48.77
	Corneal thickness (um)	523 ± 33	425	625
	Anterior chamber depth (mm)	3.21 ± 0.43	2.22	4.7
	Lens thickness (mm)	4.58 ± 0.50	3.27	5.85
AS-SS-OCT (CASIA2)	Central corneal thickness (um)	532 ± 32	438	630
	Aqueous depth (mm)	2.72 ± 0.43	1.48	3.68
	Lens thickness (mm)	4.57 ± 0.47	3.13	5.72
	Angle-to-angle depth (mm)	3.29 ± 0.21	2.69	3.92
	Lens-equator depth (mm)	4.24 ± 0.53	3.26	6.82
	IOL depth (mm)	4.15 ± 0.28	3.38	5.02
	Anterior corneal curvature (steep) (mm)	7.55 ± 0.24	6.97	8.34
	Anterior corneal curvature (flat) (mm)	7.69 ± 0.25	7.08	8.47
	Anterior corneal eccentricity	0.56 ± 0.13	−0.17	0.88
	Posterior corneal curvature (steep) (mm)	6.23 ± 0.24	5.64	6.95
	Posterior corneal curvature (flat) (mm)	6.54 ± 0.24	5.98	7.28
	Posterior corneal eccentricity	0.66 ± 0.13	−0.15	1.01

AS-SS-OCT = anterior-segment swept-source optical coherence tomography; D = diopter; IOL = intraocular lens; SD = standard deviation.

and R version 4.3.2. Because both eyes from the same patient could be included, all comparative analyses accounted for within-patient correlation using generalized estimating equations (GEE) with patient ID as the clustering factor and an independence working correlation structure. For continuous outcomes (AE, RMSAE), Gaussian GEE models were fitted; for categorical outcomes (proportion within ±0.50 D or ±1.00 D), binomial GEE models with a logit link were used. The formula type was modelled as a categorical fixed effect with the O formula as the reference. Pairwise comparisons were Holm-adjusted for multiple testing. SDs of PE were compared using a cluster-adjusted bootstrap method. MedAE was compared across formulas using a cluster-adjusted percentile bootstrap. PEs were also compared to zero for each formula to assess potential A-constant bias, using cluster-adjusted t tests for normally distributed errors or cluster-adjusted Wilcoxon signed-rank tests for non-normal distributions. AL was categorized into short (≤22.5 mm), normal (>22.5 to <26.0 mm), and long (≥26.0 mm) groups. Age, AL, and mean K were analyzed as continuous variables in univariable and multivariable mixed-effects regression models, with β coefficients (D/unit), 95% CIs, and P-values reported. P value of <.05 before correction was considered statistically significant.

We utilized A constants recommended by the ESCRS IOL power calculator. As a sensitivity analysis, we repeated all comparisons after bias-correcting ("zeroing out") PEs per formula by subtracting the patient-weighted mean. Results are provided in the Supplementary Table.

RESULTS

A total of 325 eyes from 258 patients (139 females and 119 males) were included in this study. A summary of the patient demographics is presented in Table 1.

• **OVERALL PREDICTIVE PERFORMANCE:** Figure 1 shows the comparisons of the PE between the formulas. Cluster-adjusted descriptive metrics are summarized in Table 2. The O formula showed the lowest RMSAE (0.396 D; 95% CI, 0.362-0.435) and the highest proportion within ±0.50 D (78.7%; 95% CI, 73.8-82.8) among the formulas evaluated (Fig. 2). In Gaussian GEE models (Table 3), mean AE was significantly lower with the O formula compared with BUII (+0.064 D, P = .0008), EVO (+0.048 D, P = .007), Kane (+0.048 D, P = .009), and Pearl-DGS (+0.140 D, P < .0001), but not SRK/T (+0.046 D, P = .020). In logistic GEE models for achieving ±0.50 D, the O formula significantly outperformed BUII (P = .017) and Pearl-DGS (P < .001), but not compared to EVO, Kane, or SRK/T. For ±1.00 D (Figure 3), the O formula showed a significant advantage only over Pearl-DGS (P = .0016).

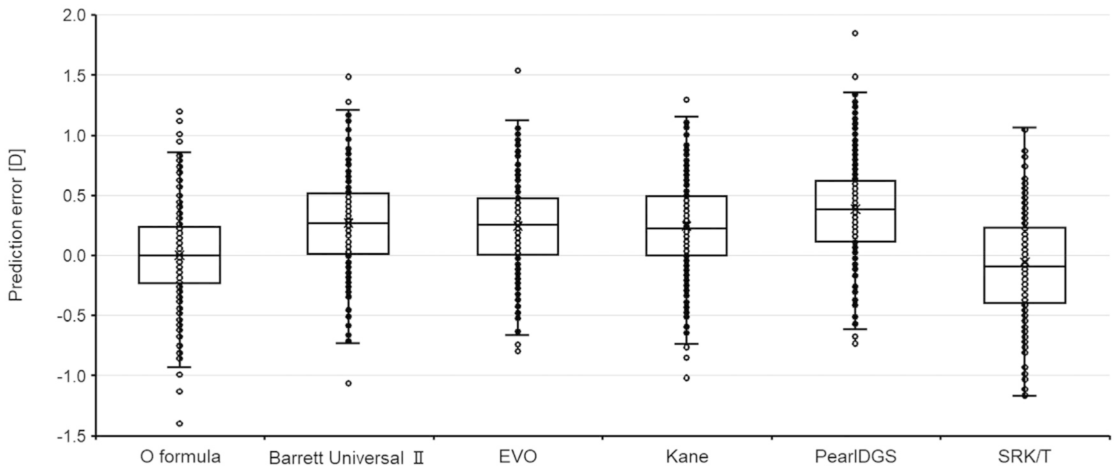

FIGURE 1. Box plots illustrating the numerical prediction errors in refraction with intraocular lens calculation formulas. EVO = Emmetropia Verifying Optical 2.0; SRK/T = Sanders–Retzlaff–Kraff/Theoretical.

TABLE 2. Comparison Between Formulas Included in the New Generation IOL Calculator (*n* = 325 Eyes of 258 Patients)

Formula	Mean PE	SD	RMSAE	MedAE	% ≤0.50 D	% ≤1.00 D
O formula	0.003 (−0.042, 0.049)	0.395 (0.358, 0.437)	0.396 (0.362, 0.436)	0.237 (0.196, 0.288)	78.7 (73.8, 82.8)	98.5 (96.9, 99.7)
BUII	0.272 (0.230, 0.313)	0.381 (0.347, 0.414)	0.468 (0.431, 0.505)	0.303 (0.273, 0.332)	71.4 (66.5, 76.3)	96.3 (94.0, 98.5)
EVO	0.246 (0.206, 0.283)	0.367 (0.337, 0.400)	0.441 (0.407, 0.475)	0.292 (0.257, 0.337)	73.6 (68.9, 78.6)	97.6 (95.8, 99.1)
Kane	0.249 (0.207, 0.285)	0.374 (0.344, 0.406)	0.449 (0.416, 0.480)	0.297 (0.248, 0.347)	73.9 (69.1, 78.9)	96.9 (95.0, 98.8)
Pearl-DGS	0.388 (0.347, 0.427)	0.390 (0.357, 0.425)	0.550 (0.510, 0.586)	0.400 (0.344, 0.447)	61.6 (56.4, 66.8)	92.9 (89.8, 95.6)
SRK/T	−0.054 (−0.099, −0.004)	0.422 (0.391, 0.456)	0.425 (0.395, 0.460)	0.302 (0.267, 0.343)	76.3 (71.3, 81.2)	97.9 (96.0, 99.4)

Values are cluster bootstrap means with 95% CIs.

BUII = Barrett Universal II; CI = confidence interval; EVO = Emmetropia Verifying Optical 2.0; MAE = mean absolute error; ME = mean error; MedAE = median absolute error; PE = prediction error; RMSAE = root mean square of absolute error; SD = standard deviation; SRK/*T* = Sanders–Retzlaff–Kraff/Theoretical.

• **AL-STRATIFIED ANALYSES:** Findings were consistent across AL strata (short ≤22.5 mm, $n = 27$; normal >22.5 to <26.0 mm, $n = 248$; long ≥26.0 mm, $n = 50$, Tables 3 and 4). In short eyes, the O formula achieved the lowest or near-lowest error and was significantly better than Pearl-DGS after patient clustering. In normal eyes, the O formula showed significantly smaller AE than BUII, EVO, Kane, and Pearl-DGS (Holm-adjusted $P = .014$ to $< .0001$), with no difference vs SRK/T. In long eyes, no significant differences among modern formulas were detected in clustered analyses; descriptively, performance was similar across formulas.

• **ASSOCIATIONS WITH COVARIATES:** Mixed-effects regressions treating age, AL, and mean K as continuous variables showed no clinically meaningful associations of age or mean K with PE after adjustment. AL remained a significant predictor for several empirical formulas, but not for the O formula (Table 5).

DISCUSSION

This study demonstrated that the O formula, which is based on ray-tracing principles and utilizes SS-OCT and anterior segment OCT measurements, achieved higher predictive accuracy than several widely used contemporary formulas, including BUII, EVO, Kane, and Pearl-DGS. Notably, even without A-constant optimization, the O formula yielded the lowest RMSAE and the highest percentage of eyes within ±0.50 D, underscoring its potential for improving refractive outcomes after cataract surgery.

The superiority of the O formula in RMSAE, a robust metric for evaluating formula performance, indicates enhanced precision in refractive prediction, especially when compared with the widely validated BUII and Pearl-DGS formulas. Unlike traditional vergence-based formulas,[18] the O formula calculates the IOL power using ray-tracing based on theoretically derived corneal power and AL, along with a precise estimation of the postoperative IOL position.[11]

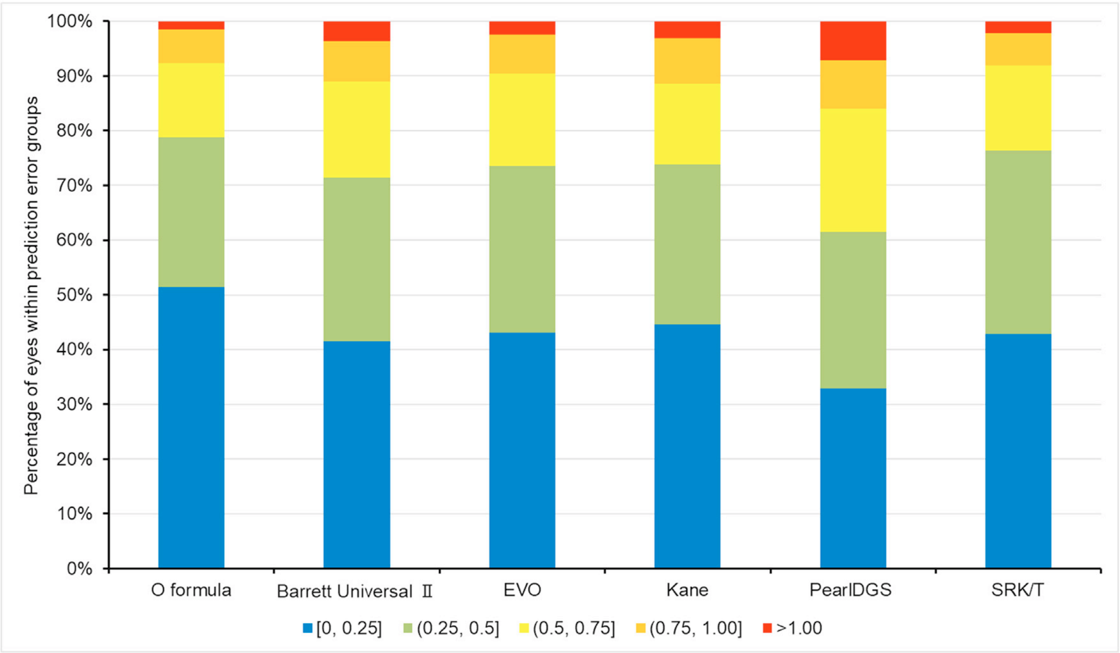

FIGURE 2. Stacked histogram showing the percentage of eyes within ±0.25 diopter (D), ±0.50 D, ±0.75 D, ±1.0 D, and >1.0 D range of prediction error.
EVO = Emmetropia Verifying Optical 2.0; SRK/*T* = Sanders–Retzlaff–Kraff/Theoretical.

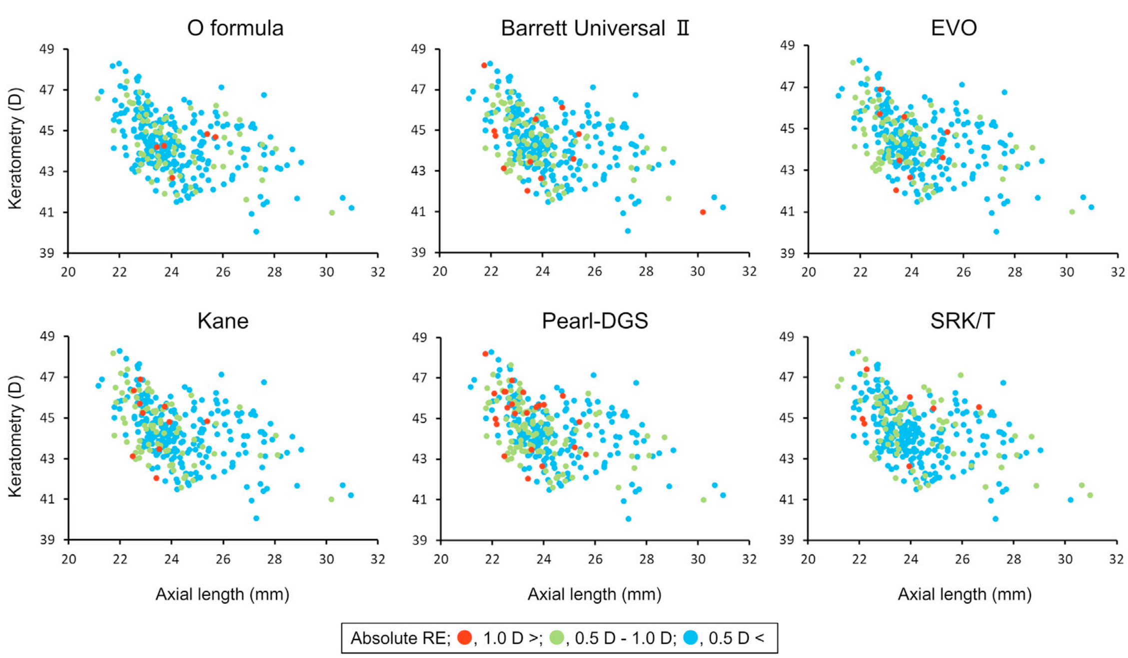

FIGURE 3. Scatterplot with 3 classes of absolute refractive error (RE) calculated using the O formula, Barrett Universal II formula, Emmetropia Verifying Optical 2.0 formula, Kane formula, Pearl-DGS formula, and SRK/T formula in relation to the axial length and the average keratometry value obtained by swept-source optical coherence tomography-based biometer. Absolute REs were color-coded into 3 classes: red dot, more than 1.0 D; green dot, 0.5 D or more and 1.0 D or less; and blue dot, less than 0.5 D.

TABLE 3. Pairwise Comparisons of Mean Absolute Prediction Error Using Patient-Clustered Generalized Estimating Equations (GEE), Stratified by Axial Length

Comparison	Difference in Mean Absolute Error	Z	*P*	Adjusted *P*
Overall (*n* = 325)				
O formula vs BUII	0.064	3.365	<.001	.003
O formula vs EVO	0.048	2.702	.007	.02
O formula vs Kane	0.048	2.631	.009	.02
O formula vs Pearl-DGS	0.140	6.639	<.0001	<.0001
O formula vs SRK/T	0.046	2.310	.02	.02
Short AL (*n* = 27)				
O formula vs BUII	0.234	2.394	.02	.07
O formula vs EVO	0.171	2.129	.03	.08
O formula vs Kane	0.184	2.238	.03	.08
O formula vs Pearl-DGS	0.304	3.180	.001	.007
O formula vs SRK/T	0.140	1.378	.17	.17
Normal AL (*n* = 248)				
O formula vs BUII	0.063	2.910	.004	.01
O formula vs EVO	0.051	2.520	.01	.03
O formula vs Kane	0.055	2.570	.01	.03
O formula vs Pearl-DGS	0.153	6.330	<.0001	<.0001
O formula vs SRK/T	0.034	1.584	.11	.11
Long AL (*n* = 50)				
O formula vs BUII	−0.019	−0.557	.58	1.0
O formula vs EVO	−0.038	−1.118	.26	1.0
O formula vs Kane	−0.057	−1.695	.09	.45
O formula vs Pearl-DGS	−0.011	−0.288	.77	1.0
O formula vs SRK/T	0.053	1.145	.25	1.0

P-values are 2-sided; Holm adjustment applied within each subgroup.

Reported difference is (comparator—O formula); positive values indicate higher mean absolute error for the comparator (ie, O formula performs better).

AL = axial length; BUII = Barrett Universal II; EVO = Emmetropia Verifying Optical 2.0; SRK/*T* = Sanders–Retzlaff–Kraff/Theoretical.

This may explain its resilience against large outliers and over 1.0 D PEs (Figure 3). Furthermore, the O formula does not rely on an A-constant, eliminating potential sources of optimization bias and further supporting its generalizability. Although no statistically significant difference was observed in SD and MedAE among formulas, the O formula's advantage in RMSAE and the highest score in the Formula Performance Index (FPI: supplemental information)[19] suggest its practical superiority in clinical settings. The greater proportion of eyes within ±0.50 D and ±1.0 D error ranges further reinforces its value, especially in cases where precision is critical, such as with premium IOLs.

Our findings align with previous reports highlighting the limitations of A-constant–based formulas, particularly when applied across diverse populations or biometry devices.[20,21] The ESCRS-provided A-constants for newer-generation formulas such as BUII and Kane may be underestimated for Japanese eyes, potentially leading to a systematic hyperopic shift (Supplementary Table). This population-specific deviation suggests that even state-of-the-art formulas may require regional A-constant adjustments to achieve optimal results. Interestingly, the SRK/T formula showed relatively good performance in this study. This is likely attributable to the fact that its A-constant (119.33) was more appropriate for the Japanese cohort evaluated. However, several reports mentioned that the SD associated with SRK/T remained suboptimal despite the lack of significant mean error, indicating limited precision.[22,23]

In AL-stratified analyses, the O formula performed favorably in short and normal eyes, showing significantly smaller clustered mean AE than Pearl-DGS in short eyes and than BUII and Pearl-DGS in normal eyes, while differences vs SRK/T were not significant. In long eyes (*n* = 50), no significant differences were detected among modern formulas after patient clustering; descriptively, Kane and EVO had the smallest RMSAE (0.296 and 0.316), with O formula at 0.365, indicating comparable rather than superior performance in this challenging subgroup. These findings are consistent with our mixed-effects regressions, in which AL was associated with systematic shifts in PE for several empirical formulas but not for the O formula, whereas age and K showed no clinically meaningful effects. Taken together, the ray-tracing, A-constant–independent approach of the O formula may mitigate AL-related bias in routine eyes, but very long eyes remain difficult across methods.

TABLE 4. Root Mean Squared Absolute Error, Mean Error, SD, and Median Absolute Error of Each Formula Stratified by Axial Length

Formula	RMSAE	SD	MedAE	±0.50 D (%)	±1.00 D (%)
Short (*n* = 27)					
O formula	0.390	0.394	0.309	77.8%	100.0%
BUII	0.637	0.463	0.453	51.9%	85.2%
EVO	0.556	0.460	0.482	51.9%	100.0%
Kane	0.566	0.434	0.537	48.1%	96.3%
Pearl-DGS	0.708	0.472	0.592	40.7%	77.8%
SRK/T	0.556	0.557	0.428	63.0%	88.9%
Normal (*n* = 248)					
O formula	0.403	0.404	0.227	79.4%	98.0%
BUII	0.468	0.371	0.303	71.0%	97.2%
EVO	0.450	0.361	0.300	73.4%	96.8%
Kane	0.461	0.371	0.322	73.4%	96.4%
Pearl-DGS	0.562	0.382	0.422	60.1%	93.1%
SRK/T	0.413	0.408	0.292	77.8%	98.8%
Long (*n* = 50)					
O formula	0.365	0.368	0.220	76.0%	100.0%
BUII	0.349	0.337	0.220	84.0%	98.0%
EVO	0.316	0.308	0.230	86.0%	100.0%
Kane	0.296	0.295	0.180	90.0%	100.0%
Pearl-DGS	0.358	0.313	0.205	80.0%	100.0%
SRK/T	0.412	0.414	0.312	76.0%	98.0%

BUII = Barrett Universal II; EVO = Emmetropia Verifying Optical 2.0; MedAE = median absolute error; RMSAE = root mean square of absolute error; SD = standard deviation; SRK/*T* = Sanders–Retzlaff–Kraff/Theoretical.

TABLE 5. Univariable and Multivariable Mixed-Effects Regressions of Prediction Error on Age, Axial Length, and Mean Keratometry (Patient-Level Random Intercept)

Formula Univariable	Age β (95% CI)	*P* value	AL (β, 95% CI, *P*) β (95% CI)	*P* value	Mean K β (95% CI)	*P* value
O formula	−0.0058 (−0.0104 to −0.0011)	.02	0.0139 (−0.0142 to 0.0419)	.33	0.0160 (−0.0162 to 0.0482)	.33
Barrett Universal II	−0.0007 (−0.0051 to 0.0037)	.76	−0.0443 (−0.0701 to −0.0185)	<.001	0.0000 (−0.0305 to 0.0304)	.99
EVO	−0.0019 (−0.0061 to 0.0023)	.37	−0.0415 (−0.0661 to −0.0169)	<.001	0.0085 (−0.0205 to 0.0375)	.56
Kane	−0.0014 (−0.0057 to 0.0028)	.51	−0.0575 (−0.0819 to −0.0331)	<.0001	0.0217 (−0.0076 to 0.0511)	.15
Pearl-DGS	0.0001 (−0.0044 to 0.0045)	.98	−0.0554 (−0.0813 to −0.0295)	<.0001	0.0494 (0.0189-0.0798)	.0014
SRK/T	−0.0025 (−0.0075 to 0.0025)	.32	0.0405 (0.0111-0.0700)	.007	−0.1017 (−0.1337 to −0.0698)	<.0001
Multivariable						
O formula	−0.0054 (−0.0101 to −0.0007)	.02	0.0185 (−0.0126 to 0.0497)	.24	0.0274 (−0.0079 to 0.0626)	.13
Barrett Universal II	−0.0021 (−0.0065 to 0.0022)	.34	−0.0572 (−0.0861 to −0.0283)	<.001	−0.0282 (−0.0611 to 0.0047)	.09
EVO	−0.0033 (−0.0074 to 0.0009)	.12	−0.0511 (−0.0786 to −0.0235)	<.001	−0.0161 (−0.0476 to 0.0153)	.31
Kane	−0.0032 (−0.0073 to 0.0009)	.13	−0.0646 (−0.0920 to −0.0372)	<.0001	−0.0099 (−0.0413 to 0.0214)	.53
Pearl-DGS	−0.0015 (−0.0059 to 0.0029)	.50	−0.0472 (−0.0763 to −0.0181)	.001	0.0260 (−0.0072 to 0.0592)	.13
SRK/T	−0.0016 (−0.0063 to 0.0031)	.50	0.0011 (−0.0302 to 0.0323)	.95	−0.1006 (−0.1360 to −0.0651)	<.0001

AL = axial length; *K* = keratometry; CI = confidence interval; EVO = Emmetropia Verifying Optical 2.0; SRK/*T* = Sanders–Retzlaff–Kraff/Theoretical.

Our results are consistent with prior comparative studies: BUII, Kane, and EVO show high accuracy across eyes, and SRK/T can remain competitive when constants are well tuned.[1,4,22,23] In our overall and normal AL cohorts, the O formula had lower or comparable AE and was significantly better than BUII, EVO, Kane, and Pearl-DGS in normal eyes, with no difference vs SRK/T. Compared with our earlier work,[11] which first introduced the O formula, the present study represents an independent validation in a different clinical setting and surgeon, with expanded comparator formulas from the ESCRS calculator, confirming external validity of the O formula.

Several limitations must be acknowledged. First, this was a single-center, retrospective study conducted exclusively in Japanese patients. All surgeries were performed by a single experienced surgeon, which may minimize inter-surgeon variability but limits generalizability. Second, the analysis included both eyes from some patients; although we applied a linear mixed-effects model with patient ID as a random effect to account for inter-eye correlation, this design could still introduce bias. Third, all biometric and anterior segment data were obtained using TOMEY SS-OCT devices (OA-2000, CASIA2). The performance of the O formula when applied with other commonly used biometers remains unknown, and cross-platform calibration studies are warranted. Finally, only a single monofocal IOL type was evaluated; applicability to other IOL designs, including Toric and premium models, requires further validation. Despite these limitations, the study has significant strengths. The use of a uniform surgical technique by a single experienced surgeon and consistent measurement protocols at a single facility allowed for a high level of internal validity. Importantly, the O formula—unlike conventional formulas—does not rely on empirically derived A-constants. Instead, it incorporates segmented AL, accurately predicted IOL position, and anatomically accurate corneal power using ray-tracing principles. This theoretical approach allowed it to achieve excellent accuracy and an absence of systematic bias, even without formula optimization. While further validation of the O formula in multicenter, multiethnic studies is needed, our results indicate that ray-tracing–based IOL power calculation has the potential to further enhance refractive predictability in cataract surgery. Given its independence from empirically derived constants and lens-specific optimization, the O formula may be particularly suitable for cases involving premium IOLs or eyes with atypical anatomy. Nevertheless, surgeons must ensure consistency in device calibration, particularly when shifting between OCT platforms.

In conclusion, the O formula demonstrated high predictive accuracy and robustness against large refractive PEs in a Japanese cohort. Its ray-tracing approach and independence from empirically derived constants make it a promising candidate for widespread clinical application.

DATA AVAILABILITY

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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