Accuracy of Artificial Intelligence Formulas and Axial Length Adjustments for Highly Myopic Eyes

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• PURPOSE: To compare the accuracy of artificial intelligence formulas (Kane formula and Radial Basis Function [RBF] 2.0) and other formulas, including the original and modified Wang-Koch (MWK) adjustment formulas for Holladay 1 (H1-MWK) and SRK/T (SRK/T-WK and SRK/T-MWK), the Barrett Universal II (BUII), the emmetropia-verifying optical (EVO), and the Haigis equation in highly myopic eyes.

• DESIGN: Retrospective consecutive case-series study.

• METHODS: A total of 370 eyes with an axial length (AL) ≥26.0 mm of 370 patients were enrolled, and subgroup analyses was performed based on ALs. The median absolute error (MedAE), the percentages of eyes with hyperopic outcome and within ±0.25 diopters (D), ±0.50 D, and ±1.00 D of prediction error were determined.

• RESULTS: Overall, the Kane equation had the lowest MedAE (0.26 D), followed by H1-WK (0.27 D) and H1-MWK (0.28 D). There were no significant differences in MedAE among the Kane equation, the RBF 2.0, the BUII, the H1-MWK, and the H1-WK, whereas the Kane equation had a significantly lower MedAE than EVO (*P* < .001), SRK/T-MWK (*P* = .001), SRK/T-WK (*P* = .006), and Haigis (*P* < .001). In extremely myopic eyes with an AL ≥30.0 mm (n = 115), the Kane equation had a significantly lower MedAE than the RBF 2.0 (*P* = .001), the EVO (*P* = .019), the BUII (*P* = .013), and the Haigis method (*P* = .005), whereas no significant differences were found among the Kane, H1-MWK, and H1-WK equations.

• CONCLUSIONS: The Kane equation was comparable to RBF 2.0, BUII, H1-MWK, and H1-WK in highly myopic eyes and was better than RBF 2.0 and BUII in extremely myopic eyes. The Kane, H1-MWK, and H1-WK methods were equally accurate in eyes with high to extreme myopia. **(Am J Ophthalmol 2021;223:100–107.**

THE RATE OF MYOPIA HAS RISEN STEEPLY RISE OVER the past 50 years, especially in Asia, with approximately 80%-90% of young adults affected by myopia and an accompanying high prevalence of high myopia (10%-20%).[1] High myopia, commonly defined as an axial length (AL) ≥26.0 mm, is associated with the early onset of cataract,[2] and myopic eyes are more likely to have nuclear cataract and posterior subcapsular cataract.[3] However, calculation of intraocular lens (IOL) power remains challenging for highly myopic eyes,[4] and various existing formulas have been shown to be deficient for highly myopic eyes due to the complex condition of the fundus.[5] For many years, vergence formulas such as SRK/T and Holladay 1 (H1) were widely used for calculation of IOL power, and they remain the standards for many ophthalmologists in clinical practice.[6] Nevertheless, those standard formulas tend to choose IOLs with insufficient power for highly myopic eyes, resulting in hyperopic surprise.[7] The Wang-Koch (WK) AL adjustment was developed to improve the accuracy of those standard formulas[8,9] and yields lower incidence of hyperopia.[10]

Artificial intelligence (AI) has been applied to refine the accuracy of IOL power calculation. The radial basis function (RBF) 2.0 (Available at: http://rbfcalculator.com/online/index.html) and Kane formula (Available at: www.iolformula.com) are recently introduced AI formulas. RBF 2.0 has been updated on a large database, and the range of in-bound calculations without warning of inaccuracy for high to extreme axial myopia has been greatly increased. RBF 2.0 has been shown to be comparable to the Barrett Universal II (BUII) and Haigis functions in eyes with high myopia.[11] The new Kane formula (developed by J.X.K.) is based on theoretical optics and incorporates regression, and AI components have been shown to be more accurate than those of all the other formulas including BUII, RBF 2.0, Olsen, and emmetropia-verifying optical (EVO) equations.[12]

To these authors' present knowledge, no peer-reviewed publications have compared the Kane formula with the Wang-Koch adjustment formulas for H1 and SRK/T, especially in extremely myopic eyes with an AL ≥30.0 mm. This study compared new AI formulas (for the Kane and RBF 2.0) with other formulas including Wang-Koch adjustment methods for H1[13] and SRK/T,[14] BUII,[15] EVO

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2.0 (Available at https://www.evoiolcalculator.com and Haigis[16] in eyes with high to extreme myopia.

METHODS

• **PATIENTS:** Cases of consecutive patients with cataracts who underwent cataract phacoemulsification and IOL implantation in the capsular bag with an AL ≥26.0 mm at Zhongshan Ophthalmic Center from April 2017 to July 2018 were reviewed in this retrospective case-series study. The following inclusion criteria were: patients 18 years and older who underwent uneventful cataract phacoemulsification without complications and had manifest refraction performed at least 1 month postoperatively with a corrected distance visual acuity of no worse than 20/40. Patients with previous ocular surgery, intraoperative complications, vision-threatening corneal pathology, or retinal diseases were excluded. Study and data accumulation were carried out under prospectively obtained approval by the Institutional Review Board of Zhongshan Ophthalmic Center (ID: 2019KYPJ124) and conformed to the tenets of the Declaration of Helsinki. Informed consent was waived because only the medical records were involved.

• **BIOMETRY AND IOL POWER CALCULATION:** Biometric measurements in all patients were performed using IOLMaster 500 (version 7.7.9; Carl Zeiss Meditec, Jena, Germany). Four-meter refractive lanes were used for the postoperative examination of subjective refraction, using the Early Treatment Diabetic Retinopathy Study (ETDRS) chart (Optec 6500; Stereo Optical, Chicago, Illinois). The constants listed by the User Group for Laser Interference Biometry (ULIB) (Available at www.ocusoft.de/ulib/c1.html) were recommended for IOL types other than MA60MA or MN60MA with Wang-Koch adjustment. To compare formulas on a more equal basis, the ULIB constants were used for the calculation of all formulas. Original and modified Wang-Koch (MWK) adjustment formulas for H1 (H1-MWK) and SRK/T (SRK/T-MWK) were calculated with published equations.[8,9] Preoperative biometry data were entered by hand into the respective online calculators for the calculation of RBF 2.0, Kane, EVO (Available at: www.evoiolcalculator.com), and BUII (Available at: https://calc.apacrs.org/barrett_universal2105/). The IOL type was chosen based on the surgeon's preference, and the IOL power was determined by the SRK/T formula.

• **STATISTICAL ANALYSIS:** All statistical analyses were performed using SPSS software (version 22.0; IBM, Armonk, New York) according to the guidelines for analyzing outcomes in IOL power calculations.[17,18] The prediction error (PE) was back-calculated as the difference between the actual postoperative refractive status and the predicted refraction. The absolute error (AE) is equal to the absolute value of PE. The mean prediction error (ME) was calculated as the mean of all PEs for each formula. Depending on whether the data were normally distributed or not, either the 1-sample *t* test or Wilcoxon signed-rank test was used to determine whether the MEs were significantly different from zero. Refractive prediction outcomes were also compared after adjusting the ME to zero for each IOL model and formula to eliminate the systematic error from the chosen lens constant. Because absolute PEs were not normally distributed, the nonparametric Friedman test with Wilcoxon signed-rank post hoc analyses were used to compare differences in median AE (MedAE) among formulas. Cochran Q test was used to compare the proportion of PEs within the given diopter (D) and the percentage of hyperopic outcomes among formulas. Bonferroni correction was applied for multiple comparisons. A *P* value less than .05 was deemed statistically significant.

TABLE 1. Characteristics of Eyes Included in the Final Analysis (n = 370)

Parameter	Mean ± S D	Range
Axial length, mm	28.98 ± 2.23	26.01-34.98
Anterior chamber depth, mm[a]	3.53 ± 0.41	2.18-4.80
Flat keratometry, D	43.21 ± 1.61	38.22-47.80
Steep keratometry, D	44.37 ± 1.72	38.97-49.71
IOL power, D	8.78 ± 5.55	−6.0 to 18.5
Age, y	59.3 ± 12.6	26-87

D = diopter; IOL = intraocular lens; S D = standard deviation.
[a]Anterior chamber depth was measured from the corneal epithelium to the lens.

RESULTS

THIS STUDY ENROLLED 370 EYES OF 370 PATIENTS, AND 115 eyes (31.1%) had an AL of 30.0 mm or longer. Preoperative biometric data are shown in Table 1. The study group was balanced by 190 females (51.4%). The mean age was 59.3 ± 12.6 years old (range: 26-87 years), and the mean AL was 28.98 ± 2.23 mm (range: 26.01-34.98 mm). AL readings were made using IOLMaster 500 (Zeiss Medical, Dublin, California) in all eyes. A total of 204 eyes (55.1%) had the "out-of-bounds" warning with the RBF 2.0 method. The following IOL types and numbers were implanted: SN60WF (n = 72; Alcon, Geneva, Switzerland), AR40e/E/M (n = 40; Allergan, Dublin, Ireland), ZA9003 (n = 42; Allergan), Adapt AO (n = 111; Bausch & Lomb, Rochester, New York), and 920H (n = 105; Rayner, Worthing, UK). The visual and refractive outcomes are shown as standard graphs (Figure 1).

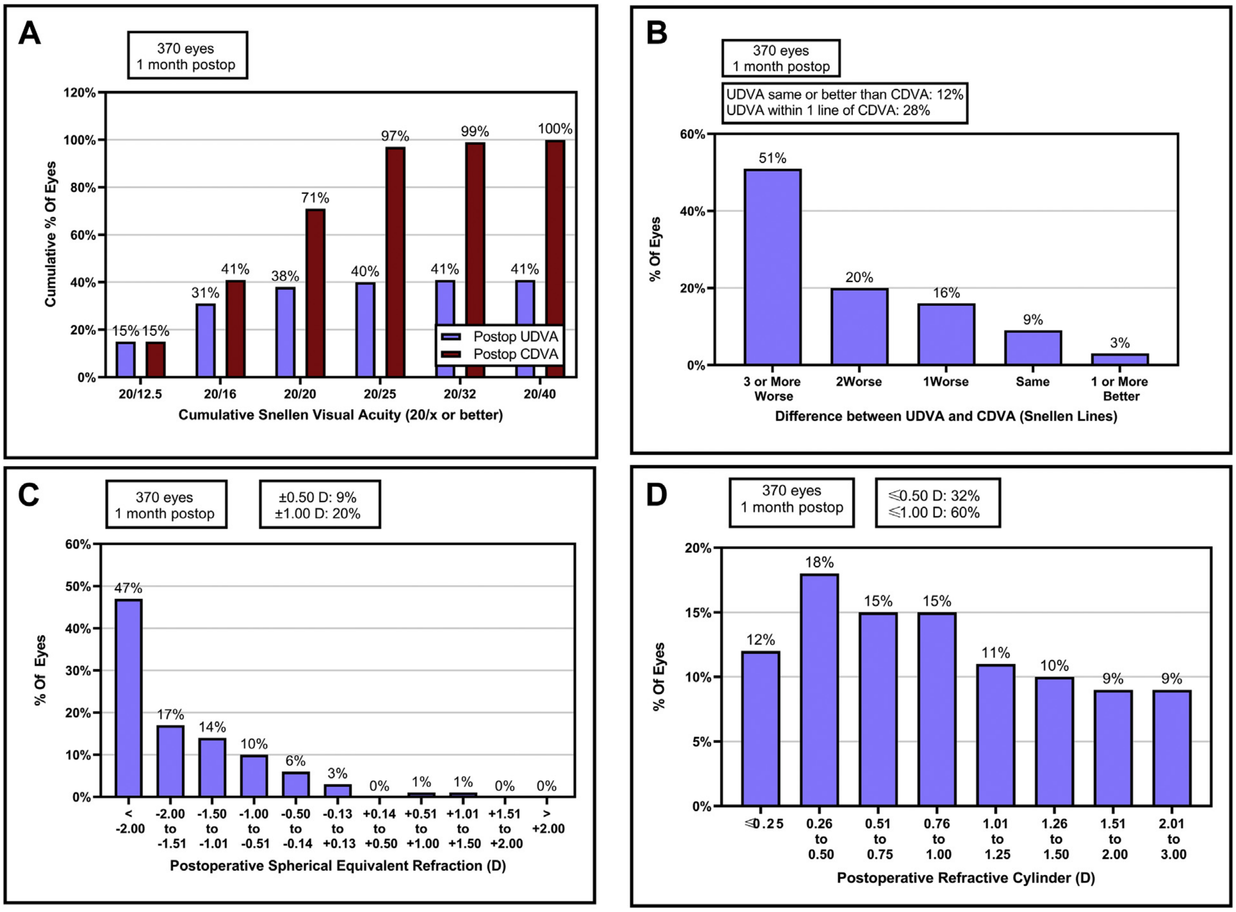

FIGURE 1. Standard graphs for reporting refractive outcomes for intraocular lens-based procedures in the myopic cataract population. A. Uncorrected distance visual acuity. B. Uncorrected distance visual acuity versus corrected distance visual acuity. C. Spherical equivalent refraction accuracy. D. Postoperative refractive cylinder. CDVA = corrected distance visual acuity; postop = postoperative; UDVA = uncorrected distance visual acuity).

• **REFRACTIVE PREDICTION ERRORS USING ULIB CONSTANTS:** The ME of Kane was not significantly different from zero ($P = .204$). BUII, EVO, Haigis, and RBF 2.0 produced hyperopic MEs, whereas H1-MWK, H1-WK, SRK/T-MWK, and SRK/T-WK had myopic MEs ($P < .01$). With regard to the percentage of eyes with hyperopic outcomes, SRK/T-WK and H1-WK (25.9% and 27.8%, respectively) had significantly lower values than all the other formulas (39.7% to 84.6%; $P < .01$). H1-MWK (45.7%) yielded a significantly lower percentage of hyperopia than did EVO, BUII, RBF 2.0, and Haigis (56.5% to 84.6%) ($P < .01$), although no significant differences were found among H1-MWK, Kane (54.1%), and SRK/T-MWK (39.7%) (Table 2). There were no correlations among AL and PE for Kane ($P = .526$), H1-WK ($P = .814$), and SRK/T-WK ($P = .770$). The PEs produced by BUII, RBF 2.0, EVO, and Haigis were positively correlated with AL ($r = 0.21$, 0.20, 0.18, and 0.48, respectively; $P < .001$). In contrast, the PEs produced by SRK/T-MWK and H1-MWK were negatively correlated with AL ($r = -0.12$ and -0.18, respectively; $P < .05$). The correlation of Haigis with AL was relatively stronger compared with other formulas (Figure 2). As shown in Figure 3, the PE of Kane remained stable in different AL subgroups, suggesting its independence from AL, whereas BUII showed slight tendency toward hyperopia, and H1-MWK showed slight tendency toward myopia in eyes with an AL over 30.0 mm.

• **ABSOLUTE PREDICTION ERRORS AFTER ELIMINATING SYSTEMATIC ERRORS:** Overall, Kane had the lowest MedAE (0.26 D) followed by H1-WK (0.27 D) and H1-MWK (0.28 D). There were no significant differences in MedAE among Kane, RBF 2.0, BUII, H1-MWK, and H1-WK, whereas Kane had a significantly lower MedAE than EVO ($P < .001$), SRKT-MWK ($P = .001$), SRKT-WK ($P = .006$), and Haigis ($P < .001$). H1-MWK and H1-WK had significantly lower MedAEs than EVO, SRK/T-MWK, and Haigis ($P < .05$). H1-WK also had a significantly lower MedAE than SRK/T-WK ($P = .009$). No significant differences were found among formulas (Table 2).

The Kane method was applied to the greatest proportion of eyes, with a PE within ±0.25 D (47.8%), whereas H1-

TABLE 2. Refractive Prediction Errors of Different Formulas in Highly Myopic Eyes (n = 370).

Formula	Using ULIB Constants				After Adjusting ME to Zero			
	ME ± S D	MedAE	MAE	% Hyperopia	ME ± S D	MedAE	MAE	% Hyperopia
Kane	0.03 ± 0.45	0.27	0.34	54.1	0.00 ± 0.44	0.26	0.34	50.3
RBF 2.0	0.28 ± 0.52	0.38	0.46	72.4	0.00 ± 0.49	0.30	0.38	49.5
H1-MWK	−0.06 ± 0.45	0.27	0.35	45.7	0.00 ± 0.44	0.28	0.34	50.5
H1-WK	−0.24 ± 0.44	0.32	0.39	27.8[a]	0.00 ± 0.44	0.27	0.34	52.4
SRK/T-MWK	−0.15 ± 0.51	0.33	0.41	39.7	0.00 ± 0.50	0.32[b]	0.39	51.9
SRK/T-WK	−0.30 ± 0.50	0.34	0.46	25.9[a]	0.00 ± 0.50	0.32[b]	0.39	52.7
EVO	0.09 ± 0.52	0.32	0.41	56.5	0.00 ± 0.51	0.31[b]	0.40	49.7
BUII	0.17 ± 0.47	0.33	0.39	63.8	0.00 ± 0.46	0.31	0.37	47.6
Haigis	0.53 ± 0.54	0.58	0.62	84.6	0.00 ± 0.50	0.34[b]	0.40	51.4

BUII = Barrett Universal II; EVO = emmetropia verifying optical; H1-MWK = Holladay 1 with modified Wang-Koch adjustment; H1-WK = Holladay 1 with original Wang-Koch adjustment; MAE = mean absolute error; ME = mean prediction error; MedAE = median absolute error; RBF = Radial Basis Function; S D = standard deviation; SRK/T-MWK = SRK/T with modified Wang-Koch adjustment; SRK/T-WK = SRK/T with original Wang-Koch adjustment; ULIB = User Group for Laser Interference Biometry.

[a]Significantly lower than other formulas (*P*<0.01).

[b]Significantly different from the Kane formula (*P*<0.05 with Bonferroni correction).

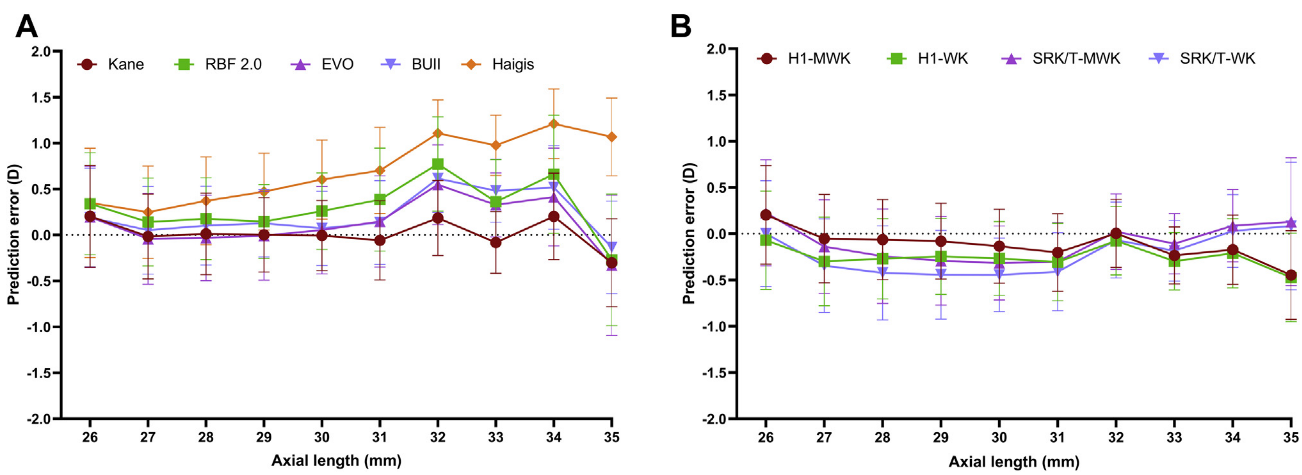

FIGURE 2. Prediction error versus axial length (in millimeter) using artificial intelligence and vergence formulas (A), and H1 and SRK/T with Wang-Koch adjustment (B). BUII = Barrett Universal II; EVO = emmetropia verifying optical; H1-MWK = Holladay 1 with modified Wang-Koch adjustment; H1-WK = Holladay 1 with original Wang-Koch adjustment; RBF = radial basis function; SRK/T-MWK = SRK/T with modified Wang-Koch adjustment; SRK/T-WK = SRK/T with original Wang-Koch adjustment.

MWK and H1-WK had the highest values for the ±0.50-D and ±1.00-D endpoint (76.8% and 96.8%, respectively). For the percentage of eyes with a PE within ±0.25 D, Kane had a significantly higher value than SRK/T-MWK (*P* < .001) and SRK/T-WK (*P* = .007) had. H1-WK also had a significantly higher value than SRK/T-MWK (*P* = .007). For the ±0.50-D endpoint, H1-WK and H1-MWK had significantly lower values than EVO and RBF 2.0 (*P* < .05). With regard to the proportion of eyes within ±1.00 D, H1-WK had a significantly lower value than EVO (*P* = .039) (Figure 4).

• **SUBGROUP ANALYSES WITH DIFFERENT ALS:** Subgroup analyses based on ALs, after eliminating systematic errors, are presented in Table 3. In eyes with ALs ≥26.0 mm to <28.0 mm, H1-WK and BUII produced the smallest MedAE (0.25 D), whereas Kane had the lowest MAE (0.36 D). Kane, RBF 2.0, H1-WK, and BUII had significantly lower MedAEs than SRK/T-MWK and Haigis (*P* < .05). In eyes with ALs ≥28.0 mm to <30.0 mm, Haigis had the lowest MedAE (0.26 D), and RBF 2.0, H1-MWK, and BUII shared the lowest MAE (0.34 D). H1-MWK had a significantly lower MedAE than EVO (*P* = .030).

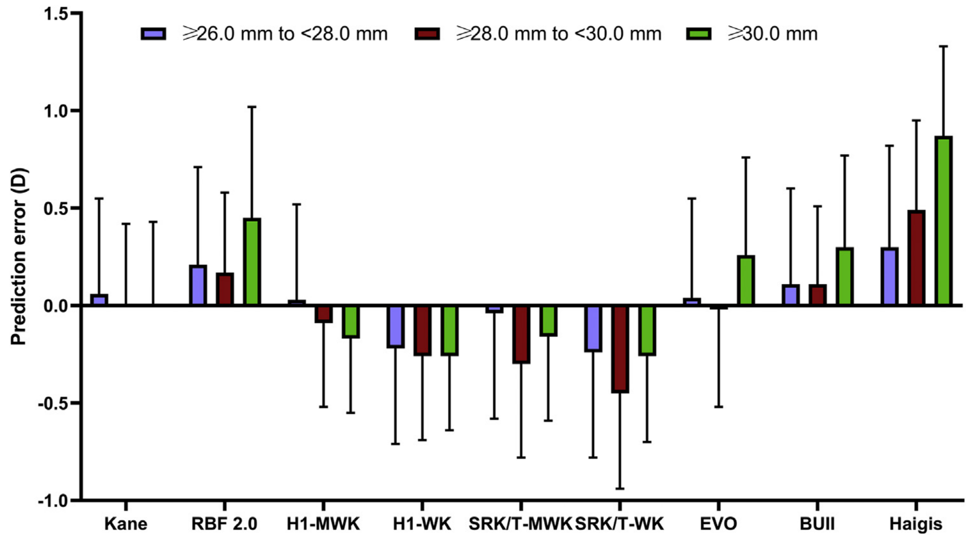

FIGURE 3. Comparison of PEs (in diopters) for various formulas in different axial length subgroups of long eyes. BUII = Barrett Universal II; EVO = emmetropia verifying optical; H1-MWK = Holladay 1 with modified Wang-Koch adjustment; H1-WK = Holladay 1 with original Wang-Koch adjustment; RBF = radial basis function; SRK/T-MWK = SRK/T with modified Wang-Koch adjustment; SRK/T-WK = SRK/T with original Wang-Koch adjustment.

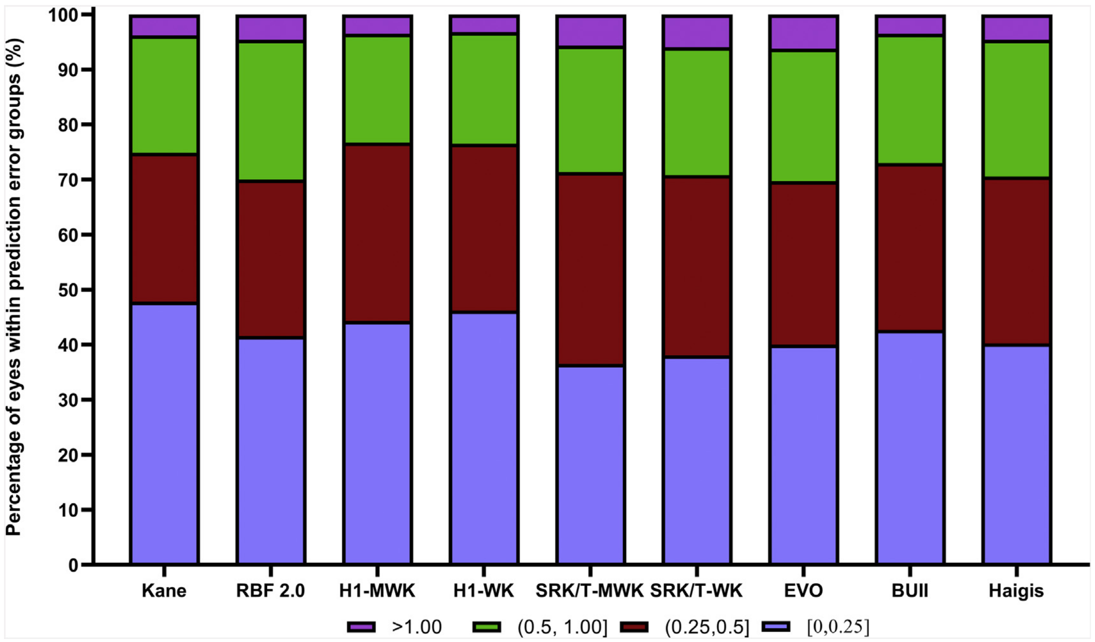

FIGURE 4. Histogram for the percentages of eyes within ±0.25 D, ±0.50 D, ±1.00 D, and ±2.00 D of prediction error. BUII = Barrett Universal II; D = diopter; EVO = emmetropia verifying optical; H1-MWK = Holladay 1 with modified Wang-Koch adjustment; H1-WK = Holladay 1 with original Wang-Koch adjustment; RBF = radial basis function; SRK/T-MWK = SRK/T with modified Wang-Koch adjustment; SRK/T-WK = SRK/T with original Wang-Koch adjustment.

In extremely myopic eyes with an AL ≥30.0 mm, Kane had the smallest MedAE (0.25 D), whereas H1-WK had the smallest MAE (0.30 D). Kane and H1-WK had significantly lower MedAEs than RBF 2.0, BUII, EVO, and Haigis ($P < .05$). Significant differences in MedAEs were also found in comparing H1-MWK with RBF 2.0 ($P = .025$). Additionally, when ULIB constants were used, Kane also yielded significantly lower MedAE than RBF 2.0, BUII, EVO, and Haigis in eyes with extreme myopia ($P < .01$) (Supplemental Table 1). Subgroup analyses based

TABLE 3. Prediction Errors Produced by Each Formula in Different Axial Length Subgroups of Highly Myopic Eyes

	≥26.0 mm to <28.0 mm (n = 157)			≥28.0 mm to <30.0 mm (n = 98)			≥30.0 mm (n = 115)		
Formula	MedAE	MAE	Error Range	MedAE	MAE	Error Range	MedAE	MAE	Error Range
Kane	0.27	0.36	−1.23 to 1.59	0.28	0.35	−1.02 to 1.10	0.25	0.31	−1.08 to 1.42
RBF 2.0	0.26	0.37	−1.30 to 1.58	0.30	0.34	−1.12 to 0.94	0.40[a]	0.43	−1.38 to 1.68
H1-MWK	0.26	0.37	−1.23 to 1.65	0.30	0.34	−1.07 to 1.16	0.29	0.31	−0.94 to 1.14
H1-WK	0.25	0.37	−1.25 to 1.54	0.29	0.35	−1.01 to 1.20	0.29	0.30	−0.88 to 1.24
SRK/T-MWK	0.36[a]	0.43	−1.37 to 1.70	0.30	0.39	−1.32 to 1.18	0.31	0.34	−1.04 to 1.39
SRK/T-WK	0.33	0.42	−1.38 to 1.63	0.31	0.39	−1.34 to 1.14	0.28	0.35	−1.05 to 1.46
EVO	0.29	0.39	−1.20 to 1.67	0.31	0.41	−1.27 to 1.37	0.35[a]	0.41	−1.33 to 1.35
BUII	0.25	0.37	−1.27 to 1.57	0.30	0.34	−0.97 to 1.09	0.36[a]	0.40	−1.06 to 1.40
Haigis	0.34[a]	0.42	−1.39 to 1.53	0.26	0.35	−1.19 to 1.38	0.37[a]	0.40	−0.83 to 1.40

BUII = Barrett Universal II; EVO = emmetropia verifying optical; H1-MWK = Holladay 1 with modified Wang-Koch adjustment; H1-WK = Holladay 1 with original Wang-Koch adjustment; MAE = mean absolute error; MedAE = median absolute error; RBF = radial basis function; SRK/T-MWK = SRK/T with modified Wang-Koch adjustment; SRK/T-WK = SRK/T with original Wang-Koch adjustment.

[a]Significantly different from Kane with mean prediction errors equal to .00 ($P < .05$ with Bonferroni correction).

on IOL types were also conducted (Supplemental Table 2). In eyes implanted with the Adapt AO IOL, Kane had a significantly lower MedAE than EVO and Haigis ($P < .05$).

DISCUSSION

THE PURPOSE OF THE PRESENT STUDY WAS TO EVALUATE the accuracy of IOL power calculation in highly myopic eyes using AI formulas (Kane and RBF 2.0) and other formulas (H1-MWK, H1-WK, SRK/T-MWK, SRK/T-WK, EVO 2.0, BUII, and Haigis). This study showed that the most accurate prediction of postoperative refraction can be achieved using Kane and H1 with Wang-Koch adjustment (both original and modified) in eyes with high to extreme myopia.

The present authors previously showed that H1 with ULIB constants or optimized constants for long eyes was not as accurate as that calculated using the modified Wang-Koch AL adjustment.[19] In the present study, the performances of Kane, H1-WK, and H1-MWK were comparable in all subgroup analyses. In addition, the original Wang-Koch AL adjustment methods yielded lower percentages of hyperopia than did other formulas when ULIB constants were used. SRK/T with Wang-Koch AL adjustments, whether original or modified, has been shown to be inferior to H1 with Wang-Koch AL adjustment.[10] The non-physiological irregularity of SRK/T has been known for years, and Sheard and associates[20] modified the steps in SRK/T that predicted corneal height, ending up with the T2 formula. Optimization of keratometry readings for SRK/T has also been proposed to refine its prediction accuracy.[21] Thus, simply optimizing AL for SRK/T is not enough, whereas AL adjustment for H1 offers a useful and convenient way to improve the accuracy of IOL calculation in long eyes.

In previous studies, BUII has been shown to be the most accurate in the IOL power calculations for highly myopic eyes.[22,23] However, there are a paucity of data comparing BUII with the new AI formulas, Kane and RBF 2.0, for highly myopic eyes, especially for eyes with an AL ≥30.0 mm. In the present study, BUII had a significantly lower MedAE than Haigis in eyes with an AL ≥26.0 mm to <28.0 mm, but no significant differences were found between BUII and RBF 2.0 across different AL ranges. These findings with the BUII formula were consistent with those reported in previous studies.[10,11] Rong and associates[24] compared 3 IOL calculation formulas (BUII, Olsen, and Haigis) in eyes with extreme myopia and found that BUII may be more accurate in eyes with an AL greater than 30.0 mm. Similar to their findings, the present study also found that BUII had a significantly lower MedAE than Haigis in eyes with extreme myopia, and its accuracy was also influenced by AL when ULIB constants were used, whereas the 2 formulas were equally accurate after eliminating systematic error.

RBF 1.0 has been shown to have a higher MAE than BUII, H1, and SRK/T.[25] In the present study, the updated RBF 2.0 outperformed Haigis, although no significant differences were found among RBF 2.0, BUII, and EVO. On the other hand, RBF 2.0 was not yet as accurate as Kane, H1-WK, and H1-MWK in eyes with extreme myopia. The present results indicate that RBF 2.0 performs better than its original version, but there is still scope for improvement with this totally data-driven method.

The new Kane formula was developed using nearly 30,000 accurate cases and was based on a combination of theoretical optics and high-performance cloud-based computing. Connell and associates[26] reported that Kane had the most accurate outcome with the lowest MedAE and the highest percentage of eyes within ±0.50 D but that there were not enough long eyes to adequately power statistical comparisons. Among the present subjects with high myopia, Kane also had the lowest MedAE and the highest percentage of eyes within ±0.25 D of PE, whereas H1-MWK had the highest value for the ±0.50-D endpoint. Melles and associates[12] reported that Kane was the most accurate formula for both overall and for long eyes. However, the longest eyes in that study had an AL between 28.0 mm and 29.0 mm. The accuracy of Kane in eyes with extreme myopia has not yet been validated. The present results showed that for extremely myopic eyes with cataract, Kane may be more accurate than other top choices such as BUII and RBF 2.0. Unlike BUII, no correlation between AL and PE was found for Kane, which may partly explain why Kane was more accurate than BUII. The present study revealed a difference of 0.11 D in MedAE between Kane and BUII in extremely myopic eyes, which may be of limited significance in some clinical settings, although statistically significant.

The present study is one of the largest reported case series with highly myopic eyes, especially extremely myopic eyes (AL ≥30.0 mm). Multiple IOL models were used to provide accurate reflection of the performance of formulas in real clinical scenario. Additionally, bias due to the fact that RBF 2.0 and BUII were formulated using the model SN60WF as the default IOL was minimized by using various IOLs. With respect to limitations, it is important to highlight the fact that lens thickness, central corneal thickness, and corneal diameter were not included in IOL power calculations. Kane uses both lens thickness and central corneal thickness as optional variables, and BUII uses lens thickness and corneal diameter as optional variables. If more variables were included, these formulas may perform more accurately. Because AL, keratometry, and anterior chamber depth are much larger sources of error than other parameters,[27] the results will probably be the same with more parameters available, but further studies are needed to validate these results using IOLMaster 700, which enables the measurement of more parameters. Another limitation was that the ULIB constants were used to compare the accuracies of different formulas because it was difficult to optimize constants with the online calculators of Kane, RBF 2.0, EVO, and BUII. Additionally, the ULIB lens constant was recommended in the online calculators of these new formulas. Although optimization of lens constants may further improve the accuracies of those formulas, most surgeons do not have optimized constants for these new proprietary formulas, especially for long eyes. Optimized constants for patients of all ALs, like the ULIB constants, should be enough, and modern formulas should take the difference at extremes of ALs into consideration without needing specific constants. The authors have also evaluated the MedAEs of formulas after adjusting ME to zero, and Kane remained one of the best-performing formulas and outperformed SRK/T-MWK, SRK/T-WK, EVO, and Haigis.

In conclusion, Kane was comparable to RBF 2.0, BUII, H1-MWK, and H1-WK in highly myopic eyes with an AL ≥26.0 mm and was better than BUII and RBF 2.0 in extremely myopic eyes with an AL ≥30.0 mm. Additionally, the Kane formula was comparable to H1-MWK and H1-WK across different AL subgroups. The most accurate prediction may be achieved with Kane, H1-MWK, and H1-WK in extremely myopic eyes.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

HUANHUAN CHENG: CONCEPTUALIZATION, METHODOLOGY, Investigation, Writing - original draft, Formal analysis. **Li Wang:** Visualization, Writing - review & editing. **Jack X. Kane:** Resources, Writing - review & editing. **Jianbing Li:** Investigation, Data curation. **Liangping Liu:** Investigation, Data curation. **Mingxing Wu:** Supervision, Project administration, Funding acquisition.

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