Accuracy of Intraocular Lens Calculation Formulas in Patients Undergoing Combined Phakic Intraocular Lens Removal and Cataract Surgery

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• PURPOSE: To investigate the prediction accuracy of intraocular lens (IOL) calculation formulas, and the impact of anterior chamber depth (ACD) and lens thickness (LT) measurement errors on IOL power calculation in patients undergoing combined phakic IOL (PIOL) removal and cataract surgery.
• DESIGN: Retrospective, consecutive case series study.
• METHODS: Thirty-six PIOL implanted eyes (12 anterior chamber PIOLs and 24 posterior chamber PIOLs [PC-PIOL]) undergoing cataract surgery were included. The prediction accuracy of new formulas (Barrett universal II, Emmetropia verifying optical, Kane, and Ladas super formula) and traditional formulas (Haigis, Hoffer Q, Holladay 1 and SRK/T) with or without Wang-Koch (WK) axial length (AL) adjustment was evaluated. The influence of ACD and LT measurement errors of IOLMaster 700 on refractive outcomes was also investigated.
• RESULTS: The Kane and traditional formulas with WK AL adjustment had no significant systematic prediction error and displayed a smaller median absolute error, whereas the other formulas showed significant hyperopia shift ($P < .05$) and relatively lower prediction accuracy. The accuracy rate of IOLMaster 700 in measuring the ACD and LT was 100% in eyes with anterior chamber PIOL implantation, and 37.50% in the PC-PIOL subgroup. No significant difference was observed in refractive outcomes of formulas using correct and wrong parameters in the PC-PIOL subgroup ($P > .05$).
• CONCLUSIONS: The Kane and traditional formulas with WK AL adjustment exhibited relatively higher prediction accuracy in patients who underwent combined PIOL removal and cataract surgery. The IOLMaster 700 displayed low accuracy in ACD and LT measurements for PC-PIOL implanted eyes, but showed negligible impact on IOL prediction accuracy. (Am J Ophthalmol 2022;234: 241–249. © 2021 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/))

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PHAKIC INTRAOCULAR LENS (PIOL) IMPLANTATION HAS gained increasing popularity for patients with refractive errors, especially for those contraindicated to keratorefractive surgeries.[1,2] The insertion of a PIOL offers many potential advantages, including fast vision recovery, reversibility of the procedure, and maintenance of the accommodation ability.[3] However, it has been reported that 40.9% and 54.8% of eyes with posterior chamber PIOL implantation (PC-PIOL) developed lens opacities at 5 and 10 years after surgery, respectively.[4] Clinically significant cataract has been one of the main reasons for PIOL extraction in clinical practice.[5–7]

Accurate ocular biometry measurement and IOL calculation are prerequisites of good visual quality after cataract surgery. It is known that measurement of preoperative anterior chamber depth (ACD), one of the key biometric parameters, could be affected by the presence of PIOL during applanation ultrasound A-scan as well as IOLMaster examinations based on partial coherence interferometry.[8] The introduction of IOLMaster 700, which is based on anterior segment swept-source optical coherence tomography, makes it possible to check whether the machine takes the PIOL as the anterior surface of crystalline lens by mistake. However, the accuracy of IOLMaster 700 in measuring ACD and lens thickness (LT) in eyes with PIOL implantation has not been reported. In addition, the performance of existing IOL calculation formulas, especially newer formu-

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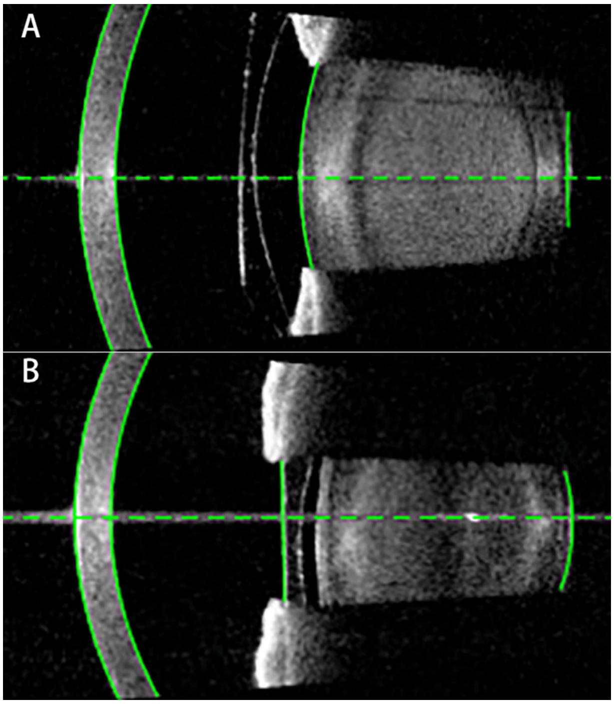

FIGURE 1. Eyes with anterior (A) and posterior (B) chamber phakic intraocular lens implantation measured by IOLMaster 700.

las incorporating preoperative ACD and LT, for this special population remains unknown.

The aim of this study was to compare the prediction accuracy of several new generation formulas (Barrett universal II [BUII], Emmetropia verifying optical [EVO], Kane, and Ladas super formula [LSF]) and traditional formulas (Haigis, Hoffer Q, Holladay 1, and SRK/T) with or without Wang-Koch (WK) axial length (AL) adjustment in patients undergoing combined PIOL removal and cataract surgery. The effect of ACD and LT measurement error by IOLMaster 700 on IOL calculation was also investigated.

METHODS

All procedures of this retrospective case series study were conformed to the Declaration of Helsinki and performed under the approval of the Institutional Review Board/Ethics Committee of Zhongshan Ophthalmic Center, Sun Yat-sen University (2019KYPJ033). The need for informed consent was waived because only the medical records were involved.

• **PARTICIPANTS:** We retrospectively reviewed the medical records of patients who underwent phacoemulsification and IOL implantation from December 2018 to May 2021 at the Cataract Department of Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangzhou, China. Patients who underwent PIOL removal combined with phacoemulsification and in-the-bag IOL implantation were included. The exclusion criteria were as follows: patients with (1) keratopathy, glaucoma, uveitis, ocular trauma, or lens dislocation; (2) previous history of corneal refractive surgery, or intraocular surgery other than PIOL implantation; (3) preoperative astigmatism of greater than 3 diopters (D); (4) severe surgical complications (eg, posterior capsular rupture); and (5) incomplete follow-up information.

• **DATA COLLECTION:** The following data were collected: patient age, gender, history of diseases and surgeries, preoperative ocular biometric parameters measured by IOLMaster 700 (Carl Zeiss Meditec AG, Jena, Germany) (AL; corneal power; ACD, measured from cornea epithelium to lens; LT; corneal diameter), preoperative and postoperative logarithm of the minimum angle resolution best-corrected visual acuity, endothelium cell density, the percentage of hexagonal cells, surgical records, type and power of the implanted IOL, and subjective refraction at 1 month after surgery or later.

• **MEASUREMENT OF THE ACD:** The anterior segment swept-source optical coherence tomography scans obtained by IOLMaster 700 were re-examined by the technician (XZ-Q) (Figure 1). The green lines on the picture represented structures automatically recognized by the IOLMaster 700, including the anterior and posterior surface of the cornea and the crystalline lens. For patients with PIOL implantation, sometimes the PIOL was mistakenly recognized as the anterior surface of the crystalline lens by the IOLMaster, resulting in incorrect measurements of ACD and LT (Figure 1, B).

We manually recalculated the ACD using the ImageJ software (http://rsb.info.nih.gov/ij; National Institutes of Health, Bethesda, Maryland, USA) based on the anterior segment swept-source optical coherence tomography scans, detailed methods were as follows. First, we checked whether the IOLMaster 700 correctly recognized the anterior surface of the crystalline lens. If the IOLMaster 700 recognized the PIOL as the anterior surface of the lens by mistake, wrong ACD (ACD_W) was displayed. Second, we manually measured the distance from the cornea epithelium to the anterior surface of the PIOL (L_{PIOL}), and to the anterior surface of crystalline lens (L_{Lens}), respectively. The correct ACD (ACD_C) was calculated using the following equation: $ACD_C/L_{Lens} = ACD_W/L_{PIOL.}$ If the IOLMaster 700 measured the ACD correctly, the ACD_W was calculated by the same equator. Similar methods were used to measure the correct LT and wrong LT. The manual measurements of ACD and LT were performed by the same technician (XZ-Q).

• **FORMULA CALCULATIONS:** The performances of several new formulas, including the BUII (version 1.05; avail-

TABLE 1. Characteristics of Participants

Parameter	Overall	Anterior chamber PIOL	Posterior chamber PIOL	*P* value
Eye	(*n* = 36)	(*n* = 12)	(*n* = 24)	
Age, years	46.94 ± 8.68	49.83 ± 8.74	45.5 ± 8.46	.161
Male, *n* (%)	13 (36.1)	7 (58.33)	6 (25%)	.071
Preoperative BCVA (logMAR)	0.81 ± 0.41	0.86 ± 0.44	0.79 ± 0.40	.673
Postoperative BCVA (logMAR)	0.16 ± 0.23	0.24 ± 0.36	0.11 ± 0.10	.099
AL, mm	31.43 ± 2.15	32.58 ± 1.39	30.85 ± 2.25	.021[b]
Corneal power, D	44.25 ± 1.20	44.19 ± 1.07	44.27 ± 1.28	.857
ACD, mm[a]	3.24 ± 0.46	3.52 ± 0.40	3.10 ± 0.42	.007[b]
LT, mm[a]	4.44 ± 0.42	4.26 ± 0.31	4.52 ± 0.44	.090
CD, mm	11.73 ± 0.36	11.78 ± 0.31	11.71 ± 0.39	.634
IOL power, D	2.82 ± 4.08	1.13 ± 2.47	3.67 ± 4.49	.077
Time between PIOL implantation and PE, year	9.64 ± 3.85	13.27 ± 2.28	7.54 ± 2.88	<.001[b]
ECD, cells/mm^2	2364.83 ± 456.82	2029.86 ± 580.37	2532.32 ± 262.03	.001[b]
Percentage of hexagonal cells, %	61.23 ± 11.35	60.0 ± 12.56	61.79 ± 10.99	.671

ACD = anterior chamber depth, as measured from corneal epithelium to lens; AL = axial length; BCVA = best-corrected visual acuity; CD = corneal diameter; D = diopter; ECD = endothelium cell density; IOL = intraocular lens; logMAR = logarithm of the minimum angle resolution; LT = lens thickness; PE = phacoemulsification; PIOL = phakic intraocular lens.

[a]The displayed ACD and LT of IOLMaster 700 were used.

[b]Statistically significant ($P < .05$).

able at http://calc.apacrs.org/barrett_universal2105/, accessed July 2021), EVO (version 2.0; available at https://www.evoiolcalculator.com/calculator.aspx, accessed July 2021), Kane (available at https://www.iolformula.com; accessed July 2021), and LSF (version 1.0b, available at http://iolcalc.com; accessed July 2021), were investigated. The performances of the traditional Haigis, Hoffer Q, Holladay 1, and SRK/T formulas with or without the first linear (WK1), second linear, and nonlinear versions of WK AL adjustment were also assessed (available at http://www.eyecalcs.com/WEBCALCS/IOLcalc2/IOL2.html; accessed July 2021). The User Group for Laser Interference Biometry constant was used to assess these formulas in real clinical practice (available at www.ocusoft.de/ulib/c1.html; accessed July 2021).

The prediction accuracy of these IOL calculation formulas with displayed ACD and LT was examined separately for patients in the anterior chamber PIOL (AC-PIOL) and PC-PIOL subgroups. Considering the IOLMaster 700 could make mistakes when measuring the ACD and LT of eyes with PC-PIOL implantation, the refractive outcomes calculated with ACD_C or ACD_w with its corresponding LT were compared in formulas including BUII, EVO, Kane, LSF, Haigis, and Haigis with WK1 AL adjustment.

• **FORMULA EVALUATION:** The accuracy of the formula was evaluated by parameters including the mean prediction error (ME), mean absolute prediction error (MAE), median absolute prediction error (MedAE), and percentage of eyes within ±0.25 D, ±0.50 D, and ±1.0 D of the prediction error. Each prediction error was back-calculated as the difference between the predicted and actual postoperative spherical equivalent. The ME was the mean of all the prediction errors for each formula evaluated, and a positive and negative value represented a hyperopic and myopic systemic error, respectively. The MAE and MedAE was the mean and the median of absolute prediction error, respectively.

• **STATISTICAL ANALYSIS:** The normality of data was examined by the Shapiro-Wilk test. The quantitative data were displayed by mean ± SD or median with interquartile range based on the normality of data, and the qualitative data were represented by number (percent). Independent *t* test or Wilcoxon rank-sum test (for continuous variables) and the χ^2 test (for categorical variables) were used to compare the differences in participant characteristics and prediction accuracy between the AC-PIOL and PC-PIOL subgroup. The 1-sample *t* test was used to test whether the ME of formulas was significantly different from zero. The Friedman test was performed to compare the absolute prediction error of different formulas, and Bonferroni correction was used for multiple comparisons. The paired *t* test was used to test whether the prediction accuracy of formulas with wrong and correct ACD was significantly different. The statistical analysis was performed using Stata (ver. 16.0; Stata Corp, College Station, TX). A *P* value of less than .05 was considered as statistically significant.

RESULTS

• **CHARACTERISTICS OF PARTICIPANTS:** In total, 36 patients (36 eyes, 13 males) with prior PIOL implantation undergoing cataract surgery were enrolled. Demographic and

TABLE 2. Performance of IOL Calculation Formula in Anterior and Posterior Chamber PIOL Subgroups

Formula	Anterior chamber PIOL (n = 12)			Posterior chamber PIOL (n = 24)		
	ME ± SD[a]	MAE ± SD	MedAE	ME ± SD[a]	MAE ± SD	MedAE
BUII	0.42 ± 0.43[b]	0.47 ± 0.37	0.50	0.35 ± 0.55[b]	0.53 ± 0.37	0.41
EVO	0.34 ± 0.36[b]	0.39 ± 0.29	0.36	0.31 ± 0.55[b]	0.49 ± 0.39	0.47
Kane	-0.20 ± 0.35	0.32 ± 0.22	0.29	-0.03 ± 0.60	0.44 ± 0.39	0.40
LSF	1.01 ± 0.37[b]	1.01 ± 0.37	1.13	0.76 ± 0.61[b]	0.87 ± 0.43	0.85
Haigis	0.94 ± 0.36[b]	0.94 ± 0.36	0.94	0.79 ± 0.49[b]	0.84 ± 0.41	0.69
Haigis-WK1	0.17 ± 0.36	0.30 ± 0.25	0.30	0.05 ± 0.50	0.38 ± 0.32	0.31
Hoffer Q	1.75 ± 0.43[b]	1.75 ± 0.43	1.78	1.41 ± 0.65[b]	1.44 ± 0.60	1.44
Hoffer Q-WK1	0.27 ± 0.37[b]	0.36 ± 0.27	0.36	0.12 ± 0.63	0.47 ± 0.42	0.33
Holladay 1	1.49 ± 0.38[b]	1.49 ± 0.38	1.55	1.31 ± 0.54[b]	1.31 ± 0.54	1.34
Holladay 1-WK1	0.12 ± 0.33	0.28 ± 0.20	0.26	0.11 ± 0.56	0.42 ± 0.37	0.31
Holladay 1-WK2	-0.25 ± 0.33[b]	0.33 ± 0.23	0.30	-0.11 ± 0.59	0.44 ± 0.40	0.29
Holladay1-WKn	0.03 ± 0.31	0.25 ± 0.18	0.24	0.11 ± 0.62	0.47 ± 0.40	0.34
SRK/T	1.10 ± 0.42[b]	1.10 ± 0.42	1.11	0.84 ± 0.58[b]	0.91 ± 0.46	0.89
SRK/T-WK1	0.08 ± 0.36	0.30 ± 0.19	0.35	0.01 ± 0.57	0.43 ± 0.36	0.33
SRK/T-WK2	-0.19 ± 0.33	0.31 ± 0.22	0.21	-0.15 ± 0.61	0.49 ± 0.37	0.39

BUII = Barrett universal II formula; EVO = Emmetropia Verifying Optical formula; LSF = Ladas super formula; MAE = mean absolute prediction error; ME = mean refractive prediction error; MedAE = median absolute prediction error; PIOL = phakic intraocular lens; SD = standard deviation of the refractive prediction error; WK1 = first linear version of Wang-Koch axial length adjustment; WK2 = second linear Wang-Koch axial length adjustments; WKn = nonlinear version of Wang-Koch axial length adjustment.

[a]Comparison between PE and zero.

[b]Statistically significant ($P < .05$).

clinical characteristics of the included patients are listed in Table 1. The mean age of the patients was 46.94 ± 8.68 years, and the average AL was 31.43 ± 2.15 mm. The preoperative logarithm of the minimum angle resolution best-corrected visual acuity was 0.81 ± 0.41, and improved to 0.16 ± 0.23 after surgery. The time between PIOL implantation and cataract surgery was 9.64 ± 3.85 years, and the major type of cataract was anterior subcapsular cataract (19 eyes [52.78%]).

Twelve eyes were implanted with AC-PIOL (Verisyse, Advanced Medical Optics, Inc., Santa Ana, CA) and 24 eyes with PC-PIOL (Implantable collamer lens [ICL], V4, Staar Surgical, Nidau, Switzerland). Patients in the AC-PIOL subgroup had longer AL and deeper ACD compared with the PC-PIOL subgroup ($P < .001$). Age, gender, and preoperative and postoperative best-corrected visual acuity were comparable between the 2 subgroups. The time between PIOL implantation and cataract surgery was shorter in the PC-PIOL subgroup (7.54 ± 2.88 years) than the AC-PIOL subgroup (13.27 ± 2.28 years; $P < .001$). Before cataract surgery, the AC-PIOL subgroup showed a lower endothelium cell density (2,029.86 ± 580.37 cells/mm^2 vs 2,532.32 ± 262.03 cells/mm^2; $P = .001$), and comparable percentage of hexagonal cells ($P = .671$). For the PC-PIOL subgroup, the vault height was 393 ± 239 μm.

• **PREDICTION ACCURACY OF IOL FORMULAS:** The prediction outcomes of 4 new formulas and 4 traditional formulas with or without WK AL adjustment in the 2 subgroups are shown in Table 2. The distribution of absolute prediction error and percentage of eyes within ±0.25 D, ±0.50 D, and ±1.0 D of prediction error are displayed in Figure 2 and Figure 3, respectively. The ME of the Kane and traditional formulas with WK AL adjustment displayed no significant difference from zero ($P > .05$), whereas the other 3 new formulas and 4 traditional formulas without WK AL adjustment showed hyperopic systematic prediction error ($P < .05$).

Kane displayed the lowest median absolute error (MedAE) (0.29 D in the AC-PIOL subgroup and 0.40 D in the PC-PIOL subgroup) among new formulas, and traditional formulas with WK AL adjustment exhibited comparable prediction accuracy (MedAE, 0.21–0.39 D). No significant difference was observed in the prediction accuracy of formulas between the 2 subgroups.

• **INFLUENCE OF ACD MEASUREMENT ERROR ON THE PREDICTION ACCURACY OF FORMULAS:** The accuracy rate of the IOLMaster 700 in measuring ACD was 100% in the AC-PIOL subgroup and 37.50% in the PC-PIOL subgroup. For the PC-PIOL subgroup, the ACD_W and ACD_C was 2.79 ± 0.31 mm and 3.41 ± 0.39 mm ($P < .001$), and the wrong LT and correct LT was 4.84 ± 0.35 mm and 4.20 ± 0.41 mm ($P < .001$), respectively.

The refractive outcomes of formulas based on ACD_W or ACD_C with its corresponding LT are shown in Table 3.

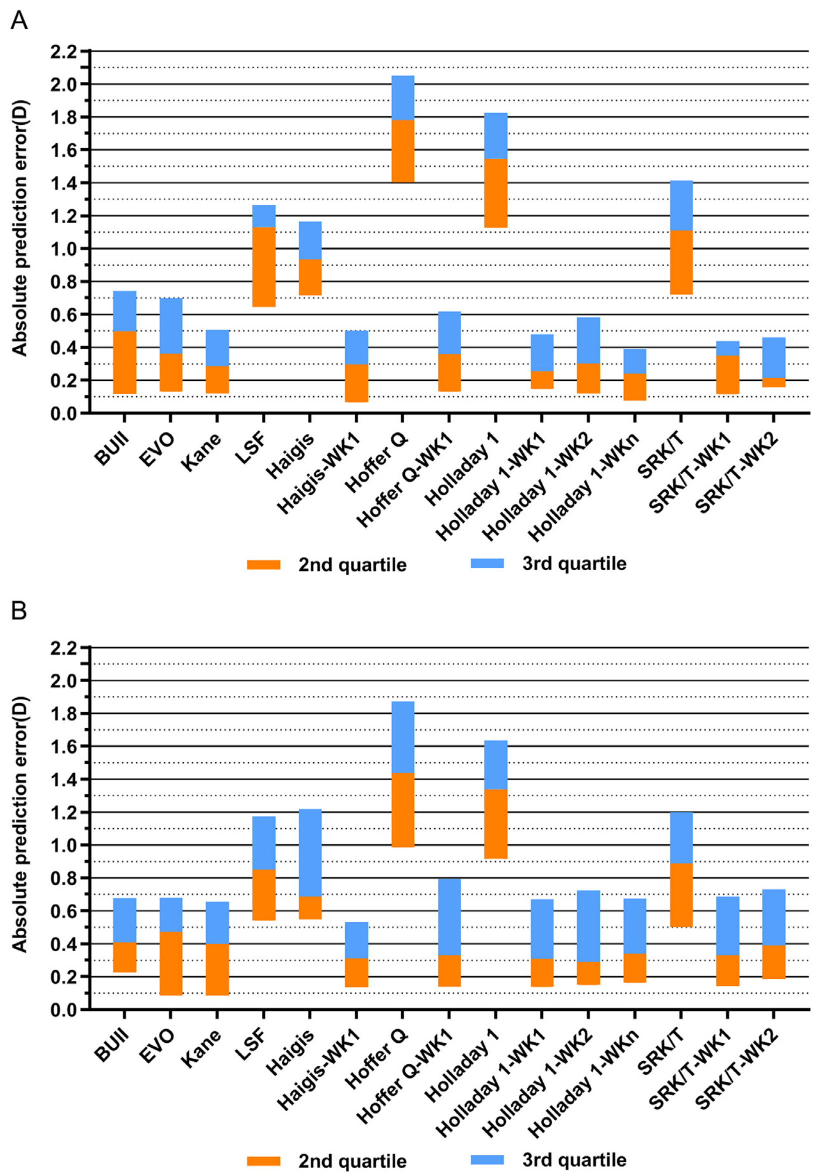

FIGURE 2. Box plots showing the absolute prediction error of intraocular lens calculation formulas in eyes with anterior (A) and posterior (B) chamber phakic intraocular lens implantation.
BUII = Barrett universal II formula; EVO = emmetropia verifying optical formula; LSF = Ladas super formula; WK1 = first linear version of Wang-Koch axial length adjustment; WK2 = second linear version of Wang-Koch axial length adjustment; WKn = non-linear version of Wang-Koch axial length adjustment.

There was no significant difference in the refractive outcomes of BUII, EVO, Kane, LSF, and Haigis with or without WK1 between the 2 groups ($P > .05$).

DISCUSSION

We demonstrated that the Kane and traditional formulas with WK AL adjustment displayed greater prediction accuracy in patients who underwent combined PIOL removal and cataract surgery. To the best of our knowledge, this result has not been reported previously. The BUII, EVO, LSF, and 4 traditional formulas without WK AL adjustment showed hyperopic bias and larger prediction error. Although the IOLMaster 700 displayed a low accuracy in measuring the ACD and LT for eyes with PC-PIOL implantation, it had negligible impact on the refractive outcomes of IOL calculation.

Cataract formation is a frequent complication of PIOL implantation. The rate of lens opacity in PIOL implanted eyes has also been reported to increase with time: 3% at 1 year,[9] 4% to 11% at 2 years,[10–13] 7% to 40.9% at 5 years,[4,14–16] and 28% to 54.8% at 10 years.[4,17] Clini-

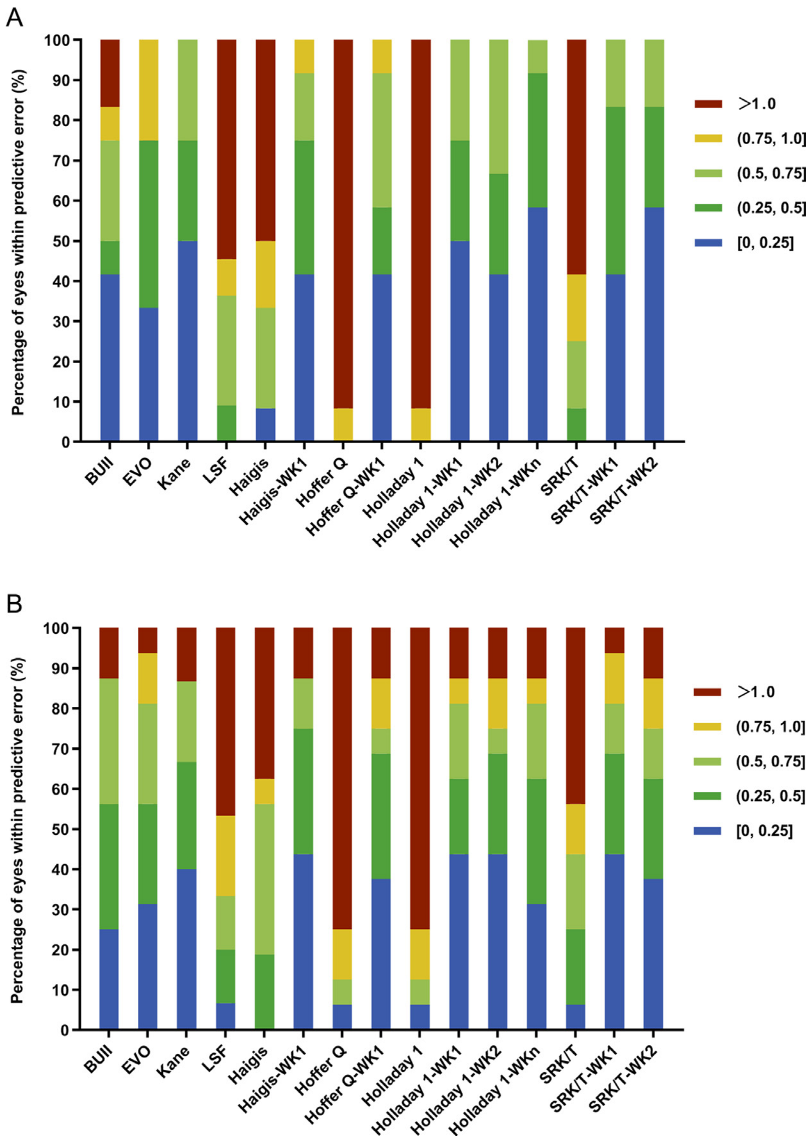

FIGURE 3. Stacked histogram showing percentage of eyes within a given the diopter range of prediction error in eyes with anterior (A) and posterior (B) chamber phakic intraocular lens implantation.
BUII = Barrett universal II formula; EVO = emmetropia verifying optical formula; LSF = Ladas super formula; WK1 = first linear version of Wang-Koch axial length adjustment; WK2 = second linear version of Wang-Koch axial length adjustment; WKn= nonlinear version of Wang-Koch axial length adjustment.

cally significant cataract is the main reason for PIOL removal.[5–7] For eyes implanted with PIOL, the rates of PIOL removal combined with cataract surgery were 2% to 4% at 2 years,[10,11] 2% to 4.9% at 5 years,[4,14] and 17% to 18.3% at 10 years.[4,17] We observed a longer interval between PIOL implantation and cataract surgery in the AC-PIOL subgroup compared with the PC-PIOL subgroup. Moreover, most of the patients (52.78%) implanted with PIOL displayed anterior subcapsular opacities, which was consistent with previous studies.[18–20] Previous studies consistently reported reduction of vault height over time in eyes implanted with PC-PIOL and suggested that insufficient vaulting might be responsible for the development of anterior subcapsular cataract.[4,16,17] In our study, the mean vault height in the PC-PIOL group decreased to 393 ± 239 μm, and 1 eye showed complete attachment of the PIOL to the crystalline lens. Regarding the PIOL removal, the size of the main surgical incision depends on the material and type of the PIOL. Iris-fixated Verisyse AC-PIOL, which is made of rigid PMMA material, requires a corneoscleral tunnel incision of approximately 5.5 mm to be extracted. ICLs made of collagen copolymer are very flexible and can be stretched and removed easily through a small incision of approximately 2.8 mm using a hand-over-hand technique.[21,22]

As far as we know, there are no published studies evaluating the prediction accuracy of IOL calculation formu-

TABLE 3. Predictive Outcomes of Intraocular Lens Calculation Formulas Based on Correct or Wrong ACD in Posterior PIOL Subgroup

Parameter	Correct ACD and LT			Wrong ACD and LT		
	ME ± SD	MAE ± SD	MedAE	ME ± SD	MAE ± SD	MedAE
BUII	0.35 ± 0.55	0.53 ± 0.37	0.42	0.34 ± 0.56	0.53 ± 0.37	0.41
EVO	0.32 ± 0.54	0.49 ± 0.38	0.48	0.32 ± 0.53	0.49 ± 0.37	0.47
Kane	0.01 ± 0.58	0.43 ± 0.36	0.35	-0.04 ± 0.59	0.43 ± 0.39	0.36
LSF	0.76 ± 0.61	0.87 ± 0.43	0.85	0.76 ± 0.61	0.87 ± 0.43	0.85
Haigis	0.78 ± 0.48	0.82 ± 0.40	0.67	0.83 ± 0.46	0.84 ± 0.44	0.77
Haigis-WK1	0.05 ± 0.49	0.36 ± 0.32	0.31	0.09 ± 0.46	0.36 ± 0.29	0.32

ACD = anterior chamber depth; BUII= Barrett universal II formula; EVO = emmetropia verifying optical formula; LSF = Ladas super formula; LT = lens thickness; ME = mean refractive prediction error; MAE = mean absolute prediction error; MedAE = median absolute prediction error; SD = standard deviation of the refractive prediction error; WK1 = first linear version of Wang-Koch axial length adjustment.

Note: The correct or wrong ACD and its corresponding LT were used in the calculation of BUII, EVO, Kane, and LSF formulas, while LT were not included in the calculation of Haigis and Haigis-WK1 formula.

las in patients undergoing combined PIOL removal and cataract surgery. Previous studies have reported that the Kane formula and traditional formulas with WK AL adjustment exhibited higher prediction accuracy in highly myopic eyes.[23–29] In this study, we also observed that Kane and traditional formulas with WK AL adjustment displayed better prediction accuracy in PIOL implanted eyes. This could be partly due to that the study participants were all highly myopic with an average AL of 31.43 ± 2.15 mm. The EVO, BUII, LSF, and 4 traditional formulas showed a hyperopic bias with larger absolute prediction error than the Kane and the traditional formulas with WK AL adjustment, and thus were not preferred for eyes with PIOL.

With the development of ocular biometry measurement devices and IOL calculation formulas, more and more biometric parameters are being included in the formulas for better prediction accuracy. The ACD, LT, and corneal diameter are important parameters included in the new generation formulas, such as the BUII and EVO formula. One previous study has reported that the measured ACD was 0.05 to 1.31 mm shorter after iris-fixed PIOL implantation using the applanation ultrasound examination or IOLMaster based on partial coherence interferometry technology, which could be due to the light reflection of the PIOL.[8] However, to our knowledge, there are no studies reporting the accuracy of IOLMaster 700 in measuring the ACD and LT for PIOL implanted eyes. We observed that the IOLMaster 700 could measure the ACD and LT correctly in all eyes with AC-PIOL implantation, whereas the accuracy rate in eyes with PC-PIOL was only 37.50%. The anterior surface of the PC-PIOL was mistakenly recognized as the crystalline lens, leading to an underestimation of the ACD and an overestimation of the LT. The performance of the IOLMaster 700 in measuring ocular biometric parameters for PC-PIOL implanted eyes still needs further improvement.

In this study, we compared for the first time the influence of ACD and LT measurement error based on IOLMaster 700 on IOL calculation formulas in cataract patients with PC-PIOL. We found that the ACD and LT measurement error did not affect the predicted values of IOL calculation formulas in these patients. Previous studies had compared the biometric parameters and IOL power calculation before and right after PC-PIOL (Visian ICL or Eyecryl PIOL) implantation, and found comparable IOL power prediction accuracy among the BUII, Haigis, Hoffer Q, Holladay 1, and SRK/T formulas.[30,31] However, these studies were conducted in participants with transparent lens who did not receive actual cataract surgery and, thus, could not reflect the performance of IOL calculation formulas in a real clinical setting. The negligible impact of ACD measurement error on prediction accuracy in patients undergoing PIOL removal and cataract surgery may be explained by that highly myopic eyes are less sensitive to ACD errors, whereas short eyes are on the contrary.[32] The PIOL can not only be used in high myopia patients, but also in hyperopia and low myopia patients,[33] among whom the measurement error of ACD and LT by IOLMaster 700 might significantly affect the prediction accuracy. Thus, for those with measurement errors, manual calculations are needed (as described in the Methods section) to get the correct ACD and LT value. Further studies are warranted to better understand the extent of measurement error regarding ACD and LT as well as its impact on the prediction accuracy in these patients.

Some limitations of this study should be addressed. First, the sample size was limited. Further studies with larger sample size are preferred in the future. Second, ACD measurements in eyes implanted with PIOL were only retrospectively evaluated using the IOLMaster 700. The performances of other devices such as the OA2000, Lenstar 900 are warranted. Third, the lens constants were not optimized separately for this special population with a small sample size, considering that the User Group for Laser Interference Biometry constants could reflect the performance of formulas in a real clinical setting.

In summary, the Kane and traditional formulas with WK AL adjustment exhibited relatively higher prediction accuracy for patients undergoing combined PIOL removal and cataract surgery. The IOLMaster 700 displayed low accuracy in ACD and LT measurements for PC-PIOL implanted eyes, but showed negligible impact on the refractive prediction accuracy.

ALL AUTHORS HAVE COMPLETED AND SUBMITTED THE ICMJE FORM FOR DISCLOSURE OF POTENTIAL CONFLICTS OF INTEREST and none were reported.
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