• Clinical Research •

Risk factors for biometry prediction error by Barrett Universal II intraocular lens formula in Chinese patients

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Abstract

● **AIM:** To investigate the influence of postoperative intraocular lens (IOL) positions on the accuracy of cataract surgery and examine the predictive factors of postoperative biometry prediction errors using the Barrett Universal II (BUII) IOL formula for calculation.

● **METHODS:** The prospective study included patients who had undergone cataract surgery performed by a single surgeon from June 2020 to April 2022. The collected data included the best-corrected visual acuity (BCVA), corneal curvature, preoperative and postoperative central anterior chamber depths (ACD), axial length (AXL), IOL power, and refractive error. BUII formula was used to calculate the IOL power. The mean absolute error (MAE) was calculated, and all the participants were divided into two groups accordingly. Independent *t*-tests were applied to compare the variables between groups. Logistic regression analysis was used to analyze the influence of age, AXL, corneal curvature, and preoperative and postoperative ACD on MAE.

● **RESULTS:** A total of 261 patients were enrolled. The 243 (93.1%) and 18 (6.9%) had postoperative MAE<1 and >1 D, respectively. The number of females was higher in patients with MAE>1 D (χ^2 = 3.833, P=0.039). The postoperative BCVA (logMAR) of patients with MAE >1 D was significantly worse (t=-2.448; P=0.025). After adjusting for gender in the logistic model, the risk of postoperative refractive errors was higher in patients with a shallow postoperative anterior chamber [odds ratio=0.346; 95% confidence interval (CI): 0.164, 0.730, P=0.005].

● **CONCLUSION:** Risk factors for biometry prediction error after cataract surgery include the patient's sex and postoperative ACD. Patients with a shallow postoperative anterior chamber are prone to have refractive errors.

● **KEYWORDS:** intraocular lens power calculation; gender; anterior chamber depth; biometry prediction error

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INTRODUCTION

Cataract surgery is currently viewed as a refractive procedure due to a growing pursuit of visual quality. Such status quo has placed greater emphasis on the accurate predictions of postoperative refraction and optimization of intraocular lens (IOL) calculation. With a continuous update, the latest fourth-generation IOL calculation formulas have presented an outstanding performance in prediction accuracy[1-4]. Plus, the application of artificial intelligence methods adds greater robustness to the calculation accuracy[5-8]. However, biometry prediction errors still occur in some patients postoperatively, which intensively affects their daily lives. According to the current definition, an ideal biometry prediction error should be less than 1 D for an optimized IOL calculation[1,3-4]. Previous reports claimed that the risk factors of biometry prediction errors included age[9] and postoperative IOL position[10-11], while the input of lens thickness showed no impact on the prediction error[12]. However, the postoperative anterior segment parameters were seldom considered for prediction. Therefore, this study aimed to analyze risk factors for biometry prediction errors in Chinese cataract patients of different ages, gender, corneal curvature, axial lengths (AXL), and anterior chamber depths (ACD).

PARTICIPANTS AND METHODS

Ethical Approval The current study was approved by the institutional ethics committee of Peking University Third

Hospital (Approval No.IRB00006761-M2017249) and adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all the patients.

Study Design Prospective study. Patients who underwent cataract phacoemulsification combined with IOL implantation surgery by a single surgeon (Hong Y) at the Department of Ophthalmology of Peking University Third Hospital from June 2020 to April 2022 were consecutively recruited.

Eligibility Criteria Inclusion criteria were: 1) AXL≥20.0 mm; 2) preoperative intraocular pressure≤21 mm Hg; 3) postoperative subjective refraction with best-corrected visual acuity (BCVA) of 20/40 or better[2]. Only one eye of each patient was randomly selected for analysis[2]. Exclusion criteria were: 1) congenital eye abnormalities; 2) corneal astigmatism≥4 D measured by keratometry; 3) a history of corneal disease, refractive surgery, uveitis; 4) a history of uncontrolled hypertension, diabetes, or autoimmune diseases; 5) intraoperative or postoperative complications.

Data Collection Demographic data, including the patient's gender and age, were recorded. Corneal curvature and ACD were measured by Pentacam HR (Oculus, Inc., Lynnwood, WA, USA). IOL Master 700 (Carl Zeiss Meditec Inc., Dublin, CA, USA) was used to measure AXL for ocular biometry. Barrett Universal II (BUII) formula was used to calculate the IOL power. BCVA, postoperative ACD, and postoperative refraction were measured at a three-month follow-up[2]. The mean absolute error (MAE) was calculated by subtracting the actual refraction from the predicted postoperative refraction.

Surgical Procedure Surgery was performed under sub-Tenon's anesthesia. Surgery consisted of routine phacoemulsification *via* a 3.2-mm temporal clear corneal incision, capsulorhexis size aimed at 5.0 mm, with in-the-bag IOL implantation. The implanted IOL was RAY-61PL (ROHTO Pharmaceutical Co. Ltd, Osaka, Japan).

Statistical Analysis All data were analyzed using SPSS 26.0 (IBM SPSS Inc., Chicago, IL, USA). Continuous variables were recorded as means±standard deviations. Quantitative measures were recorded as percentages. The Shapiro-Wilk test and Q-Q plots were used to assess the normality of variables. All the participants were divided into two groups according to MAE. Independent *t*-tests were applied to compare the variables between groups. Quantitative data were analyzed with the Chi-square or Fisher's exact test. Logistic regression analysis was fitted for the outcomes and used to analyze the relationship between MAE and the age, AXL, corneal curvature, and preoperative and postoperative ACDs with enter method. The results were presented as odds ratios (ORs) with 95% confidence intervals (CIs). $P<0.05$ was considered statistically significant difference.

RESULTS

Demographics Characteristics Two hundred sixty-one eyes of 261 patients were enrolled, including 100 men and 161 women, with a mean age of 67.1±8.8 (range: 35-87)y. The mean AXL was 23.2±1.3 (range: 20.6-29.7) mm. Among all the patients, 33 (13%), 194 (74%), and 34 (13%) had short (20.0-22.0 mm), normal (22.0-24.5 mm), and long (24.5-30.0 mm) AXL, respectively. The average corneal curvature measured was 44.3±1.4 (range: 41.0-49.0) D. A total of 8 (3%), 217 (83%), and 36 (14%) patients had flat (<42 D), moderate (42-46 D), and steep (>46 D) corneal curvatures, respectively. The preoperative ACD was 2.30±0.52 (range: 0.79-3.81) mm, with 84 (32%), 151 (58%), and 26 (10%) patients having an ACD<2, 2-3, and >3 mm, respectively.

The postoperative BCVA logMAR was 0.06±0.09 (range: 0.0-0.3), and the postoperative ACD was 3.81±0.23 (range: 1.12-5.10) mm. Among all patients, 24 (9%), 131 (50%), and 106 (41%) had ACDs<3, 3-4, and >4 mm, respectively. Postoperative refractive errors <1 and >1 D were found in 243 (93.1%) and 18 (6.9%) patients, respectively.

The difference between the age of patients with MAE>1 D and those with MAE<1 D was insignificant (t=-0.648; P=0.525), and most patients with MAE >1D were women (χ^2=3.833; P=0.039). The postoperative BCVA of patients with MAE >1 D was relatively lower (t=-2.448; P=0.025), while the postoperative ACD was shallower (t=2.509; P=0.013). The other indicators showed no significant difference between the two groups (Table 1).

Binary Logistic Regression Among the 261 patients, 243 (93.1%) and 18 (6.9%) had MAE<1 and >1 D, respectively. Age, gender, AXL, corneal curvature, preoperative and postoperative ACDs were included in the logistic model. After adjusting for gender in the logistic model, the risk of postoperative MAE was higher in patients with shallow postoperative anterior chambers (OR=0.346; 95%CI: 0.164, 0.730, P=0.005; Table 2).

DISCUSSION

Our study showed that risk factors associated with MAE>1 D after cataract surgery were female gender and postoperative ACD. In contrast, corneal curvature, AXL, or preoperative ACD was not an independent risk factor.

Our included patients were all Chinese, with a slightly higher female prevalence, consistent with previous studies[1,13-16]. Normal corneal curvatures were the most prevalent, accounting for 83% of cases. In our study, AXL ranged widely from 20.6 to 29.7 mm. Normal, short, and long AXL were found to be 74%, 13%, and 13%, respectively. The ratio of patients with a short AXL was higher than that reported from other countries[1], possibly because of the ocular characteristic of the Asian race[1,15]. Similarly, patients with a shallow preoperative ACD

Table 1 Demographics of patients with MAE>1 and <1 D

Demographic data	MAE<1 D (n=243)	MAE>1 D (n=18)	t/χ^2	P^a
Age (y)	67.0±8.5	68.9±12.5	-0.648	0.525
Gender (male:female, n)	97:146	3:15	3.833	0.039
Axial length (mm)	23.2±1.3	23.2±1.6	-0.111	0.911
Corneal curvature (D)	44.3±1.4	44.7±1.9	-1.098	0.273
Astigmatism (D)	0.83±0.57	0.83±0.50	-0.007	0.994
Preoperative ACD (mm)	2.30±0.52	2.32±0.67	-0.123	0.903
BCVA (logMAR)	0.06±0.09	0.14±0.13	-2.448	0.025
Postoperative ACD (mm)	3.82±0.59	3.46±0.64	2.509	0.013

[a]SPSS independent-samples t-test/Fisher exact test was used for all analyses. Data are expressed as mean±standard deviation, unless otherwise indicated. ACD: Anterior chamber depth; BCVA: Best corrected visual acuity; MAE: Mean absolute error.

Table 2 Binary logistic regression analysis of postoperative refractive error

Parameters	OR (95%CI)	P
Gender		
Male	1	-
Female	0.241 (0.063, 0.919)	0.037
Age	1.042 (0.983, 1.105)	0.162
Axial length	1.382 (0.894, 2.137)	0.145
Corneal curvature	1.263 (0.868, 1.839)	0.223
Preoperative central ACD every 1-mm decrease	0.950 (0.344, 2.622)	0.921
Postoperative central ACD every 1-mm decrease	0.346 (0.164, 0.730)	0.005

ACD: Anterior chamber depth; CI: Confidence interval; OR: Odds ratio.

(<2 mm) accounted for one-third of the cases. Approximately 40% of patients had a central ACD≥4 mm postoperatively. These patients' preoperative and postoperative ACDs were shallower than previous articles[1,15]. The characteristics of our included patients indicated the need to analyze the predictive factors of surgical performance.

BUII formula was chosen for IOL calculations in our study. Compared with the third-generation formulas, it can increase the proportion of patients with a postoperative diopter within ±0.5 D by 3%-15%[1,4]. With the adoption of the "thick lens" theory, the formula has considered the correlations of ACD, AXL, corneal curvature, A constant, and lens factors. Therefore, the postoperative refractive error was relatively small, as previously reported[1], and the formula has shown good prediction accuracy in patients with different AXL[1,3,17]. Our study showed that the MAE of 93.1% of patients was less than 1 D postoperatively, in accordance with other studies[9]. However, some patients still suffered high postoperative refractive errors, which deeply affected their visual quality. The risk factors remained to be explored.

In our study, the female gender was an independent risk factor for postoperative refractive errors, similar to previous studies[13,15-16]. Sex-induced postoperative calculation errors were considered related to female-specific anatomical structures. Such trends in females may be caused by shorter AXL and shallower anterior chambers compared with males[13-16], even when different IOL calculation formulas were tested[13,15-16]. Nowadays, some IOL calculation formulas, such as the Kane formula, VRF-G formula, and HILL-RBF formula, have taken gender into account and reached preferable results in limited cases[18]. Nevertheless, more attention should be paid to the potential sex-induced calculation errors in future biological measurements.

Another independent risk factor was patients' postoperative ACD in the current study. A previous study revealed that patients with a shallow postoperative ACD were prone to IOL calculation errors[19]. The refractive accuracy of IOL depends on the effective lens position (ELP)[1,11,20]. If the postoperative IOL is not at the intended position, a certain degree of postoperative refractive error will occur. In our cohort, the preoperative and postoperative central ACDs are significantly lower than those from other regions as we only involved Asians[1,20-21]. Typically, the postoperative ACDs in the MAE>1 D group were shallower than the MAE<1 D group. A forward positioning of the IOL may lead to a myopic shift postoperatively, which partially explain the significant postoperative refractive errors.

In our study, patients' AXL, corneal curvature, and preoperative ACDs were not risk factors for postoperative refractive errors. The accuracy of fourth-generation formulas has been proved in conventional corneal curvature[1,22-23], but postoperative refractive errors are prone to occur when the corneal curvature is steep (>46 D) or flat (<42 D)[1,23]. Reitblat *et al*[23] showed that test accuracy met the benchmark when the seven common formulas were used for flat cornea (corneal curvature <42 D). Nevertheless, BUII showed better results for steep corneas with a corneal curvature >46 D, while other formulas resulted in significant errors[23]. Our study showed that corneal curvature was not a risk factor, probably due to the majority of the normal cornea in the current case series. Meanwhile, following cataract surgery, the iris septum of the lens shifted backward, allowing the posterior capsule to extend into the vitreous cavity. This results in the IOL being placed in a retro position, which is affected by the preoperative ACD and AXL. Shallower preoperative ACD and shorter AXL may give rise to a more apparent IOL position change[24]. Though preoperative ACD and AXL are related to the prediction of ELP, the fourth-generation formulas have taken this into account. Therefore, it is unsurprising that AXL and preoperative ACD were not risk factors for MAE.

The most important finding in our study was the prediction value of postoperative measurements since most previous studies analyzed preoperative indicators to predict postoperative IOL position. Specifically, the anterior segment analysis system can improve the accuracy of predicted ELP after the surgery[25]. Yet, limited studies have investigated the actual postoperative IOL positions[1,26]. With the improvement in the IOL calculation formula, inaccuracies in measuring preoperative ACDs have been gradually overcome. Our study also showed that corneal curvature, preoperative ACD, and axial length were no longer risk factors for postoperative refractive errors. However, significant errors would occur if the IOL is not in the intended position postoperatively because of lens ligament position or other patient-specific factors. Therefore, we conducted an initial exploration to improve prediction accuracy while searching for the connection between the preoperative and postoperative conditions. A previous study[26] also used the refractive error of the first eye after cataract surgery to guide the IOL selection for the second eye and achieved good results, reflecting the role of postoperative indicators in error correction. This suggests that our future research should focus on improving the prediction accuracy of the real postoperative IOL position.

The limitation of our study included a single race and single institute. The limited sample size was because patients were required to undergo scheduled follow-ups and corneal topography postoperatively again. In addition, the current study involved patients with different AXL and ACDs, which have broad coverage but need further subgroup analyses.

In conclusion, our study found that the risk factors for biometry prediction errors after cataract surgery include the female gender and postoperative ACD. In contrast, corneal curvature, AXL, or preoperative ACD was not an independent risk factor. Identifying these independent risk factors would help determine corresponding constants and corrections for these risk factors and optimize the IOL calculation formula.

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REFERENCES

1 Melles RB, Holladay JT, Chang WJ. Accuracy of intraocular lens calculation formulas. *Ophthalmology* 2018;125(2):169-178.

2 Hoffer KJ, Savini G. Update on intraocular lens power calculation study protocols: the better way to design and report clinical trials. *Ophthalmology* 2021;128(11):e115-e120.

3 Chung J, Bu JJ, Afshari NA. Advancements in intraocular lens power calculation formulas. *Curr Opin Ophthalmol* 2022;33(1):35-40.

4 Kane JX, Chang DF. Intraocular lens power formulas, biometry, and intraoperative aberrometry: a review. *Ophthalmology* 2021;128(11):e94-e114.

5 Hipólito-Fernandes D, Luís ME, Serras-Pereira R, Gil P, Maduro V, Feijão J, Alves N. Anterior chamber depth, lens thickness and intraocular lens calculation formula accuracy: nine formulas comparison. *Br J Ophthalmol* 2022;106(3):349-355.

6 Ladas J, Ladas D, Lin SR, Devgan U, Siddiqui AA, Jun AS. Improvement of multiple generations of intraocular lens calculation formulae with a novel approach using artificial intelligence. *Transl Vis Sci Technol* 2021;10(3):7.

7 Debellemanière G, Dubois M, Gauvin M, Wallerstein A, Brenner LF, Rampat R, Saad A, Gatinel D. The PEARL-DGS formula: the development of an open-source machine learning-based thick IOL calculation formula. *Am J Ophthalmol* 2021;232:58-69.

8 Carmona González D, Palomino Bautista C. Accuracy of a new intraocular lens power calculation method based on artificial intelligence. *Eye (Lond)* 2021;35(2):517-522.

9 Koga Y, Kojima K, Yoshii K, Kusada N, Kagitani Y, Aoki T, Horiuchi N, Kitazawa K, Sotozono C. Prediction error of intraocular lens power calculation in very elderly patients over 90 years old. *Curr Eye Res* 2021;46(8):1148-1153.

10 Li TY, Reddy A, Stein JD, Nallasamy N. Ray tracing intraocular lens calculation performance improved by AI-powered postoperative lens position prediction. *Br J Ophthalmol* 2023;107(4):483-487.

11 Norrby S, Bergman R, Hirnschall N, Nishi Y, Findl O. Prediction of the true IOL position. *Br J Ophthalmol* 2017;101(10):1440-1446.

12 Taroni L, Hoffer KJ, Lupardi E, Barboni P, Savini G. Accuracy of new intraocular lens power calculation formulas: a lens thickness study. *J Refract Surg* 2021;37(3):202-206.

13 Zhang YB, Li TY, Reddy A, Nallasamy N. Gender differences in refraction prediction error of five formulas for cataract surgery. *BMC Ophthalmol* 2021;21(1):183.

14 Kansal V, Schlenker M, Ahmed IIK. Gender does not appear to play a role in biometry prediction error and intra-ocular lens power calculation: in response to: 'Gender differences in biometry

prediction error and intra-ocular lens power calculation formula' -behnig *et al*, 2014 (*Acta Ophthalmologica*). *Acta Ophthalmol* 2019;97(7):e1028-e1030.

15 Hoffer KJ, Savini G. Effect of gender and race on ocular biometry. *Int Ophthalmol Clin* 2017;57(3):137-142.

16 Behndig A, Montan P, Lundström M, Zetterström C, Kugelberg M. Gender differences in biometry prediction error and intra-ocular lens power calculation formula. *Acta Ophthalmol* 2014;92(8):759-763.

17 Pereira A, Popovic MM, Ahmed Y, Lloyd JC, El-Defrawy S, Gorfinkel J, Schlenker MB. A comparative analysis of 12 intraocular lens power formulas. *Int Ophthalmol* 2021;41(12):4137-4150.

18 Kothari SS, Reddy JC. Recent developments in the intraocular lens formulae: an update. *Semin Ophthalmol* 2023;38(2):143-150.

19 Muthappan V, Paskowitz D, Kazimierczak A, Jun AS, Ladas J, Kuo IC. Measurement and use of postoperative anterior chamber depth of fellow eye in refractive outcomes. *J Cataract Refract Surg* 2015;41(4):778-784.

20 Shajari M, Sonntag R, Niermann T, Holland D, Kohnen T, Priglinger S, Mayer WJ. Determining and comparing the effective lens position and refractive outcome of a novel rhexis-fixated lens to established lens designs. *Am J Ophthalmol* 2020;213:62-68.

21 Hamoudi H, Correll Christensen U, la Cour M. Agreement of phakic and pseudophakic anterior chamber depth measurements in IOLMaster and Pentacam. *Acta Ophthalmol* 2018;96(3):e403.

22 Kim JW, Eom Y, Yoon EG, Choi Y, Song JS, Jeong JW, Park SK, Kim HM. Algorithmic intraocular lens power calculation formula selection by keratometry, anterior chamber depth and axial length. *Acta Ophthalmol* 2022;100(3):e701-e709.

23 Reitblat O, Levy A, Kleinmann G, Lerman TT, Assia EI. Intraocular lens power calculation for eyes with high and low average keratometry readings: comparison between various formulas. *J Cataract Refract Surg* 2017;43(9):1149-1156.

24 Hu J, Zhang WP, Cao DM, Lei Q. Research progress on prediction of postoperative intraocular lens position. *Indian J Ophthalmol* 2024;72(Suppl 2):S176-S182.

25 Zhang JJ, Li JQ, Li C, Cao YH, Lu PR. Influence of lens position as detected by an anterior segment analysis system on postoperative refraction in cataract surgery. *Int J Ophthalmol* 2021;14(7): 1006-1012.

26 Turnbull AMJ, Barrett GD. Using the first-eye prediction error in cataract surgery to refine the refractive outcome of the second eye. *J Cataract Refract Surg* 2019;45(9):1239-1245.