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ORIGINAL RESEARCH

Refractive Accuracy of Intraocular Lens Power Calculation Formulas in Nonagenarians: A Retrospective Study

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Purpose: To compare the refractive predictive accuracy of three intraocular lens (IOL) power calculation formulas (SRK/T, Barrett Universal II, and Haigis) in patients aged 90 years and older.

Methods: This retrospective observational study included 62 eyes of 62 patients aged ≥90 years who underwent cataract surgery between April 2021 and March 2023. All procedures were performed by a single surgeon using a single IOL model (HOYA XY1). Preoperative biometry was performed using the IOL Master 700. The accuracy of each formula was evaluated by comparing the predicted spherical equivalent to the manifest refraction at 3 months postoperatively. The primary outcome was the mean absolute error (MAE) and root mean square absolute error (RMSAE), with secondary outcomes including the percentage of eyes within ±0.5 D and ±1.0 D of the predicted refraction.

Results: The mean age of the patients was 92.2 ± 2.0 years. The MAE was 0.504 ± 0.363 D for SRK/T, 0.441 ± 0.339 D for Barrett Universal II, and 0.503 ± 0.388 D for Haigis. The RMSAE was 0.607 ± 0.552 D for SRK/T, 0.532 ± 0.463 D for Barrett Universal II, and 0.565 ± 0.496 D for Haigis. No statistically significant difference in MAE and RMSAE was found among the three formulas (p = 0.12, p = 0.54). The proportion of eyes within ±0.5 D of the predicted refraction was highest for the Barrett Universal II formula at 64.5%. Multivariate logistic regression analysis found no biometric parameters to be significant predictors of achieving a refractive error within ±0.5 D.

Conclusion: In patients aged ≥90 years, the SRK/T, Barrett Universal II, and Haigis formulas demonstrated comparable refractive accuracy. In this demographic, overall refractive outcomes may be more influenced by the reliability of biometric measurements and the minimization of intraoperative risks than by the choice of formula.

Keywords: cataract surgery, nonagenarians, intraocular lens power calculation, refractive accuracy

Introduction

Japan, like many developed nations, has become a super-aged society, and the population aged ≥90 years is projected to increase further in the coming decades.[1] Cataract remains the leading cause of reversible visual impairment in this demographic, and achieving precise refractive outcomes after surgery is essential for maintaining independence and quality of life (QOL).[2–4] Modern intraocular lens (IOL) power calculation formulas, such as the Barrett Universal II and Haigis, have demonstrated improved accuracy compared to older-generation formulas like SRK/T.[5–12] However, most validation studies have focused on younger or general elderly populations, with few specifically including patients over 90 years old.[7,9,12,13] This age group presents unique biometric and surgical challenges—such as zonular weakness, dense nuclear sclerosis, fixation instability, and a higher prevalence of ocular comorbidities—that may compromise both the reliability of preoperative biometry and the prediction of the effective lens position (ELP).[2,14,15] To our knowledge, few studies have specifically examined refractive accuracy in nonagenarians.[2,4,14,15] Therefore, this study aimed to compare

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the predictive performance of the SRK/T, Barrett Universal II, and Haigis formulas in patients aged ≥90 years and to assess the influence of intraoperative and postoperative complications on refractive outcomes.

Methods

This retrospective observational study included 62 eyes of 62 patients aged ≥90 years who underwent cataract surgery at Jikei University Daisan Hospital (Tokyo, Japan) between April 2021 and March 2023. This study was approved by the ethics committee of Jikei University School of Medicine (approval number: 35-348-11980) and adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all participants.

Inclusion criteria were: age ≥90 years, uncomplicated phacoemulsification, and in-the-bag implantation of a monofocal acrylic IOL (HOYA XY1). Exclusion criteria included: lens dislocation, severe corneal opacity or irregularity, poor capsular fixation, capsular tension ring insertion, or insufficient postoperative follow-up. Eyes with postoperative corneal or macular edema that precluded reliable refraction measurement were excluded from analysis.

All patients underwent measurement of best-corrected visual acuity (BCVA, logMAR), slit-lamp examination, and dilated funduscopy. Biometry was performed using optical coherence biometry (IOL Master 700, Carl Zeiss Meditec), including axial length (AL), anterior chamber depth (ACD), lens thickness (LT), and mean keratometry (mean K). Pre-existing ocular comorbidities, such as glaucoma, diabetic retinopathy, and age-related macular degeneration, were recorded.

All procedures were performed by a single experienced surgeon (Y.K.) under topical anesthesia. A 2.4-mm corneoscleral incision and phacoemulsification were performed, and a HOYA XY1 monofocal acrylic IOL was implanted in the capsular bag. The A-constant recommended by the manufacturer for the HOYA XY1 IOL was applied without additional optimization. When both eyes were eligible, only the right eye was included in the analysis.

At 3 months postoperatively, manifest refraction was obtained, and the spherical equivalent (SE) was calculated. The predicted SE for each formula (SRK/T, Barrett Universal II, Haigis) was derived from the IOL Master 700. The SRK/T, Barrett Universal II, and Haigis formulas, which are the default settings in the IOL Master 700 in Japan, were used for refractive prediction.

The absolute refractive error (ARE) was calculated as the absolute difference between the predicted and postoperative SE: |predicted SE – postoperative SE|.

The primary outcome was the mean absolute error (MAE) and root mean square absolute error (RMSAE). Secondary outcomes included the median absolute error (MedAE), the percentage of eyes within ±0.5 D and ±1.0 D of the predicted refraction, and the incidence of intraoperative and postoperative complications. Predictors of a successful outcome (ARE ≤ 0.5 D) were evaluated using multivariate logistic regression.

MAEs and RMSAEs were compared among formulas using the Friedman test, followed by Wilcoxon signed-rank tests with Bonferroni correction for post hoc analysis. The percentages of eyes within specific refractive targets were compared using McNemar's test. The logistic regression model included AL, ACD, LT, mean K, and corneal diameter as independent variables. P-value <0.05 was considered statistically significant. Statistical analysis was performed using JMP®16 (SAS Institute Inc., Cary, NC).

Results

A total of 62 eyes from 62 patients were included in the analysis. The mean age was 92.2 ± 2.0 years, and 74.2% (46/62) were female. The mean preoperative BCVA was 0.69 ± 0.49 logMAR, which improved to 0.27 ± 0.42 logMAR postoperatively (Table 1).

Pre-existing ocular comorbidities were present in 38.7% of eyes, most commonly glaucoma (22.6%), followed by age-related macular degeneration (8.1%), diabetic retinopathy (4.8%), corneal opacity (1.6%), and retinal vein occlusion (1.6%). Intraoperative complications included poor pupil dilation (12.9%) and iridodialysis (9.7%). Postoperative complications were relatively uncommon, consisting of corneal edema in 6.5% and cystoid macular edema in 1.6% of eyes (Table 2).

The refractive prediction errors of the three formulas are summarized in Table 3. The MAE was 0.504 ± 0.363 D for SRK/T, 0.441 ± 0.339 D for Barrett Universal II, and 0.503 ± 0.388 D for Haigis. The RMSAE was 0.607 ± 0.552 D for SRK/T, 0.532 ± 0.463 D for Barrett Universal II, and 0.565 ± 0.496 D for Haigis. The MedAE was 0.415 D, 0.375 D, and

Table 1 Patient Demographics and Ocular Characteristics

Variable	Mean ± SD or n (%)	Range
Demographics		
Age (years)	92.2 ± 2.0	90–98
Female	46 (74%)	
Male	16 (26%)	
Visual acuity		
Preoperative BCVA (logMAR)	0.69 ± 0.49	0.1–2.0
Postoperative BCVA (logMAR)	0.27 ± 0.42	0–0.82
Ocular biometry		
Axial length (mm)	23.31 ± 1.10	21.28–25.75
Anterior chamber depth (mm)	2.90 ± 0.40	2.41–3.92
Lens thickness (mm)	4.87 ± 0.32	4.24–5.58
Corneal diameter (mm)	11.6 ± 0.42	10.6–13.5
Mean keratometry (mm)	7.56 ± 0.24	7.19–8.18
K1 (mm)	7.66 ± 0.26	7.11–8.45
K2 (mm)	7.46 ± 0.23	7.16–8.02
Implanted IOL power (D)	20.45 ± 3.50	8.0–26.0

Abbreviations: BCVA, best corrected visual acuity; K, keratometry; IOL, intraocular lens.

Table 2 Comorbidities, Intraoperative Findings, and Postoperative Complications

Variable	n
Comorbidities	
Glaucoma	14
Diabetic retinopathy	3
Macular degeneration	5
Corneal opacity	1
Retinal vein occlusion	1
Intraoperative findings	
Poor pupil dilation	8
Iridodialysis	6
Postoperative complications	
Corneal edema	4
Macular edema	1

Table 3 Predictive Accuracy of Intraocular Lens Power Calculation Formulas

Formula	Mean Absolute Error ± SD (D)	Root Mean Square Absolute Error ± SD (D)	Median Absolute Error (D)	± 0.5 D (%)	± 1.0 D (%)
SRK/T	0.504 ± 0.363	0.607 ± 0.552	0.415	54.8	91.9
Barrett	0.441 ± 0.339	0.532 ± 0.463	0.375	64.5	93.5
Haigis	0.503 ± 0.388	0.565 ± 0.496	0.438	51.6	85.5

0.438 D, respectively. The proportion of eyes within ±0.5 D of predicted refraction was 54.8% for SRK/T, 64.5% for Barrett Universal II, and 51.6% for Haigis, while the proportion within ±1.0 D was 91.9%, 93.5%, and 85.5%, respectively. The Friedman test revealed no statistically significant difference in MAE ($\chi^2 = 4.25$, $p = 0.12$) and RMSAE ($\chi^2 = 1.25$, $p = 0.54$) among the three formulas.

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Table 4 Logistic Regression Analysis for Predictors of Refractive Accuracy (Success Defined as Prediction Error Within ±0.5 D)

Predictor	SRK/T OR (95% CI)	p	Barrett OR (95% CI)	p	Haigis OR (95% CI)	p
Axial length (mm)	1.30 (0.52–3.57)	0.58	1.52 (0.54–4.91)	0.45	1.96 (0.80–5.53)	0.17
Anterior chamber depth (mm)	0.84 (0.04–16.58)	0.91	1.78 (0.09–41.40)	0.71	0.25 (0.01–4.01)	0.33
Lens thickness (mm)	4.85 (0.49–61.31)	0.19	5.58 (0.53–78.24)	0.17	0.42 (0.04–3.94)	0.45
Corneal diameter (mm)	1.79 (0.42–10.42)	0.47	1.49 (0.33–8.79)	0.63	1.02 (0.25–4.49)	0.98
Mean keratometry (mm)	3.14 (0.17–58.04)	0.43	0.64 (0.02–14.21)	0.78	0.89 (0.05–14.23)	0.93

Multivariate logistic regression analysis was performed to evaluate the effect of biometric parameters (axial length, anterior chamber depth, lens thickness, corneal diameter, and mean keratometry) on refractive accuracy (Table 4). No parameter was found to be a significant predictor of achieving an absolute refractive error ≤0.5 D for any of the three formulas (all $p > 0.05$).

Discussion

This study is one of the few investigations to evaluate the refractive accuracy of three IOL power calculation formulas in patients aged ≥90 years. We found no statistically significant differences in MAE among the SRK/T, Barrett Universal II, and Haigis formulas. This finding contrasts with previous reports demonstrating the superiority of the Barrett Universal II over older-generation formulas in general elderly populations.[10,12,16] Although the differences among formulas did not reach statistical significance, the Barrett Universal II consistently showed the lowest mean and median absolute errors in our cohort. This trend, while not statistically significant, may still be clinically meaningful, as it reflects the enhanced modeling of effective lens position incorporated in the Barrett Universal II formula. Considering the small sample size and the inherently higher measurement variability in nonagenarians, the observed numerical trend in favor of Barrett Universal II should be regarded as clinically relevant.

Several factors may account for this discrepancy. First, zonular laxity, common in this age group due to cumulative oxidative and mechanical stress, can lead to postoperative IOL tilt or decentration. This may reduce the accuracy of ELP prediction, even with advanced formulas.[17] Second, obtaining reliable preoperative biometry in nonagenarians is often challenging due to fixation difficulties, ocular surface irregularities, and dense nuclear sclerosis. This can introduce variability that masks performance differences among the formulas.[18] Third, the presence of eyes with extreme axial lengths, which is not uncommon in this population, may have disproportionately influenced mean errors.

Furthermore, nearly 40% of our cohort had ocular comorbidities that could have confounded refractive outcomes. For instance, glaucomatous changes or macular degeneration can impair fixation, thereby compromising the accuracy of both preoperative measurements and postoperative subjective refraction.

Clinically, the finding that over 90% of eyes in some groups achieved outcomes within ±1.0 D suggests that acceptable refractive accuracy is attainable in this population, regardless of the formula chosen. For nonagenarians, minimizing surgical risks and ensuring stable IOL fixation may be more critical to postoperative QOL than the selection of a specific formula. Future advances, such as AI-driven formulas (eg, Kane, Hill-RBF), may offer improved performance, but their success will also depend on enhancing the precision and reproducibility of biometry in this challenging patient group.[12] Incorporating patient-reported outcome measures (PROMs) will also be valuable for better capturing the functional and QOL benefits of cataract surgery in nonagenarians.

Strengths and Limitations

A key strength of this study is its use of a single surgeon and a single IOL model, which minimized confounding factors related to surgical technique and IOL constants. However, several limitations should be acknowledged. First, this was a retrospective, single-center study with a limited sample size, which may restrict the generalizability of our findings. Second, the retrospective design prevented a quantitative assessment of how intraoperative and postoperative complications contributed to refractive error. Third, the limited sample size precluded a robust subgroup analysis based on axial length (eg, short, normal, and long eyes). It is well established that eyes with extreme axial lengths are prone to greater prediction errors,[6,19–22] making this an important area for future investigation in this population.

Considering these limitations, larger, prospective, multicenter studies are warranted. Such studies should incorporate stratification by ocular comorbidity and axial length, as well as PROMs, to provide a more comprehensive evaluation.

Conclusion

In patients aged ≥90 years, the SRK/T, Barrett Universal II, and Haigis formulas demonstrated comparable overall refractive accuracy. However, the consistently lower mean and median absolute errors observed with the Barrett Universal II suggest a clinically meaningful advantage in predicting postoperative refraction, even though statistical significance was not reached. In this age group, refractive outcomes are likely to be influenced more by the reliability of biometric measurements, the presence of ocular comorbidities, and the minimization of intraoperative risks than by formula selection alone. Larger, prospective multicenter studies are warranted to further validate these findings and to refine refractive prediction in this super-aged population.

Disclosure

The authors declare no conflicts of interest in this work.

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