

Consistency evaluation of intraocular lens power calculation methods in eyes that have undergone small-incision lenticule extraction

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Research article

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Abstract

Background

To compare the differences in the consistency of intraocular lens (IOL) power calculations with four different formulas for cataract surgery after small-incision lenticule extraction (SMILE), and to select the most suitable formula to calculate the IOL power of cataract patients after SMILE.

Methods

98 eyes of 51 patients who underwent small-incision lenticule extraction (preoperative spherical equivalents, -2.05 to -10.10D) between June 2019 to July 2019 in our department were included, all surgeries were performed by the same surgeon. IOLMaster 500 was used for biometric measurement and Haigis-L correction formula was calculated. AL-Scan was used to calculate Shammas-PL correction formula, Camellin-Calossi formula and Barret True K formula. We simulated the intraocular lens calculation before cataract surgery in all eyes with these four formulas. The consistency of the calculated IOL powers were evaluated by correlation analysis, one-way ANOVA, and Bland-Altman analysis.

Results

The average values of Barret True K formula, Shammas-PL correction formula, Camellin-Calossi formula and Haigis-L correction formula are 22.32 ± 1.14 D, 23.28 ± 1.21 D, 22.91 ± 1.26 D, 23.54 ± 1.23 D respectively. Simple correlation analysis: The average values of these four formulas were correlated, and the correlation coefficients were 0.94(Barrett True K and Shammas-PL), 0.98 (Barrett True K and Camellin-Calossi), 0.89(Barrett True K and Haigis-L), 0.98(Haigis-L and Shammas-PL), 0.88(Haigis-L and Camellin-Calossi) and 0.93(Shammas-PL and Camellin-Calossi)(significant, $p=0.00$); One-way ANOVA: There was no significant difference between the Shammas-PL correction formula and the Haigis-L correction formula. The Camellin-Calossi formula and the Barret True K formula were significantly different from the Haigis-L correction formula. Bland-Altman analysis: for the difference-mean scatter plot and the ratio-mean scatter plot: the maximum allowable error of the 95% limit is 9.61%, 7.45%, and 2.99%, respectively, indicating that the results are consistent.

Conclusions

Haigis-L and Shammas-PL formulas had good consistency when calculating the IOL power in eyes after SMILE.

Background

By 2050, the number of people (45–89 years of age) affected by cataract in China will reach 240.83 million [1]. As cataract surgery is also a refractive procedure now, patient expectations continue to rise, achieving a precise postoperative target refraction is an important goal in cataract surgery. Precise postoperative target refraction depends on the accurate calculation of IOL power. So, the accurate

calculation of IOL power for these patients would be very important soon. Small incision lenticule extraction (SMILE) surgery was firstly reported by Sekundo [2] and Shah[3] in 2011, it is popular for excellent visual outcomes, superior biomechanics, faster recovery of dry eye and corneal nerve reinnervation [4]. Over 2 million patients have undergone SMILE, including 1 million Chinese patients. An unfortunate consequence of corneal refractive surgery is difficulty in accurately calculating intraocular lens (IOL) power in eyes undergoing cataract surgery[5]. During the last few decades, IOL power calculation after keratorefractive surgery has been the subject of numerous studies and publications[6].

As far as we know, there is still no study on how to calculate the IOL power in patients receiving SMILE. In SMILE, an intrastromal lenticule is cut with a femtosecond laser, and subsequently removed through a minor incision. The variant lenticule extraction design makes SMILE differ from all the other corneal refractive surgeries in corneal biomechanical properties [7], which may have influences on corneal refractive power estimation and creates difficulties in accurately calculating IOL power. Haigis-L[8], Shammas-PL[9], Camellin-Calossi[9] and Barret True K[11] formula are commonly used formulas for IOL power calculation for cornea refractive surgery eyes[9, 12]. The aim of our study was to evaluate the consistency of IOL power calculations in these four different formulas for cataract surgery in eyes after SMILE, and provide a basis for the calculation of the IOL power of cataract patients after SMILE.

Methods

This prospective study included patients who had undergone SMILE (preoperative spherical equivalents, -2.05 to -10.10D) between June 2019 to July 2019 in our department. Exclusion criteria included vitreoretinal or corneal disease, uveitis, trauma, or systemic diseases affecting vision, and history of other ocular surgery. All surgeries were performed by the same surgeon. All procedures adhered to the tenets of the Declaration of Helsinki of the World Medical Association. Ethical approval was provided by the Ethics Committee of Ethics Committee of the First Affiliated Hospital of Army Medical University.

Measurements of preoperative and postoperative keratometry (K), anterior chamber depth (ACD), and horizontal white-to-white (WTW) distance were performed using partial coherence interferometry (PCI) (IOLMaster 500, Carl Zeiss Meditec, Germany). Axial length (AL) measurements were taken with both IOLMaster and AL-Scan (Nidek Co, Ltd., Gamagori, Japan). Additionally, corneal curvatures were measured using the Sirius topography device (Costruzione Strumenti Oftalmici, Florence, Italy).

Haigis-L algorithm within the partial coherence interferometer's software and Shammas-PL, Camellin-Calossi (medical history needed) and Barret True K (medical history needed) within the software of AL-Scan were evaluated. The devices' optimized lens constants were obtained from the User Group for Laser Interference Biometry (ULIB).

Statistical analysis

Correlation analysis, one-way ANOVA, and Bland-Altman analysis were used to assess the consistency of the prediction performance by different methods. Statistical analysis was performed using SPSS for

Windows software (version 22.0, SPSS, Inc.). A p value less than 0.05 was considered statistically significant.

Results

The study comprised 98 eyes of 51 patients. Table 1 shows the mean values and standard deviation of arithmetic IOL prediction power calculated by the four formulas.

Table 1
Arithmetic IOL prediction power calculated for different formulas

Formula	N	Mean	Standard Deviation
Barrett Ture K	98	22.32	1.14
Shammas-PL	98	23.28	1.21
Camellin-Calossi	98	22.91	1.26
Haigis-L	98	23.54	1.23

Correlation analysis

The correlation coefficients (R) between the calculated lens powers were 0.94 (Barrett Ture K and Shammas-PL), 0.98 (Barrett Ture K and Camellin-Calossi), 0.89 (Barrett Ture K and Haigis-L), 0.98 (Haigis-L and Shammas-PfL), 0.88 (Haigis-L and Camellin-Calossi) and 0.93 (Shammas-PL and Camellin-Calossi) (significant, $p = 0.00$) (Table 2). Although the four calculation methods match well with one another, the correlation coefficients were highest for the Haigis-L between Shammas-PL and Barrett Ture K with Camellin-Calossi method.

Table 2
Correlation analysis of IOL prediction power calculation.

	R	p
Barrett Ture K and Shammas-PL	0.94	0.00
Barrett Ture K and Camellin-Calossi	0.98	0.00
Barrett Ture K and Haigis-L	0.89	0.00
Haigis-L and Shammas-PL	0.98	0.00
Haigis-L and Camellin-Calossi	0.88	0.00
Shammas-PL and Camellin-Calossi	0.93	0.00

Analysis of Variance

According to the ANOVA analysis, there were no statistically significant difference between Shammas-PL and Haigis-L ($p = 0.135$). But there were statistically significant difference between the calculated lens powers by other formulas (Barrett Ture K & Shammas-PL, $p < 0.01$; Barrett Ture K & Camellin-Calossi, $p < 0.01$; Barrett Ture K & Haigis-L, $p < 0.01$; Shammas-PL & Camellin-Calossi, $p = 0.03$; Camellin-Calossi & Haigis-L, $p < 0.01$).

Bland–Altman analysis was used to assess the extent of agreement of the formulas. Figure 1 shows the Bland–Altman plot demonstrating differences in average IOL power calculations between the formulas. Maximum allowed difference of 95% limits of agreement: Barrett Ture K & Haigis-L is 9.61%, Camellin-Calossi & Haigis-L is 7.45%, and Shammas-PL & Haigis-L is 2.99%, indicating high correlations, and Shammas-PL is the best consistency with Haigis-L.

Discussion

In our study, we evaluated the four most accurate methods of estimating the refractive power of IOL after corneal refractive surgeries, and compared the consistency of the calculations. There was no significant difference between the Shammas-PL correction formula and the Haigis-L correction formula. We also evaluated the correlations of the formulas, and it showed that the all the calculations matched well, but Shammas-PL is the best consistency with Haigis-L.

Postoperative spherical equivalent prediction errors or manifest refraction after cataract surgery are always used for the study on IOL predictability of formulas[13, 14]. Since SMILE surgery was introduced in 2011, few patients have met the age-related cataract problem. So, we couldn't assess the accuracy of the formulas or adjust the calculation by compare the postoperative result. The best way for evaluation would be the consistency of different calculations.

The methods to correct or minimize prediction errors in the IOL power calculations for cataract surgery after corneal refractive surgery can be classified roughly as methods not requiring historical data, e.g., the Shammas-PL formula[12], the Haigis-L formula[15, 16], with the advantage of being independent of potentially inaccurate historical data. And methods requiring historical clinical data[17], e.g. the Camellin–Calossi formula[18] and the Barrett Ture K formula[19], which is infeasible if previous clinical patient's data are not available. The consistency of Haigis-L and Shammas-PL in the four formulas is higher, indicating that the calculation of IOL can obtain relatively accurate values even without previous case data, which is more convenient for clinical calculation. And the high correlation of all the formulas demonstrated Camellin-Calossi formula and the Barret True K formula are available as a reference.

Haigis-L and Shammas-PL have been widely used and shown promising results which are based on a correction of the corneal power by adjusting the keratometric index[9, 12]. The use of the adjusted keratometric index is a valid and easy method to estimate the central corneal power in corneas with previous keratorefractive surgery. The keratorefractive surgeries always require cutting of corneal

lamellae that may reduce the biomechanical stability of the cornea. However, SMILE preserves the anterior corneal integrity and may, in theory, better preserve the corneal biomechanical strength than laser-assisted in situ keratomileusis(LASIK) and Photorefractive Keratectomy(PRK) after surgery[20]. Whether this would result in the difference in corneal power changes has not been investigated yet. Our results showed that Haigis-L and Shammas-PL could be better choices for IOL power calculations, which also helped to prove the minor differences of the corneal power changes between SMILE and LASIK/PRK. The results demonstrated the estimation of corneal power can be performed with the only requirement of measuring the postoperative corneal radius without influences of the different surgery methods.

Conclusions

Our results show that for eyes with previous SMILE correction, the Haigis-L and Shammas-PL have higher consistency than Camellin-Calossi formula and Barret True K formula. Our research provides a basis for the calculation of the IOL power of cataract patients after SMILE. Further studies are needed to evaluate Spherical equivalent prediction errors or manifest refraction after cataract surgery.

Abbreviations

IOL: intraocular lens; SMILE: small-incision lenticule extraction; K: keratometry; ACD: anterior chamber depth; WTW: white-to-white; PCI: partial coherence interferometry; AL: Axial length; ULIB: User Group for Laser Interference Biometry; LASIK: laser-assisted in situ keratomileusis; PRK: Photorefractive Keratectomy.

Declarations

Ethics approval and consent to participate

Ethical approval was provided by the Ethics Committee of the First Affiliated Hospital of Army Medical University (Approval Number: KY201975). Written consent for procedures described was obtained from all participants.

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Conceptualization and design, JL, SH; Methodology, BC; Data collection, JX, YHZ, SH; Formal analysis, JL, BC; Writing—original draft preparation, SH; writing—review and editing, JL, SH; We confirm that the manuscript has been read and approved by all named authors and that the order of authors listed in the manuscript has been approved by all of us.

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Figures

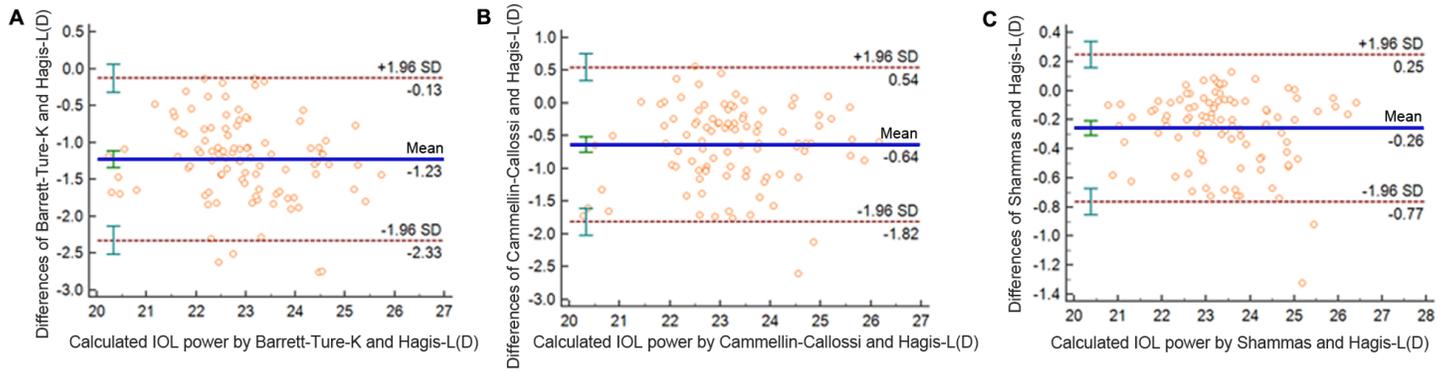


Figure 1

Bland–Altman plots showing differences in IOL power calculations. Differences between Barrett Ture K and Haigis-L(A), Camellin-Callossi and Haigis-L(B), Shammias-PL & Haigis-L(C). The bold horizontal line shows the mean differences between devices. The dotted lines above and below that line represent the 95% limits of agreement.