Original Article

Optimizing lens constants specifically for short eyes: Is it essential?

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Purpose: Optimization of lens constants is a critically important step that improves refractive outcomes significantly. Whether lens constants optimized for the entire range of axial length would perform equally well in short eyes is still a matter of debate. The aim of this study was to analyze whether lens constants need to be optimized specifically for short eyes. **Methods**: This retrospective observational study was conducted at a tertiary care hospital in Central India. Eighty-six eyes of eighty-six patients were included. Optical biometry with IOLMaster 500 was done in all cases and lens constants were optimized using built-in software. Barrett Universal II, Haigis, Hill-RBF, Hoffer Q, Holladay 1, and SRK/T formulae were compared using optimized constants. Mean absolute error, median absolute error (MedAE), and percentage of eyes within ±0.25, ±0.50, ±1.00, and ±2.00 diopter of the predicted refraction, of each formula were analyzed using manufacturer's, ULIB, and optimized lens constants. MedAE was compared across various constants used by Wilcoxon signed-rank test and among optimized constants by Friedman's test. Cochran's Q test compared the percentage of eyes within ± 0.25, ±0.50, ±1.00, and ± 2.00 diopter of the predicted refraction. A value of $P < 0.05$ was considered statistically significant. **Results**: Optimized constant of Haigis had significantly lower MedAE ($P < 0.00001$) as compared to manufacturers. However, there was no statistically significant difference between ULIB and optimized constants. Postoptimization, there was no statistically significant difference among all formulae. **Conclusion**: Optimizing lens constants specifically for short eyes gives no added advantage over those optimized for the entire range of axial length.

Key words: Formulae, intraocular lens power, lens constant optimization, phacoemulsification, short eyes

Accurate postoperative outcome is the dream of every cataract surgeon. Several ways have been developed to improve surgical precision such as an improvement in biometry technology from ultrasound to optical and swept-source based, continual advances in surgical techniques, optimization of lens constants, and advent of newer generation lens power calculation formulae. The results are quite satisfying in normal eyes. However, in challenging scenarios viz short eyes, long eyes, postrefractive surgery, the accuracy varies.[1] Optimization of lens constants is a critically important step that improves refractive outcome significantly.[2-4] The protocols for studies of intraocular lens (IOL) formulae accuracy by Hoffer *et al.* clearly recommend optimization of lens constants for the best of results, though, there was no mention about atypical eyes (e.g. short, or long eyes).[5] Guest editorial on series, "Pursuing perfection in IOL calculations: III" by Wang *et al.* has discussed the importance of optimization in atypical eyes too.[6]

Zhang *et al.* have studied the effect of optimizing lens constants in highly myopic eyes, whereas Sudhakar *et al.* have studied the same in short eyes.[7,8] Whether lens constants optimized for entire range of axial length (AL) would perform equally well in atypical eyes, is still a matter of debate. Considering these facts this study was undertaken to study the effect of optimizing lens constants in short eyes and whether User Group for Laser Interference Biometry (ULIB) constants work in short eyes as well. The effect of various lens constants on performance of IOL power calculation formulae (Barrett Universal II,[9] Haigis,[10] Hill-RBF (version 2.0),[11] Hoffer Q,[12] Holladay 1[13] and SRK/T[14]) was seen by comparing MAE, MedAE and percentage of eyes with refractive prediction error (RPE) within ± 0.25, ±0.50, ±1.00 and ± 2.00 diopter (D) of predicted refraction (PR).

Methods

This retrospective, observational study was conducted at a tertiary care hospital in Central India. It was approved by the Institutional Ethics Committee and it followed the tenets of the Declaration of Helsinki. A total of 86 eyes of 86 patients with AL less than 22 mm, who underwent uneventful clear corneal phacoemulsification surgery with in-the-bag IOL implantation, between October 1, 2018 and September 30, 2019, were included in the study. The first operated eye was included in patients where both eyes were eligible.

The exclusion criteria of the study were as follows: corneal pathology (corneal scar, keratoconus), previous ocular surgery (ptosis, pterygium, squint), ocular comorbidity (ocular injury, uveitis), intraoperative complications (posterior capsular rent, vitreous loss, nucleus drop, zonular dehiscence), preoperative corneal astigmatism more than 2.5

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diopters (D), and postoperative corrected distance visual acuity worse than 20/40. Patients with keratometry (K) values not within the range of 37 to 52 D which were found to be out of bounds in Hill-RBF formula, dense cataracts or poor fixation requiring ultrasound (US) biometry and IOL implantation other than the capsular bag (sulcus-placed IOL, open-loop anterior chamber IOL, scleral-sutured posterior chamber IOL or iris-sutured posterior chamber IOL) were also excluded from the study.

Retrospectively preoperative, intraoperative, postoperative and refractive details of all subjects were collected. The variables recorded were demographic characteristics like age, sex and biometric data like laterality, AL, preoperative anterior chamber depth (ACD), average K and IOL power. For all cases, optical biometry with partial coherence interferometry (PCI) was

performed. AL, ACD, average K and white-to-white (WTW) corneal diameter were calculated using IOLMaster 500 (Version 5.4, Carl Zeiss Meditec AG, Jena, Germany). Lens thickness (LT) was measured with immersion A-scan ultrasonography (Compact touch, Quantel medical, France).

IOL power calculated with Hoffer Q formula was chosen for implantation, as recommended for short eyes.[15,16] The target refraction for each eye was typically emmetropia. The PR was then back calculated using manufacturer's lens constants and IOL power implanted, for Haigis, Hoffer Q, Holladay 1 and SRK/T formulae. Aspheric acrylic foldable IOL (Acrysof SN6CWS, Alcon Laboratories, Inc.) was implanted in all the cases. The manufacturer's A-constant for this IOL was 118.7, Hoffer Q personalized ACD (pACD) 5.64, Holladay 1 surgeon factor (SF) 1.84 and SRK/T A-constant 119.00. Haigis
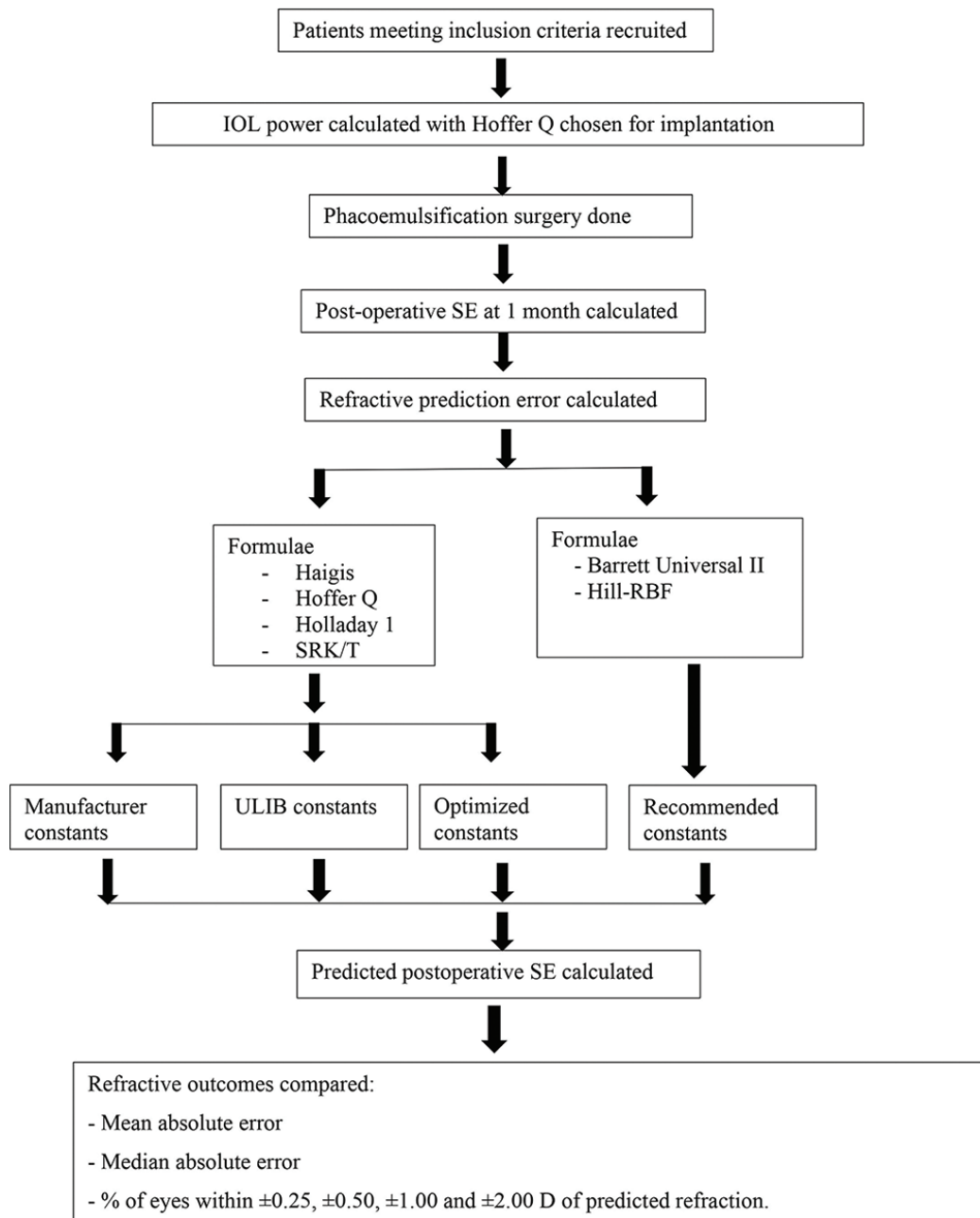

Figure 1: Flow chart of the study

formula instead uses three lens constants (a0, a1 and a2) for the accurate prediction of effective lens position and its manufacturer's values are –0.769, 0.234, and 0.217, respectively. Final postoperative refraction was done by a pre-designated refractionist using automated refractometer (Accuref K-900/R-800, Rexxam, Japan) 1-month postoperatively and was converted into its spherical equivalent (SE).

RPE was defined as the difference between actual postoperative SE at 1-month follow-up and the predicted postoperative SE (actual refraction – PR). MAE was calculated as the average of absolute RPE. Optimization of lens constants was done using built in software of IOLMaster. This resulted in optimized constant value of Haigis a0 as 1.350, Hoffer Q pACD as 4.99, Holladay 1 SF as 1.77 and SRK/T A-constant as 118.966. The recommended constants of 118.99 and 119.02 were used for Barrett Universal II and Hill-RBF formulae, respectively. The PR was then back calculated for all the formulae. ULIB constants downloaded from the website provided us with lens constants of Haigis a0 1.350, a1 0.400, a2 0.100, Hoffer Q pACD 5.53, Holladay 1 SF 1.76 and SRK/T A-constant 118.9.[17] For four formulae (Haigis, Hoffer Q, Holladay 1 and SRK/T) comparison was done using manufacturer's, ULIB and optimized constants, whereas for six formulae (Barrett Universal II, Haigis, Hill-RBF, Hoffer Q, Holladay 1 and SRK/T) comparison was done using optimized constants only as no method for online optimization of Barrett Universal II and Hill-RBF exists.

Statistical analysis

Statistical analysis was performed using SPSS software (version 26.0, IBM Corporation, USA). Before analysis, the normality of data was checked using Kolmogorov–Smirnov test. Descriptive variables were described as mean, median, standard deviation and range of values. Outcome measures like RPE and absolute RPE were described as mean ± SD with 95% confidence interval (CI). Wilcoxon signed-rank

test was used to compare MedAE across various constants used. A comparison of refractive outcomes obtained using manufacturer's, ULIB and optimized constants was done. Non-parametric Friedman's test was used to compare MedAE among optimized lens constants. Cochran's Q test was used for comparing the percentage of eyes within ±0.25, ±0.50, ±1.00 and ±2.00 D of PR. *Post hoc* analysis was performed in case of significant results. Bonferroni correction was applied for multiple comparisons. A value of $P < 0.05$ was considered statistically significant.

Results

Fig. 1 shows the plan of work of the study. A total of 86 eyes of 86 patients of Asian origin with AL less than 22 mm were recruited for the study. Of these, 72 (83.7%) were females and 14 (16.3%) were males. The mean age of the enrolled patients was 59.57 ± 10.27 years. Table 1 shows preoperative demographic characteristics of the study population.

Table 2 shows comparison between MAE and MedAE obtained by using manufacturer's, ULIB and optimized lens constants for various formulae. Optimized lens constants in our study were lower than manufacturer's constants for Hoffer Q, Holladay 1 and SRK/T formulae and had higher a0 value for Haigis. The constants were almost of the same value as reported on the ULIB website except for Hoffer Q which was lower. Figs. 2 and 3 shows reduction in absolute error of Haigis using ULIB and optimized lens constants, whereas that of Hoffer Q, Holladay 1 and SRK/T does not show significant change.

Wilcoxon signed-rank test showed that ULIB as well as optimized constant of Haigis formula had significantly lower MedAE ($P < 0.00001$) as compared to manufacturer's lens constants. However, there was no statistically significant difference between ULIB and optimized constants. Postoptimization, Hoffer Q had the least MedAE (0.38), whereas SRK/T had the highest value (0.5), although there was no statistically significant difference in outcomes among all formulae.

The percentage of eyes with RPE within ±0.25, ±0.50, ±1.00, and ±2.00 D of PR of the six formulae, using various lens constants is shown in Table 2. For Haigis, Holladay 1, and SRK/T there was an increase in this number, on using optimized constants as compared to ULIB, whereas for Hoffer Q there was an increase only within ±0.25 and ±0.50 D. On comparing manufacturer's with optimized constants, almost the same number of eyes could achieve refractive outcomes within ±0.25, ±0.50, ±1.00, and ±2.00 D of PR in cases of Hoffer Q, Holladay 1 and SRK/T, whereas for Haigis these numbers increased.

Table 1: Preoperative demographic characteristics of the study population

Parameters	Mean±SD	Median	Range
Age (years)	59.57±10.27	60	35,83
AL (mm)	21.56±0.30	21.66	20.76,21.96
ACD (mm)	2.64±0.30	2.61	2.2,3.53
K average (D)	46.34±1.39	46.19	43.38,49.5
LT (mm)	4.16±0.58	4.22	2.86,5.49

Abbreviations: AL- Axial length, ACD- Anterior chamber depth, D-Diopters, K- Keratometry, LT- Lens thickness, mm-millimetres, SD-Standard deviation
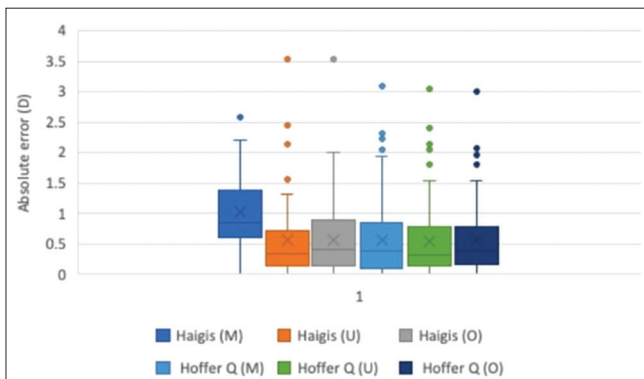

Figure 2: Graph showing absolute error (in Diopters) using various lens constants of Haigis and Hoffer Q formulae
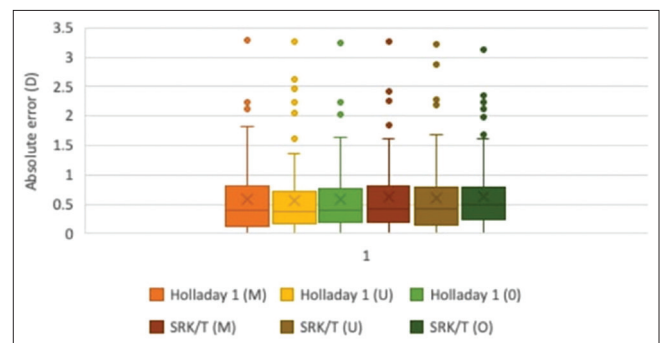

Figure 3: Graph showing absolute error (in Diopters) using various lens constants of Holladay 1 and SRK/T formulae

Table 2: Postoperative refractive outcomes of IOL formulae

Formula	MAE±SD (95%CI)	MedAE	Percentage of eyes with refractive prediction error within			
			±0.25 D (%)	±0.50 D (%)	±1.00 D (%)	±2.00 D (%)
Haigis (M)	1.023±0.594 (0.89,1.15)	0.85	4 (4.65)	15 (17.44)	49 (56.97)	80 (93.02)
Haigis (U)	0.56±0.61 (0.43,0.69)	0.35	30 (34.88)	39 (45.35)	66 (76.74)	81 (94.18)
Haigis (O)	0.562±0.596 (0.44,0.69)	0.4	37 (43.02)	51 (59.30)	72 (83.72)	85 (98.83)
Hoffer Q (M)	0.566±0.612 (0.44,0.69)	0.39	33 (38.37)	53 (61.62)	68 (79.06)	81 (94.18)
Hoffer Q (U)	0.53±0.58 (0.41,0.65)	0.33	26 (30.23)	49 (56.97)	74 (86.04)	83 (96.51)
Hoffer Q (O)	0.574±0.595 (0.45,0.69)	0.38	31 (36.04)	54 (62.79)	69 (80.23)	82 (95.34)
Holladay 1 (M)	0.575±0.624 (0.44,0.71)	0.4	32 (37.2)	52 (60.46)	70 (81.39)	81 (94.18)
Holladay 1 (U)	0.56±0.62 (0.43,0.69)	0.39	20 (23.25)	44 (51.16)	71 (82.55)	81 (94.18)
Holladay 1 (O)	0.579±0.596 (0.45,0.70)	0.4	32 (37.2)	52 (60.46)	72 (83.72)	81 (94.18)
SRK/T (M)	0.626±0.632 (0.49,0.76)	0.43	25 (29.06)	45 (52.32)	71 (82.55)	81 (94.18)
SRK/T (U)	0.59±0.65 (0.45,0.73)	0.43	23 (26.74)	43 (50.00)	67 (77.91)	80 (93.02)
SRK/T (O)	0.635±0.615 (0.48,0.75)	0.5	23 (26.74)	44 (51.16)	74 (86.04)	81 (94.18)
Barrett Universal II	0.605±0.614 (0.48,0.73)	0.435	30 (34.88)	47 (54.65)	73 (84.88)	82 (95.34)
Hill-RBF	0.587±0.609 (0.46,0.72)	0.4	26 (30.23)	50 (58.13)	76 (88.37)	82 (95.34)

IOL-Intraocular lens, CI-Confidence Interval, D-Diopters, MAE-Mean absolute error, MedAE-Median absolute error, SD-Standard deviation, M-Manufacturer's, U-ULIB, O-Optimized

Discussion

Optimization is a process by which lens constants are adjusted to minimize systematic prediction errors (myopic or hyperopic). Every IOL comes with a theoretical lens constant calculated using a population-average model eye by the IOL manufacturer. As manufacturer's lens constants are based on ultrasound measurements they cannot be directly used in PCI.[18] Even Aristodemou et al. have reported that using manufacturer's lens constant with PCI results in suboptimal outcomes as compared to contact ultrasound measurement.[19] In a study by Melles et al. the optimized lens constants used were found to be slightly higher than manufacturer's A-constants and slightly lower than ULIB constants.[3] Also, a study by Savini et al. has shown that optimized lens constants for IOL calculation differ according to race as well. It further mentioned that an average hyperopic error of 0.18 D could be incorporated in all formulae on using ULIB constants.[20] When we talk about atypical eyes in terms of AL, the predictive accuracy of lens constants varies across the range of AL from short eyes to long eyes, even if it is optimized. Zheng et al. drew attention that a single optimized A-constant is not sufficient for the range of ALs, rather it would lead to greater error when calculating IOL power and hence needs optimization separately for short or long eyes.[2] Haigis emphasized that even for same instrument, different lens constants were necessary for different ranges of AL.[21] Cooke et al. stated that same change in lens constants alters predictions more for short eyes than for long eyes.[22] Nevertheless, optimizing lens constants and that too specifically for atypical eyes, is not routinely practiced. If, in short eyes, optimization improves performance of even one formula then surgeons can be advised to go through this cumbersome process for enhanced patient care and with this rationale, this study was undertaken.

In this study, there was a statistically significant difference in the performance of Haigis on using optimized constants as compared to manufacturer's constants. No improvement was seen in performance of Hoffer Q, Holladay 1 and SRK/T formulae after optimization. The probable reason for this could be that these third-generation formulae use only two variables, AL and keratometry for IOL power calculation. They don't take into consideration the actual ACD measurement, rather work under the assumption that short eyes will have shallow ACD.[23] However, accurate prediction of postoperative ACD is imperative in short eyes, in view of the high IOL power required and comparatively short distance between IOL and retina.[24] Even minute errors of 0.25 mm in measurement of postoperative ACD can result in 0.5 D error in IOL power calculation in an eye with AL of 20.0 mm.[23] This accuracy in predicting postoperative ACD has been accomplished by the fourth-generation Haigis formula by including another variable, preoperative ACD.[24] Of the three constants (a0, a1 and a2) of Haigis formula, a0 mainly moves the power prediction curve up or down, whereas a1 constant (tied to measured anterior chamber depth) and a2 constant (tied to measure AL) vary the shape of power prediction curve based on central keratometry readings, anterior chamber depth, AL and individual lens geometry. In our study, single optimization of Haigis a0 constant was done instead of triple optimization in order to compare the formulae on a more uniform basis as suggested by Melles et al.[3] Moreover, a minimum of 200 eyes are required for triple optimization of Haigis which is a difficult number to achieve in short eyes.[25]

On comparing ULIB with optimized constants, there was no statistically significant difference in the performance of any of the formulae used in our study. The ULIB constants, based on pre and postoperative clinical data compiled from different surgical centers, are already optimized across the range of AL. Thus, the results of our study indicate that there is no need to optimize lens constants specifically for short eyes. Similar result was found in study by Zhang et al. where they found that lens constants optimized across entire range of AL work equally well in long eyes.[7]

Various studies have analyzed the performance of IOL formulae after optimizing lens constants specifically for short eyes. Sudhakar et al. showed that on comparing the accuracy of formulae postoptimization, none was significantly different from other.[8] The results were consistent with that of Gokce et al.

as well as Shrivastava *et al.*[24,26] Even Terzi *et al.* showed that, although Haigis produced the smallest MAE, the difference in MAE values between the formulae postoptimization was not statistically significant.[27] In this study, though Hoffer Q had the lowest MedAE (0.38), there was no statistically significant difference between the formulae on using optimized constants.

There were few limitations of our study. Firstly it was retrospective in nature. Secondly, the sample size was small. A multicentric study would be required to achieve a larger sample, particularly for short eyes. However, data acquisition from multiple sources may be affected by several errors thus compromising its quality and leading to worse outcomes than expected.[28] We have evaluated only single type of IOL. Studies have shown that IOL design can also affect prediction errors. Hence more studies need to be done comparing the impact of optimization and different IOL designs.

Conclusion

Thus to conclude, the result of our study shows that optimizing lens constants specifically for short eyes gives no added advantage over lens constants optimized for the entire range of AL.

Data availability statement

The data that support the findings of this study are openly available in Mendeley at http://dx.doi.org/10.17632/8ks7m7gd39.1.

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Conflicts of interest

There are no conflicts of interest.

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