Original Article

Intraoperative aberrometry versus preoperative biometry for intraocular lens power selection in patients with axial hyperopia

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Purpose: This study was conducted to evaluate the accuracy of intraoperative aberrometry (IA) in intraocular lens (IOL) power calculation and compare it with conventional IOL formulas. **Methods:** This was a prospective case series. Eyes with visually significant cataract and axial hyperopia (AL <22.0 mm) underwent IA-assisted phacoemulsification with posterior chamber IOL (Alcon AcrySof IQ). Postoperative spherical equivalent (SE) was compared with predicted SE to calculate the outcomes with different formulas (SRK/T, Hoffer Q, Haigis, Holladay 2, Barrett Universal II and Hill-RBF). Accuracy of intraoperative aberrometer was compared with other formulas in terms of mean absolute prediction error (MAE), percentage of patients within 0.5 D and 1 D of their target, and percentage of patients going into hyperopic shift. **Results**: Sixty-five eyes (57 patients) were included. In terms of MAE, both Hoffer Q (MAE = 0.30) and IA (MAE = 0.32) were significantly better than Haigis, SRK/T, and Barrett Universal II ($P < 0.05$). Outcomes within ±0.5 D of the target were maximum with Hoffer Q (80%), superior to IA (Hoffer Q > IA > Holladay 2 > Hill-RBF > Haigis > SRK/T > Barrett Universal II). Hoffer Q resulted in minimum hyperopic shift (30.76%) followed by Hill-RBF (38.46%), Holladay 2 (38.46%), Haigis (43.07%), and then IA (46.15%), SRK/T (50.76%) and Barrett Universal II (53.84%). **Conclusion**: IA was more effective (statistically significant) in predicting IOL power than Haigis, SRK/T, and Barrett Universal II although it was equivalent to Hoffer Q. Hoffer Q was superior to all formulas in terms of percentage of patients within 0.5 D of their target refractions and percentage of patients going into hyperopic shift.

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Cataract is the leading cause of blindness in the world and cataract surgery is the most commonly performed surgeries among all. Nowadays, this surgery is not just about removing cataractous lens and implanting an intraocular lens (IOL), but providing the patient a spectacle-free life. With ever increasing patient expectations, there is a need to establish the most accurate IOL power calculation formula.

Conventional methods for calculating intraocular lens (IOL) power are based on preoperative biometry measurements. Different IOL power calculation formulas include 2nd generation SRK II formula, 3rd generation formulas (Holladay 1, SRK/T, Hoffer Q), and 4th generation (Haigis, Holladay 2) formulas. Newer algorithms (Holladay 2, Barrett Universal II and Hill-RBF) use additional parameters (white-to-white distance and lens thickness) to improve the accuracy of calculation of IOL power. Eyes with normal axial length (AL) (between 22.0 mm and 25.0 mm) postoperatively after phacoemulsification, fall within 1.0 diopter (D) of the predicted target although 100% of the eyes do not achieve a spherical equivalent (SE) within 0.5 D of that predicted.[1] In eyes with axial hyperopia, outcomes are even less accurate when conventional IOL power calculation methods are used. The reason is that in short eyes, to achieve emmetropia, IOL with higher powers require accurate effective lens position (ELP) and any deviation results in exaggerated error postoperatively compared to eyes with normal axial length.[2] Studies have been done over the years to determine the most accurate IOL power calculation method in these eyes to achieve minimum residual refractive error postoperatively. Earlier studies showed that Hoffer Q was the most reliable method for short eyes[3,4] but later as newer algorithms were introduced, Holladay 2 was considered more precise.[5,6] The majority[2,7–9] of the studies showed no significant difference in accuracy among the formulas (Haigis, Holladay 2, Hoffer Q, Holladay 1, SRK/T and SRK II, Barrett Universal II, Hill-RBF) for patients with short AL. Therefore, there is no common consensus over the optimal formula for IOL power selection in short eyes.

Nowadays intraoperative aberrometry (IA) has brought a revolution in ophthalmic surgeries especially in challenging situations. The Optiwave Refractive Analysis (ORA) (Alcon Laboratories, Inc.)[10,11] is an intraoperative wavefront

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aberrometer used to measure the refractive power of an aphakic eye intraoperatively and calculate the expected residual refractive error after placement of an IOL. It is a revolutionary technology based on the principle of Talbot Moiré interferometry. ORA has already been used to calculate IOL power in challenging situations like in post-refractive (laser *in situ* keratomileusis [LASIK][12,13] and photorefractive keratectomy [PRK]) patients and those with toric IOL implantation. It has been shown to give better predictions than traditional formulas.[14,15] A recent retrospective study compared the accuracy of preoperative biometry-based formulas (Hoffer Q, Holladay 2, Haigis, Barrett Universal II and Hill-RBF) to IA with respect to predicting outcomes after cataract surgery in short eyes. The authors concluded that IA is not significantly different from the best preoperative biometry-based methods.[16]

Efforts are ongoing to achieve accuracy in postoperative results. To the best of our knowledge, there has been no published prospective study to accurately determine the IOL power in axial hyperopes. The purpose of our study was to determine the accuracy of the intraoperative wavefront aberrometer and its comparison with the conventional third, fourth, and fifth generation formulas with respect to residual refractive error after cataract surgery in eyes with axial hyperopia.

Methods

This was a prospective study that included 65 eyes (57 patients) with visually significant cataract and axial hyperopia (AL <22.0 mm), attending the cataract and refractive services of a tertiary eye center from January 2018 to June 2019. Informed consent was taken from all patients and institutional ethical committee clearance was sought. They underwent IA-assisted phacoemulsification with posterior chamber IOL implantation (suggested by Barrett Universal II). All surgeries were performed by a single surgeon (AKJ). All procedures adhered to the tenets of the Declaration of Helsinki and were conducted in accordance with the approved research protocol. The patients of either sex and age >30 years were included in the study. IOL design of the same type was planned in all eyes: Alcon AcrySof® IQ Monofocal IOL or AcrySof SA60AT. The eye with any corneal opacity, corneal astigmatism >1.5 D, history of previous ocular surgery or trauma, ocular inflammatory conditions, retinal or optic nerve disease limiting vision, unreliable optical biometry data, or with any intraoperative complication during cataract surgery were excluded from the study. Optical biometry was performed using partial coherence interferometry (PCI) (ZEISS IOL Master 700, Carl Zeiss Meditec, Jena, Germany) and IOL power was calculated using (1) SRK/T; (2) Hoffer Q; (3) Haigis; (4) Holladay 2; (5) Barrett Universal II.

All surgeries were done on day care basis or on outpatient basis under topical anesthesia. Standard steps of closed chamber phacoemulsification were performed. After cortical cleanup, each eye was inflated to an intraocular pressure (IOP) of 20 mmHg (measured with Barraquer tonometer) using Healon GV. The intraoperative wavefront aberrometer was then used to measure the eye in the aphakic state and estimate the postoperative refractive error for the IOL the surgeon had selected for implantation based on preoperative biometry. Barrett Universal II formula was used to decide the IOL power preoperatively. The IA provides an IOL power with predicted postoperative target refraction intraoperatively. If the IA recommended an IOL different from that originally intended, the surgeon's best judgement was used to implant the IOL most likely to result in emmetropia.

Postoperatively after 4 weeks, the final refraction was done and prediction error (PE) for each formula was then calculated.

PE (for any formula) = Final residual spherical equivalent − Target spherical equivalent (from that formula)

(−) sign of PE suggests myopic shift and (+) sign suggests hyperopic shift.

Outcomes of IA were measured in terms of mean absolute PE, percentage of patients going into hyperopia and myopia, and percentage of patients achieving refraction within ±0.5 D and ± 1 D of target. Mean absolute prediction error was calculated by taking mean of absolute values of prediction error, that is, neglecting the (−) or (+) sign. In a separate analysis, the formulas were optimized for the study population, zeroing out the mean numerical error for each eye by adding or subtracting the mean prediction error in that group of IOL calculation formula.

Statistical analysis

Data was analyzed using commercially available software (SPSS 17.0, SPSS Inc, Chicago, IL). The actual postoperative refractive error was checked for its normality using Kolmogorov–Smirnov test. The closeness of each value of the targeted refraction using various IOL calculation formulas from the average actual postoperative residual error was tested via sample t-test. Actual postoperative error was compared with estimated predicted error (with IA) using paired student t-test if data was normally distributed, else Wilcoxon signed rank test for data not distributed normally was used. The degree of association between targeted and actual postoperative error by IA was seen by the Pearson correlation coefficient. A P value of less than 0.05 was considered to indicate statistical significance.

Results

This study included 65 eyes from 57 patients (80% female and 20% male) with mean age of 59.7 ± 11.3 years (range 34–80 years). Fity-nine eyes received Alcon AcrySof® IQ Monofocal IOL in 59 eyes and 6 eyes received AcrySof SA60AT. The preoperative parameters of the study population are illustrated in Table 1. Mean residual spherical equivalent (MRSE) was 0.73 ± 0.54 D. The preoperative corrected distance visual acuity (CDVA) (in logMAR units) was 0.66 ± 0.41 and postoperative CDVA was 0.20 ± 0.16 ($P \leq 0.001$). There was statistically significant improvement in CDVA postoperatively ($P < 0.001$).

Outcome of intraoperative aberrometry

Results of outcome of IA are shown in Table 2. There was no statistical difference in final postoperative manifest refractive SE and predicted target refraction with intraoperative aberrometry (error of ± 0.3 D is considered acceptable). The mean PE and absolute mean PE was calculated for each of the seven formulas. However, all statistical calculations are based on mean absolute PE, that is, without considering the positive or the negative value of the prediction errors. Comparison of IA with other formulas in terms of mean absolute PE with and without optimization has been tabulated in Table 3. Hoffer Q was superior to IA (although the difference was not statistically significant; $P = 0.61$) with respect to minimum mean absolute prediction error (0.30 ± 0.31). IA was superior (statistically significant) to Barrett's Universal II, Haigis and SRK/T ($P < 0.05$).

Fig. 1 and Table 4 show the comparison of various formulas in terms of percentage of patients achieving target refraction within ± 1 D and ± 0.5 D with and without optimization. Considering target refraction within 0.5 D, Hoffer Q was superior (statistically non-significant difference) to IA ($P = 0.83$). Both IA and Hoffer Q performed better than all the remaining formulas (Hoffer Q > IA > Holladay 2 > Hill-RBF > Haigis > SRK/T > Barrett Universal II); although not statistically significant (except Barret Universal II).

Table 5 depicts percentage of patients ending up in hyperopic shift postoperatively (calculated using different IOL formulas). Hoffer Q gives minimum hyperopic shift (30.76%) followed by Hill-RBF and Holladay 2, Haigis, and then IA. Thus, in respect to postoperative hyperopic shift, Hoffer Q faired better than the other formulas.

Discussion

Outcomes of cataract surgery in short eyes have remained unpredictable since many years. There have been many retrospective case series to determine the accuracy of various IOL calculation formulas in short eyes but till date there has been no consensus. Accurate prediction of ELP is challenging because of high IOL powers and relatively short distance between the IOL and retina. There have been only two studies till now comparing outcomes of IA with preoperative biometry in short eyes but they were retrospective and have used different IOLs.[16,17] Our study, to the best of our knowledge, is a first-of-its-kind prospective study in which outcomes of IA have been compared with preoperative biometry-based IOL power calculating formulas in short eyes.

Intraoperative aberrometry is a new paradigm in cataract surgery that takes into account both the anterior and posterior corneal astigmatism, minimizing dependence on preoperative parameters like keratometry. The optical measurement is obtained directly from infrared laser reflection from the retina. Instead of relying on estimated corneal power, it automatically takes into account the refractive state of the entire optical media. Intraoperative aberrometry has proven to show better results in previous major studies in axial myopes by Hill *et al*.[1] and post refractive surgery patients by Ianchulev

Table 1: Preoperative Parameters of the Study Population

Parameter	Mean±standard deviation
Mean K1	45.64±1.69 D
Mean K2	46.57±1.67 D
Mean lens thickness	4.44±0.45 mm
Mean anterior chamber depth	2.73±0.34 mm
Mean WTW (white to white)	11.48±0.44 mm
Mean axial length	21.41±0.42 mm
Mean IOL power	26.60±2.45 D

Table 2: Results of Refractive Outcomes of Intraoperative Aberrometry

Parameters	Outcomes
Mean prediction error	-0.10±0.50D (-0.98 to 1.84D) (Median: 0.01D)
Mean absolute prediction error	0.37±0.35D (0.01 to 1.32D) (Median: 0.34D)
Percentage of hyperopic shift	46.15%
Percentage of myopic shift	53.84%
Within±0.5 D of the predicted	78.5%
Within 1.0 D of the predicted	95.40%

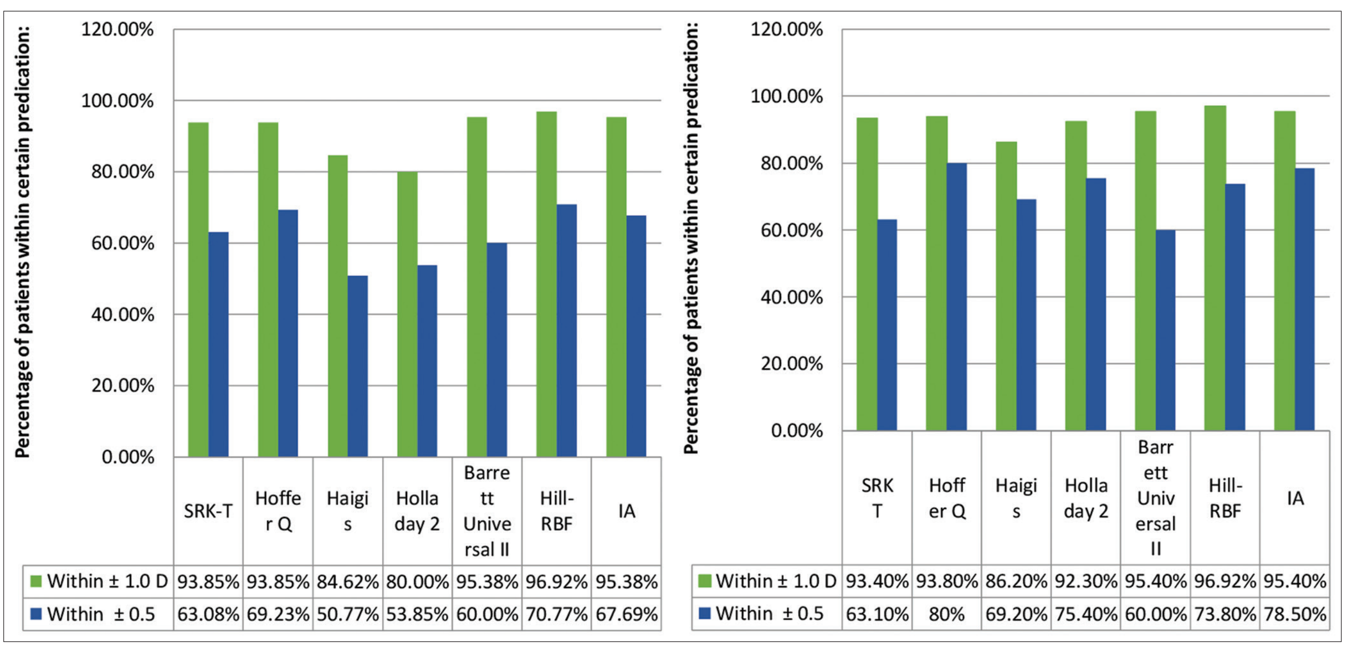

Figure 1: Showing comparison of various formulas in terms of percentage of patients achieving target refraction within ±0.5 D and ±1 D of the predicted target with and without optimization

Table 3: Comparison of Mean Absolute Prediction Error of Various Formulas with Intraoperative Aberrometry without and with Optimization

Formula	Without Optimization							With Optimization			
	Mean Prediction Error±SD	Range	Median	Mean Absolute Prediction Error±SD	Range	Median	*P* (Compared to IA)	Mean Absolute Prediction Error±SD	Range	Median	*P* (Compared to IA)
SRK/T	−0.02±0.56 D	−0.98 to 1.84 D	0.10 D	0.46±0.32 D	0.03 to 1.84 D	0.38 D	0.454	0.44±0.32	0.01 to 1.82 D	0.36 D	0.001*
Hoffer Q	−0.24±0.55 D	−1.35 to 1.75 D	−0.20 D	0.42±0.42 D	0 to 1.75 D	0.36 D	1.000	0.30±0.31	0 to 1.51 D	0.18 D	0.613
Haigis	−0.20±0.82 D	−2.79 to 1.22 D	0 D	0.63±0.56 D	0 to 2.79 D	0.50 D	0.002*	0.47±0.53	0 to 2.59 D	0.30 D	0.018*
Holladay 2	−0.23±0.66 D	−1.98 to 1.25 D	−0.19 D	0.54±0.44 D	0 to 1.98 D	0.44 D	0.053	0.38±0.37	0.37 to 1.75 D	0.22 D	0.172
Barrett Universal II	+0.01±0.60 D	−1.68 to 1.49 D	0.14 D	0.49±0.34 D	0 to 1.68 D	0.44 D	0.121	0.49±0.34	0.01 to 1.67 D	0.43 D	0.000*
Hill-RBF	−0.06±0.53 D	−1.53 to 1.70 D	−0.04 D	0.40±0.35 D	0.01 to 1.70 D	0.34 D	1.000	0.36±0.34	0.00 to 1.65D	0.30 D	0.238
IA	−0.10±0.50 D	−1.19 to 1.32 D	0.01 D	0.37±0.35 D	0.01 to 1.32 D	0.33 D		0.32±0.32	0.01 to 1.23 D	0.26 D	

*statistically significant

et al.[14] Another study by Zhang *et al.*[11] in 234 eyes of normal axial length, on the other hand, concludes that IA provides postoperative refractive results comparable to conventional biometry with IOLMaster.

Raufi *et al.*[17] in their retrospective study compared IA with modern preoperative formulas including Barrett Universal II and Hill-RBF. They found that Barrett Universal II outperformed the IA in short eyes with axial length <22.75 mm ($P = 0.026$) and toric multifocal ($P = 0.011$) groups in terms of mean prediction error. The result of this study was unlike the results of our study in which we found that the intraoperative aberrometry was superior to Barrett Universal II and Hill-RBF in terms of mean absolute prediction error (IA [0.32 D] > Hill-RBF [0.36 D] > Barrett Universal II [0.49D]). IA was also superior in terms of results within 0.5 D of target refraction (IA [78.5%] > Hill-RBF [73.80%] > Barrett Universal II [60%]) but the statistical significance was achieved only with respect to Barrett Universal II. It also performed better in terms of less hyperopic shift (46.15%) compared to Barrett Universal II (53.84%).

In another retrospective case series by Sudhakar *et al.*,[16] six IOL formulas were compared (IA, Hill-RBF, Hoffer Q, Barrett II, Holladay 2, Haigis) in 51 eyes undergoing phacoemulsification with IOL implantation with short axial length <22.1 mm. The authors found that the prediction outcomes with IA were better (statistically significant) than Haigis but not with other formulas with and without optimization of results. Hoffer Q, Holladay 2, and IA had the lowest mean numerical errors and were not significantly different from one another. All three of these formulas were superior to Haigis, which performed worst ($P = 0.001$). There was no statistically significant difference with regard to the proportion of eyes within 0.5 D and 1.0 D of the target refraction. Multiple IOL's were used in this study compared to a single IOL used in our study. One shortcoming of this study was that optimization was done only in eyes that received same monofocal IOL. However, after optimization, performance of formulas in terms of results within 0.5 and 1.0 D of target and overall outcomes remained same in terms of statistical significance. Another limitation of this study is that the results were based on mean numerical error and not mean absolute prediction error, which is considered to be a more reliable parameter. In contrast to this study, our study found that after optimization of results, Hoffer Q was superior to (statistically non-significant) all other formulas as well as IA with respect to mean absolute PE (0.30). However, both Hoffer Q and IA were significantly better than Haigis, SRK/T, and Barrett Universal II ($P < 0.05$). The authors wish to highlight that optimization of the results in terms of mean absolute PR is essential to reduce the arithmetic mean error to 0, thereby eliminating the myopic and hyperopic PE. Since our study included patients with small axial length, optimization of results was important to reach a reliable conclusion.

Kane *et al.*[9] in their retrospective case series assessed the accuracy of seven IOL formulas (Barrett Universal II, Haigis, Hoffer Q, Holladay 2, SRK/T, and T2) in patients with subgroups over the entire AL range. They concluded that in eyes with AL <22 mm, the Barrett Universal II formula was not an accurate predictor (statistically non-significant) of actual postoperative refraction than all the other formulas. The results of this study were in sync with our study, in which we found that Hoffer Q faired better ($P < 0.05$) than Barrett Universal II in patients with axial hyperopia (AL <22.0 mm).

Table 4: Comparison of Various Formulas in Terms of Percentage of Patient Achieving Target Refraction (with and without Optimization) within±0.5 D and±1 D of the Predicted Target

Formula	Without Optimization				Formula	With Optimization			
	Within±1.0 D	*P*	Within±0.5 D	*P*		Within±1.0 D	*P*	Within±0.5 D	*P*
SRK/T	93.85%	0.000*	63.08%	0.001*	SRK/T	93.40%	0.687	63.10%	0.054
Hoffer Q	93.85%	0.000*	69.23%	0.000*	Hoffer Q	93.80%	0.687	80%	0.833
Haigis	84.62%	0.582	50.77%	0.003*	Haigis	86.20%	0.071	69.2%	0.299
Holladay 2	80.00%	0.005*	53.85%	0.005*	Holladay 2	92.30%	0.464	75.40%	0.676
Barrett Universal II	95.38%	0.045*	60.00%	0.000*	Barrett Universal II	95.40%	1	60.00%	0.022*
Hill-RBF	96.92%	0.009*	70.77%	0.000*	Hill-RBF	96.92%	0.658	73.80%	0.531
IA	95.38%		67.69%		IA	95.40%		78.5%	

*statistically significant

Table 5: Table showing hyperopic shift in various IOL formulas

IOL Formulas	Hyperopic Shift
SRK/T	50.76%
Hoffer Q	30.76%
Haigis	43.07%
Holladay 2	38.46%
Barrett Universal II	53.84%
Hill-RBF	38.46%
IA	46.15%

The results of another study comparing various IOL calculating formulas in small eyes (AL ≤22) showed no statistically significant difference in median absolute errors (after optimization of results) between the seven formulas (Barrett Universal II, Haigis, Hill-RBF, Hoffer Q, Holladay 1, Holladay 2, and Olsen).[2]

Conclusion

In conclusion, IA is effective in predicting IOL power in cases of axial hyperopia and was found to be superior to most of the available formulas except Hoffer Q. Thus, the modern preoperative biometry-based formulas give excellent performance in axial hyperopes and supplementing it with IA does not provide additional advantage. Hoffer Q is effective in predicting IOL power in cases of axial hyperopia and was found to be superior to IA (least mean absolute PE, outcomes within ±0.5 D of target, minimum hyperopic shift.)

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Conflicts of interest

There are no conflicts of interest.

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