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Original Article

Ophthalmology Section

A Comparative Study to Assess the Predictability of Different IOL Power Calculation Formulas in Eyes of Short and Long Axial Length

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ABSTRACT

Introduction: Accurate Intraocular Lens (IOL) power calculation in cataract surgery is very important for providing postoperative precise vision. Selection of most appropriate formula is difficult in high myopic and hypermetropic patients.

Aim: To investigate the predictability of different IOL (Intra Ocular Lens) power calculation formulae in eyes with short and long Axial Length (AL) and to find out most accurate IOL power calculation formula in both groups.

Materials and Methods: A prospective study was conducted on 80 consecutive patients who underwent phacoemulsification with monofocal IOL implantation after obtaining an informed and written consent. Preoperative keratometry was done by IOL Master. Axial length and anterior chamber depth was measured using A-scan machine ECHORULE 2 (BIOMEDIX). Patients were divided into two groups based on AL. (40 in each group). Group A with AL<22 mm and Group B with AL>24.5 mm. The IOL power calculation in each group was done by Haigis, Hoffer Q, Holladay-I, SRK/T formulae using the software of ECHORULE 2. The actual postoperative Spherical Equivalent (SE), Estimation error (E) and Absolute Error (AE) were calculated at one and half months and were used in data analysis. The predictive accuracy of each formula in each group was analyzed by comparing the Absolute Error (AE). The Kruskal Wallis test was used to compare differences in the (AE) of the formulae. A statistically significant difference was defined as p-value<0.05.

Results: In Group A, Hoffer Q, Holladay 1 and SRK/T formulae were equally accurate in predicting the postoperative refraction after cataract surgery (IOL power calculation) in eyes with AL less than 22.0 mm and accuracy of these three formulae was significantly higher than Haigis formula. Whereas in Group B, Hoffer Q, Holladay 1, SRK/T and Haigis formulae were equally accurate in predicting the postoperative refraction after cataract surgery (IOL power calculation) in eyes with AL more than 24.5 mm.

Conclusion: Hoffer Q, Holladay 1 and SRK/T formulae were showing significantly higher accuracy than Haigis formula in predicting the postoperative refraction after cataract surgery (IOL power calculation) in eyes with AL less than 22.0 mm. In eyes with AL more than 24.5 mm Hoffer Q, Holladay 1, SRK/T and Haigis formulae were equally accurate.

Keywords: Axial length, Cataract surgery, IOL formula, Lens power, Phacoemulsification

INTRODUCTION

Accurate Intraocular Lens (IOL) power calculation in cataract surgery is a very important aspect of cataract surgery. Patients' expectations for perfect vision after surgery are increasing day by day. So, there has been an ongoing effort to predict the postoperative refractive outcome with accuracy and consistency [1]. The refractive power of the human eye depends on the power of the cornea, the lens and the AL of the eye and the axial position of the lens. All these factors play a major role in determining the postoperative visual outcome [1-3].

IOL power calculation has changed dramatically. From simple first generation formulae like SRK-I to second generation formulae like SRK-II IOL, power calculation has evolved to the modern formulae. Third generation formulae, such as Holladay 1, Hoffer Q, and SRK/T; attempt to predict the estimated lens power using AL, corneal curvature (K), and A constant, as the variables. Fourth generation formulae, like Haigis, also take into account the preoperative Anterior Chamber Depth Anterior Chamber Depth (ACD) and use three constants (a0, a1, and a2), which are analogous to Surgeon Factor (SF), ACD and AL, respectively [1]. These modern formulae predict the IOL power with much greater accuracy.

The IOL power calculation formulae as discussed above have good predictability of postoperative refractive status in case of eyes with normal axial length. For eyes of long and short axial length, their accuracy has yet to be proven. So, our study was done with a purpose to evaluate and compare the predictive ability of four IOL power calculation formulae (SRK/T, Hoffer Q, Holladay 1 and Haigis) in eyes shorter than 22.0 mm and longer than 24.50 mm.

MATERIALS AND METHODS

A prospective, comparative study was carried out at our institute from October 2013 to August 2014 (10 months) to investigate the predictability of different IOL power calculation formulae in eyes with short and long AL. The protocol was approved by the local Institutional Review Board. The study was conducted adhering to the tenets of Declaration of Helinski. For the study, patients were selected from the outpatient department of our institute. Informed and written consent was obtained from all patients. A total of 80 cases were studied. All of them were cases of uncomplicated cataract. Diagnosis was made after detailed medical history, thorough general and ocular examination with slit lamp biomicroscopy.

Inclusion criteria were, patients with cataract of any type with normal anterior and posterior segment; uneventful cataract surgery with "in the bag" monofocal IOL implantation with same A constant (118.7) in all patients; eyes with axial length of either < 22 mm or >24.5 mm and postoperative Best Corrected Visual Acuity (BCVA) of 6/12 or more at the sixth week.

The children and patient with psychiatric illness, traumatic cataract, severe corneal degeneration, corneal opacity, vitreous degeneration and other vitreous pathology, diabetic retinopathy, developmental and acquired retinal diseases were excluded. Also, the patients with squint and high corneal astigmatism were not considered.

Patients were divided into two groups based on the axial length. Patients with axial length <22mm were included in Group A and patients with axial length >24.5mm were included in Group B. Patients were operated by phacoemulsification with monofocal IOL implantation in our department after obtaining an informed and written consent. Preoperative Keratometric values (Ks) were measured by IOL MASTER. AL and ACD were measured by immersion ultrasound technique with the help of an ultrasound A-scan machine ECHORULE 2 (BIOMEDIX).

The IOL power calculation in each group was done with the Haigis, Hoffer Q, Holladay I and SRK/T formulae using the software of ECHORULE 2 with optimization of A-constant.

Postoperatively, Ofloxacin (0.3%) and Dexamethasone (0.1%) eye drops were given in gradually tapering frequency for one and half month. The actual postoperative SE was recorded at one and half months by auto-refractometer, retinoscopy and subjective correction.

SE= spherical power+ ½ cylindrical power

The predictive accuracy of each formula in each group was analyzed by comparing the difference between the actual Corrected SE (CSE) and predicted postoperative SE; ideally, which should be zero. All the patients had follow-up period of total one and half months with regular followup at day one, one week, three weeks and six weeks. At the end of six weeks SE and CSE were calculated. The Kruskal Wallis test was used to compare differences in the AE of the formulae.

Target in IOL power selection was a lens power that would yield a postoperative refraction nearest to plano, erring on the side of myopia. The IOL formula that predicted a lens power with the above postoperative refraction was selected. All patients underwent uneventful phacoemulsification surgery with a standard technique by the same surgeon. An incision and side-port paracentesis were made. Ophthalmic Viscoelastic Device (OVD) was injected into the anterior chamber and a Continuous Curvilinear Capsulorrhexis (CCC) was created. Hydrodissection was done with Balanced Salt Solution (BSS). This was followed by phacoemulsification, aspiration of cortex and implantation of the foldable posterior chamber IOL using the recommended injector system. The OVD was subsequently removed and surgical wounds were hydrated with BSS. No sutures were applied. All wounds were checked for leakage. Subconjuctival gentamycin and dexamethasone injections were given at the end of surgery.

STATISTICAL ANALYSIS

Data entry was done in Microsoft Excel 2010. Mean, Median and Standard deviation (SD) was calculated. Postoperatively, patients were examined on the first day, seventh day, third week and sixth week. Estimation error (E) was defined as the difference between the actual postoperative SE at the one and half month follow up and the predicted postoperative SE. The AE was defined as the absolute value of E. Mean AE was calculated for each formula. The differences in the mean AE for the four formulae were analyzed. Furthermore, the percentage of eyes with AEs within ± 0.50 and ±1.0 D for each formula was estimated.

The Kruskal Wallis test which is a nonparametric ANOVA test was used to compare differences in the AEs of the formulae. A statistically significant difference was defined as p<0.05. Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) 22.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

A total of 80 eyes were included in the study which were divided in two groups.

Group A - 40 eyes of hypermetropic patients. (AL< 22 mm)

Group B - 40 eyes of myopic patients (AL > 24.5 mm).

Analysis of Group A Results

The number of males was 11 and females was 29. The mean age was 58.98±9.29 years. All patients reached BCVA of > 6/12 postoperatively. The mean AL was 21.39±0.58 mm, the mean ACD was 2.43 mm, while the mean average K was 46.28±1.22D. The mean E (±SD) for Holladay 1, Hoffer Q, Haigis and SRK-T was 0.07±0.70, -0.15±0.68, 1.32±0.80 and 0.08±0.71, respectively. The mean AE (±SD) for Holladay-1, Hoffer-Q, Haigis and SRK-T was 0.57±0.40, 0.59±0.36, 1.36±0.75 and 0.54±0.46, respectively. The median AE for Holladay-1, Hoffer-Q, Haigis and SRK-T was 0.50, 0.57, 1.48 and 0.44 respectively [Table/Fig-1].

The Haigis formula had statistically significant higher mean AE in comparison to Holladay 1 (p<0.001), Hoffer Q (p<0.001), and SRK-T (p<0.001). There was no statistically significant difference in mean AE of Holladay 1, Hoffer Q and SRK-T formulae (p>0.05) [Table/Fig-2].

Analysis of Group B Results

The number of males was 25 and females was 15. The mean age was 59.23±11.82 years. All patients reached BCVA of > 6/12 postoperatively. The mean AL was 24.93±0.80 mm, the mean ACD was 3.56 mm, while the mean average K was 43.30±1.75. The mean E (±SD) for Holladay 1, Hoffer Q, Haigis and SRK-T was 0.05±0.72, -0.01±0.84, 0.70±0.81 and 0.10±0.66, respectively. The mean AE (±SD) for Holladay 1, Hoffer Q, Haigis and SRK-T was 0.56±0.44, 0.68±0.48, 0.83±0.67 and 0.51±0.42, respectively. The median AE for Holladay-1, Hoffer-Q, Haigis and SRK-T was 0.52, 0.56, 0.6 and 0.43, respectively [Table/Fig-3]. There was no statistically significant difference in between mean AE of Haigis, Holladay 1, Hoffer Q and SRK/T formulae (p>0.05) [Table/Fig-4].

DISCUSSION

Group A: The Haigis formula had statistically significant higher mean AE in comparison to Holladay 1 (p<0.001), Hoffer Q (p<0.001), and SRK-T (p<0.001). There was no statistically significant difference in mean AE of Holladay 1, Hoffer Q and SRK-T formulae (p>0.05). Thus, Hoffer Q, Holladay 1 and SRK/T formulae were equally accurate in predicting the postoperative refraction after cataract surgery in eyes with AL less than 22.0 mm and accuracy of these three formulae was significantly higher than Haigis formula. We also

Group A				
	HOLLADAY-I	HOFFER-Q	HAIGIS	SRK-T
Mean Estimation Error (D)±SD	0.07±0.70	-0.15±0.68	1.32±0.80	0.08±0.71
Range of Estimation Error (D)	(-1.42 to +1.54)	(-1.63 to +1.29)	(-0.67 to +2.46)	(-1.51 to +1.75)
Mean Absolute Error (D)±SD	0.57±0.40	0.59±0.36	1.36±0.75	0.54±0.46
Range of Absolute Error (D)	(0.00 to 1.54)	(0.02 to 1.63)	(0.07 to 2.50)	(0.01 to 1.75)
Median Absolute Error (D)	0.50	0.57	1.48	0.44

[Table/Fig-1]: Statistical analysis of Group A.

Comparison (Mean AE)	p-value (Kruskal Wallis Test)
Holladay vs. Hoffer Q	p>0.05
Holladay vs. Haigis	p<0.001
Holladay vs. SRK-T	p>0.05
Hoffer Q vs. Haigis	p<0.001
Hoffer Q vs. SRK-T	p>0.05
Haigis vs. SRK-T	p<0.001

[Table/Fig-2]: The p-value in Group A.

Group B				
	HOLLADAY-I	HOFFER-Q	HAIGIS	SRK-T
Mean Estimation Error (D)±SD	0.05±0.72	-0.01±0.84	0.70± 0.81	0.10±0.66
Range of Estimation Error (D)	(-1.30 to +1.79)	(-1.98 to +1.55)	(-1.17 to +2.28)	(-1.01 to +1.88)
Mean Absolute Error (D)±SD	0.56±0.44	0.68±0.48	0.83±0.67	0.51±0.42
Range of Absolute Error (D)	(0.00 to +1.79)	(0.01 to +1.98)	(0.04 to +2.28)	(0.01 to +1.88)
Median Absolute Error (D)	0.52	0.56	0.6	0.43

[Table/Fig-3]: Statistical analysis of Group B.

Comparison (Mean AE)	p-value (Kruskal Wallis Test)
Holladay vs. Hoffer Q	p>0.05
Holladay vs. Haigis	p>0.05
Holladay vs. SRK-T	p>0.05
Hoffer Q vs. Haigis	p>0.05
Hoffer Q vs. SRK-T	p>0.05
Haigis vs. SRK-T	p>0.05

[Table/Fig-4]: The p-value in Group B.

demonstrated the percentage of eyes that fell within specified target refraction for each formula [Table /Fig 5].

Narvaez J et al., used immersion ultrasonography and manual keratometry to evaluate 25 eyes with AL less than 22.0 mm, suggesting no statistically significant difference between Holladay 1, Holladay 2, Hoffer Q, and SRK/T [4]. Gavin EA and Hammond CJ investigated 41 eyes with AL less than 22 mm, measured by IOL Master, concluding that the Hoffer Q formula was more accurate than the SRK/T [5]. MacLaren RE et al., reported 72 eyes with mean AL of 20.79 mm, reporting that in both IOL Master and ultrasonography group, the Haigis formula was the most accurate followed by the Hoffer Q, while Holladay 1 and SRK/T were the least accurate [6].

The mean E of each formula is significant to indicate the overall direction and magnitude of refractive error. A mean E value close to zero indicated an optimized formula. A negative value indicated a tendency for myopic outcomes, whereas a positive value indicated a tendency for hyperopic outcomes. As a result, The Holladay 1, Hoffer Q and SRK-T formulae were optimized for the parameters used in this study. On the other hand, Haigis formula had a strong tendency for hyperopic results [1,2].

Group B: There was no statistically significant difference in between mean AE of Haigis, Holladay 1, Hoffer Q and SRK/T formulae (p>0.05). Thus Hoffer Q, Holladay 1, SRK/T and Haigis formulae were equally accurate in predicting the postoperative refraction after cataract surgery in eyes with AL more than 24.5 mm. We also demonstrated the percentage of eyes that fell within specified target refraction for each formula. [Table/Fig 6]

Roessler GF et al., showed that Haigis provided the best predictability of postoperative refractive outcome than the Holladay 1 and SRK/T for 37 eyes with AL more than 26 [7]. Wang JK et al., demonstrated that SRK/T and Haigis performed equally well and outperformed the Hoffer Q and Holladay one in 34 eyes between 25 and 28 mm [8]. Petermeier K and Szurman P reported that SRK-T, Haigis and Holladay-1 formulae resulted in a mean hyperopic refractive error of +0.84D (SRK-T), +0.67D (Haigis), and +1.18D (Holladay-1), respectively, but within smaller range (SRK-T −0.55±1.79D), Haigis (+0.04±1.56D), Holladay-1 (-0.1±2.07D). The mean axial length in this study was 32.35 mm (range, 29.22–36.51 mm) [9].

The mean E of each formula is significant to indicate the overall direction and magnitude of refractive error. A mean E value close to zero indicated an optimized formula. A negative value indicated a tendency for myopic outcomes, whereas a positive value indicated a tendency for hyperopic outcomes [1]. As a result, The Holladay 1, Hoffer Q and SRK-T can be considered as an optimized for the parameters used in this study. On the other hand, Haigis formula showed a little tendency for hyperopic results.

A potential limitation of our study was that partial coherent interferometry method (IOL Master) was not used for AL measurement and moderate number of sample size.

CONCLUSION

Hoffer Q, Holladay 1 and SRK/T formulae were equally accurate in predicting the postoperative refraction after cataract surgery (IOL power calculation) in eyes with AL less than 22.0 mm and accuracy of these three formulae was significantly higher than Haigis formula. Hoffer Q, Holladay 1, SRK/T and Haigis formulae were equally accurate in predicting the postoperative refraction after cataract surgery (IOL power calculation) in eyes with AL more than 24.5 mm.

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Percentage of Eyes within Specified Target Refraction for Each Formula (Group A)						
	Upto±0.50D		Upto±1D		>±1D	
	No. of patients	Percentage	No. of patients	Percentage	No. of patients	Percentage
HOLLADAY-I	21	52.50%	35	87.50%	5	12.50%
HOFFER-Q	17	42.50%	36	90.00%	4	10.00%
HAIGIS	7	17.50%	14	35.00%	26	65.00%
SRK-T	22	55.00%	33	82.50%	7	17.50%

[Table/Fig-5]: Analysis of eyes within specified target refraction for each formula in Group A.

Percentage of Eyes within Specified Target Refraction for Each Formula (Group B)						
	Upto±0.50D		Upto±1D		>±1D	
	No. of patients	Percentage	No. of patients	Percentage	No. of patients	Percentage
HOLLADAY-I	20	50.00%	35	87.50%	5	12.50%
HOFFER-Q	17	42.50%	30	75.00%	10	25.00%
HAIGIS	17	42.50%	27	67.50%	13	32.50%
SRK-T	20	50.00%	34	85.00%	6	15.00%

[Table/Fig-6]: Analysis of eyes within specified target refraction for each formula in Group B.

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