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A COMPARATIVE STUDY OF INTRAOCULAR LENS POWER CALCULATION FORMULAE (SRK/T, HOFFER Q, SRK II AND HAIGIS) IN EYES OF PATIENTS WITH VARIOUS AXIAL LENGTHS

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ABSTRACT
Title: A Comparative Study of Intraocular Lens Power Calculation Formulae (SRK/T, Hoffer Q, SRK II and Haigis) in Eyes of Patients with Various Axial Lengths. **Aim:** To compare intraocular lens power calculation formulae (SRK/T, Hoffer Q, SRK II and Haigis) in eyes of patients with various axial lengths. **Material and Methods:** The study was a prospective study conducted in a tertiary care hospital in North India. 90 patients were enrolled and divided into groups of 30 with axial length <22mm; 22-24.5mm and >24.5mm. At the end of 6 weeks the post-operative residual / consecutive spherical equivalent (SE), was calculated. The predictive accuracy of each formula was analysed by comparing the difference between the actual and predicted post-operative spherical error, mean estimation error (ME) and mean absolute error (MAE). **Result:** The mean post-operative unaided vision at the end of 6 weeks was 0.16±0.06, 0.17±0.07 and 0.16±0.06 log MAR units in Groups 1, 2 and 3 respectively with no statistically significant difference among the three groups (p value = 0.924). The mean values of post-operative spherical equivalents of the three groups at the end of 6 weeks were -0.25±0.78 D, -0.23±0.61 D, -0.19±0.73 D, with difference being statistically significant (p value=0.049). SRK II formula had the least MAE and ME in group 1 and 2 whereas in group 3, SRK/T had the least MAE and ME. **Conclusion:** SRK II has better predictive accuracy for calculations of IOL power in eyes with axial length (AL) <22 and (AL) =22-24.5 mm and SRK/T has better predictive accuracy for calculation of IOL power in eyes with (AL)>24.5mm.

KEYWORDS: Intraocular lens power, SRK/T, Hoffer Q, SRK II, Haigis formula.

INTRODUCTION
Cataract surgery, one of the most commonly performed ocular surgeries, is fast becoming a refractive surgery in place of vision restorative procedure. With more emphasis being laid on correction of refractive errors such as astigmatism and prevention of surgery induced astigmatism, accurate calculation of intraocular lens (IOL) power has now become a pre-requisite. Therefore, there is an ongoing effort to predict the postoperative refractive outcome with accuracy and consistency.[1] IOL power calculation formulae have markedly evolved over the past 3 decades. The most recent formulae (third and fourth generation) are the most useful and precise. These formulae vary with anterior chamber depth (ACD), axial length (AL) and corneal curvature. Third generation formulae such as Holladay 1, Hoffer Q, and SRK/T use constants associated with the expected position of the IOL. Holladay 1 uses the surgeon factor and distance from the iris plane to the IOL plane. Haigis uses 3 constants for better Effective Lens Position (ELP) prediction. Hoffer Q uses the ACD constant, average distance between the power plane of the cornea and that of the IOL. SRK/T uses A constant to calculate the ACD, using the retinal thickness and corneal refractive index.[2,4] Though there are studies comparing the performance of various formulae in different axial lengths, however, literature search shows only a few studies on Indian population comparing the various IOL calculation formulae. So our study aims to compare the predictive accuracy of various IOL calculation formulae in eyes with various axial lengths in Indian eyes.

MATERIALS AND METHODS
The study was a prospective clinical study conducted on 90 patients with uncomplicated senile cataract reporting to the OPD of a tertiary care health institute in North India for undergoing cataract surgery. Phacoemulsification with IOL implantation was performed by a single surgeon. In all patients hydrophilic acrylic foldable in-the-bag IOL was implanted. Patients

with pre-existing astigmatism >3.0 diopters (D), ocular pathologies, uncooperative patients, inability to measure AL accurately, patients with uncontrolled diabetes, hypertension or any other systemic diseases, any previous refractive surgery, intra- and post-operative complications significantly affecting the refractive status like vitreous loss, IOL implanted in sulcus or anterior chamber, high surgically induced astigmatism and other ocular pathology causing visual impairment that were not apparent prior to the surgery, like age related macular degeneration, macular oedema, glaucoma, and retinal detachment, were excluded from the study. Keratometry was done with Bausch and Lomb Keratometer and biometry: axial length and anterior chamber depth was measured with A scan applanation ultrasonography. Patients were divided into 3 groups having 30 patients each based on the axial length (AL) – **GROUP 1** (AL <22 mm), **GROUP 2** (AL 22-24.5 mm) and **GROUP 3**(AL>24.5mm). The IOL power was calculated in each patient with four formulae (SRK II, Hoffer Q, SRK/T, Haigis). However, the power of the IOL to be implanted was as per latest recommendations from the literature, i.e. as below[2]:

- Patient's eye with axial length (AL 22-24.5 mm) - SRK/T
- Patient's eye with axial length (AL <22 mm) - Hoffer Q
- Patient's eye with axial length (AL >24.5 mm)- Haigis

Post-operatively, follow up was done on day 1, 1 week and 6 weeks after the surgery. At the end of 6 weeks, refraction was done for each patient and the post-operative residual/consecutive spherical equivalent (SE) was calculated. The predictive accuracy of each formula was analysed by comparing the difference between the actual and predicted post-operative spherical error, mean estimation error (ME) and mean absolute error (MAE).

Statistical Analysis

Quantitative data was presented as mean and standard deviation and was analysed by sample t-test, Analysis of Variance (ANOVA) and Kruskal Wallis H test. Qualitative variables were presented as simple proportions, percentages and analysed using Chi-square test. For data analysis, SPSS version 20.0 was used. Statistical significance was considered when p-value was less than 0.05.

RESULT

The mean age of patients in the study was 58.53±8.15 years. The best corrected visual acuity (BCVA) of affected eye in Groups 1, 2 and 3 in log MAR units, was 0.60±0.24, 0.73±0.20 and 0.68±0.18, respectively. The differences of visual acuity among the three groups were not statistically significant (Table 1). The mean axial length of eye was 21.58±0.25 mm, 23.40±0.56 mm and 25.79±0.48 mm in Groups 1, 2 and 3 respectively. Mean IOL power for each group was then calculated and tabulated as shown in table 2. Statistically significant difference was noted in the power calculated by the formulae within each group. Emmetropic IOL power was decided as per literature suggestions using Hofffer Q formula for AL<22mm, SRK II for AL 22-24.5mm, and Haigis for AL>24.5mm. However, as IOLs are available in powers which are multiples of 0.5, there was slight difference in the power calculated and power implanted. This difference was noted and was found to be statistically significant in group 2 and 3 but not in group 1. (Table 3) The mean post-operative unaided vision at the end of 6 weeks was 0.16±0.06, 0.17±0.07 and 0.16±0.06 log MAR units in Groups 1, 2 and 3 respectively with no statistically significant difference among the three groups (p value = 0.924). (Table 4, Figure 1). Seventy five patients (83.33%) required spherical correction after the surgery and 15 (16.67%) did not require any spherical number. Out of 75 patients, 51 (68%) were myopic and 24 (32%) were hypermetropic. The mean post-operative spherical equivalents of the three groups at the end of follow up period of 6 weeks were -0.25±0.78 D, -0.23±0.61 D, -0.19±0.73 D in Groups 1, 2 and 3 respectively and the differences among the three groups were statistically significant. (Table 5). Estimation error was defined as the difference between the actual postoperative spherical error at the 6 weeks follow-up and the predicted postoperative spherical error for each formula. The differences of mean estimation error (ME) among the various formulae in each group were statistically significant. (Table 6, Figure 2). Absolute error was defined as the absolute values of estimation error. Table 7 and figure 3 show the comparison of mean absolute error (MAE) in three groups. The differences of mean absolute error (MAE) among the various formulae in each group were statistically significant. SRK II formula had the least MAE and ME in group 1 and 2 whereas in group 3, SRK/T had the least MAE and ME.

Table 1: Table showing visual acuity of three groups preoperatively.

Visual Acuity	Group 1	Group 2	Group 3	p Value
	Mean ± SD	Mean ± SD	Mean ± SD	
Unaided	0.70±0.25	0.76±0.20	0.75±0.17	0.457
With Spectacles	0.60±0.24	0.73±0.20	0.68±0.18	0.055

ANOVA test.

Table 2: Table showing comparison of IOL power calculated by SRK/T, SRK II, Hoffer Q and Haigis in each group.

Formula	IOL POWER (in Dioptres)		
	Group 1	Group 2	Group 3
SRK/T	25.57±1.51	21.11±1.89	13.19±1.44
SRK II	25.17±1.35	20.92±1.56	13.81±1.26
Hoffer Q	26.10±1.88	21.31±2.33	12.82±1.65
Haigis	27.63±2.09	22.39±2.54	13.40±1.60
p value*	0.001	0.037	0.042

*Analysis of variance (One way ANOVA).

Table 3: Table showing mean IOL power implanted and calculated in each group

Mean IOL (in Dioptre)	Group 1	Group 2	Group 3
	Mean ± SD	Mean ± SD	Mean ± SD
Mean IOL power implanted	25.28±1.55	20.75±1.72	13.21±1.54
Mean IOL power calculated	26.10±1.88	21.11±1.89	13.40±1.60
p value*	0.056	0.023	0.001

*Independent sample t-test.

Table 4: Table showing comparison of postoperative visual acuity.

Visual acuity Unaided (in log MAR unit)	Group 1	Group 2	Group 3	P Value*
	Mean ± SD	Mean ± SD	Mean ± SD	
First Post-Operative Day	0.27±0.16	0.22±0.13	0.19±0.08	0.058
First Post-Operative Week	0.19±0.10	0.18±0.07	0.19±0.08	0.980
Sixth Post-Operative Week	0.16±0.06	0.17±0.07	0.16±0.06	0.924

*ANOVA TEST.

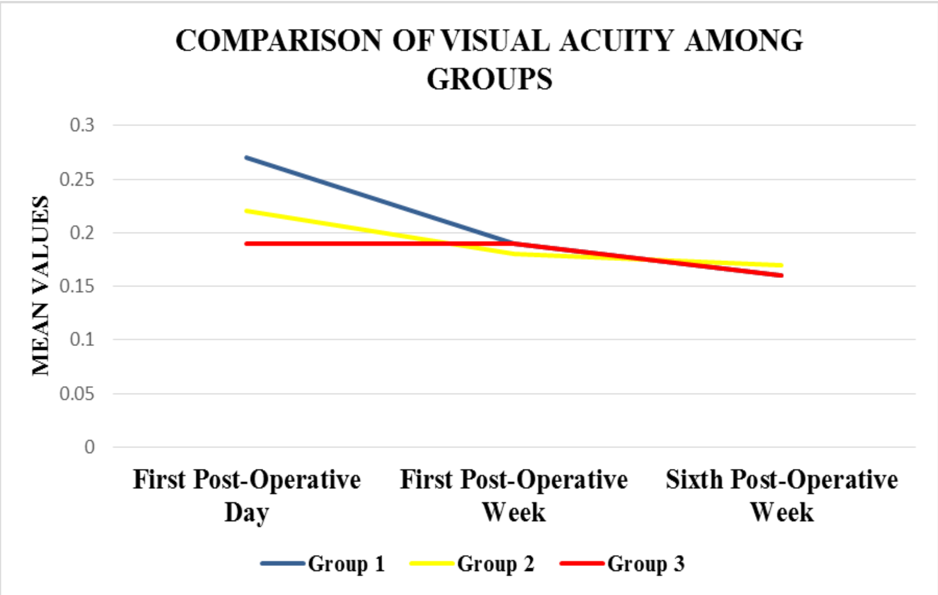

Fig. 1: Graphical representation of comparison of postoperative visual acuity.

Table 5: Table showing mean of postoperative spherical equivalent in groups.

Group	Spherical equivalent (in diopters)		p Value*
	Mean± SD	Range	
Group 1	-0.25±0.78	-1.50 to 1.00	0.049
Group 2	-0.23±0.61	-0.50 to 1.25	
Group 3	-0.19±0.73	-1.00 to 1.00	

*ANOVA test.

Table 6: Table showing mean estimation error with each formulae in each group.

Formula	Mean estimation error (in dioptres)		
	Group 1	Group 2	Group 3
SRK/T	-0.56±0.68	-0.49±0.60	-0.15±0.60
SRK II	-0.15±0.67	-0.28±0.64	-0.86±0.65
Hoffer Q	-1.08±0.86	-0.74±0.80	0.22±0.79
Haigis	-2.61±0.91	-1.76±1.06	-0.33±0.63
p value*	0.001	0.001	0.001

*Kruskal Wallis H test.

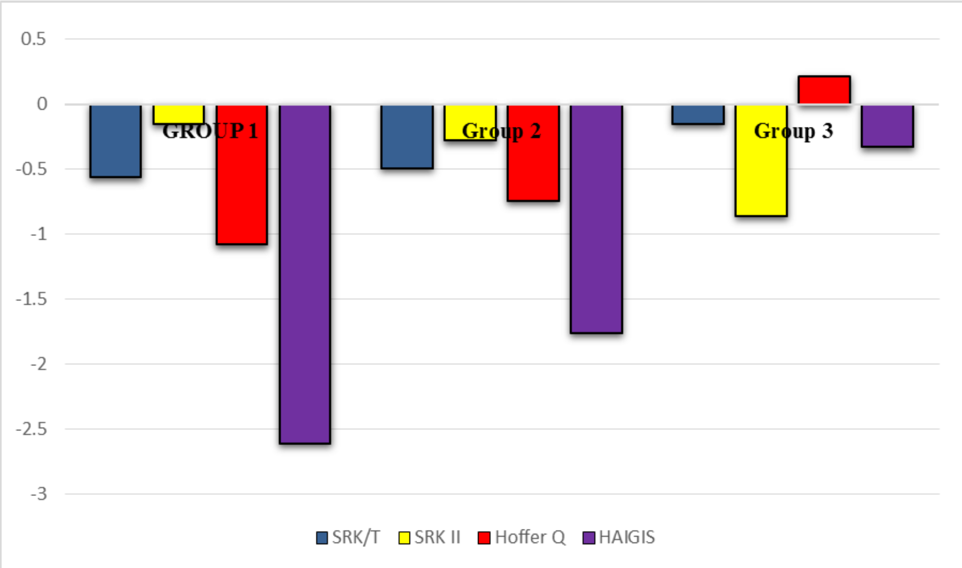

Fig. 3: Bar diagram showing mean estimation error with each formula in each group.

Table 7: Table showing mean absolute error (MAE) with each formula in each group.

Formula	Mean absolute error (in dioptres)		
	Group 1	Group 2	Group 3
SRK/T	0.76±0.43	0.67±0.38	0.49±0.36
SRK II	0.56±0.38	0.54±0.43	0.89±0.60
Hoffer Q	1.18±0.71	0.90±0.60	0.63±0.51
Haigis	2.61±0.91	1.83±0.94	0.62±0.34
P value*	0.001	0.001	0.001

*Kruskal Wallis H test.

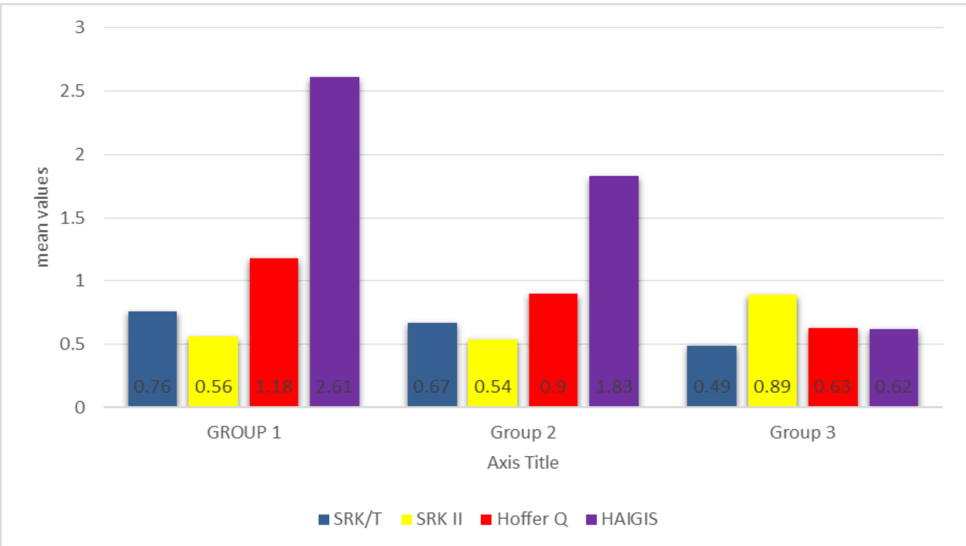

Fig. 4: Bar diagram showing comparison of mean absolute error in each group.

DISCUSSION

In modern times, cataract surgery has evolved into a refractive surgery with the aim of achieving near perfect visual outcome. This depends largely on our ability to predict accurate IOL power for each patient. This has been made possible by the various formulae available at our disposal which in addition with latest surgical techniques such as micro incision surgeries and foldable IOLs ensure satisfactory visual outcome both for the patient and the surgeon. In our study, the number of patients with post-operative refractive error within the range of ±0.5 D was 17 (56.7%), 21 (70%) and 18 (60%) in groups 1, 2 and 3, respectively. The number of patients with a post-operative refractive error within the range of ± 1 D was 29 (96.7%), 28 (93.3%) and 30 (100%) in groups 1, 2 and 3 respectively. The number of patients with a post-operative refractive error within the range of ± 2 D was 30 (100%), 30 (100%) and 30 (100%) in groups 1, 2 and 3 respectively. This observation is better than that of other studies such as Fritch et al who reported patients with error ± 1 D in 54% patients and ± 2D in 85% patients.[5] Thompson et al in 1986 had 74.3% patients with ± 1D, 91.4% with ± 2D and 100% with ± 3 D error.[6] Gregory et al in 1989 used SRK formula in his study showed 90.7% patients within ± 2 D range and 67.9% in ± 1D range of error.[7] Hillman and Kraff using Binkhorst formula had 92.93% patients in ± 1D range and upto 98% in ±2 D range of error.[8] Studies by Sanders, Retzlaff and Kraff are very promising with upto 90% or more patients with errors less than ± 2 D.[9] The improvement in post-operative refractive error in our study may be attributed to better techniques of biometry and surgical procedures at present. The clinical accuracy is compared with mean estimation error (ME) and mean absolute error (MAE). The clinical accuracy of ME and MAE within ±0.5 D and within ± 1 D with each of the formulae was compared. SRK II formula had the least MAE and ME in group 1 and 2 whereas in group 3, SRK/T had the least MAE and ME. Hence it may be safely concluded that SRK II has better predictive accuracy for calculations of IOL power in eyes with axial length (AL) <22 and (AL) 22-24.5 mm and SRK/T has better predictive accuracy for calculation of IOL power in eyes with (AL)>24.5mm as the MAE and ME for formula is least. Kijima et al in 1999 reported that for AL 24.5-29.6 mm SRK/T is the best formula available which is similar to the observation made by our study.[10] In 2007, Mac Laren et al proposed that Haigis and Hoffer Q formula is quite accurate in cataract surgery for extreme hyperopic patients.[11] In 2013, Wang published a study to investigate the predictability of intraocular lens (IOL) power calculation using the IOL Master and different IOL power calculation formulae in eyes with various axial lengths (AL). They concluded that compared with other formulae, the Haigis formula yields superior refractive results in eyes with various ALs.[12] In 2014, Mitra et al studied the efficacy of intraocular lens power calculation formulae in a subset of Indian myopic population. They retrospectively reviewed 43 patients who underwent phacoemulsification with high axial length (AL) (>24.5 mm, range 24.75-32.35 mm). A subcategory of axial length 24.5-26.5 mm was also tested. Holladay 1, Hoffer Q and SRK/T formulae showed a slight tendency toward resultant hyperopia, with a mean error of +0.24 diopters (D), +0.58 D, and +0.92 D, respectively. The Holladay 1 formula provided the best predictive result.[13] Nilanga et al in 2015 reviewed 274 patients, the results support SRK II formula as a good option to predict the refractive error after cataract extraction by phacoemulsification in eyes with medium axial length.[14] In 2016 Zhang et al reviewed 407 eyes of 219 patients with AL longer than 26.0 mm. The refractive prediction errors of IOL power calculation formulas (SRK/T, Haigis, Holladay, Hoffer Q, and Barrett Universal II). The Barrett Universal II formula had the lowest mean absolute error (MAE) and SRK/T and Haigis had similar MAE.[15]

In 2016 Karabela et al reviewed patients in 2 groups based on axial length (AL). group1: (AL) <22 mm and group 2: (AL) 22-24.5mm. They concluded that SRK/T is better predictor in both the groups.[16] The optimization of visual results after cataract surgery is dictated by the predictive efficacy of the intraocular lens to be implanted in the eye. The present study showed a high and similar predictive value for the common formulae used for preoperative intraocular power calculation in a range of patients normally presenting with cataract. SRK/T, SRK II were comparable in axial length (AL) >22 mm and 22-24.5 mm and SRK/T, Hoffer Q and Haigis were comparable in AL>24.5mm.

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