ORIGINAL RESEARCH

A Comparative Analysis Of Various Intraocular Lens Power Calculation Formulae To Achieve Emmetropia Following Cataract Surgery By Phacoemulsification

[1]Dr. Anvay Gandhi, [2]Dr. Rajendra Choudhary, [3]Dr. Avinash Kaundiniya, [4]Maj Gen Dr. Deepak Kalra, [5]Dr. Samrity Gandhi

[1,5]PG Resident, [2]Associate Professor, [3]Professor, [4]Professor and Head, Department of Ophthalmology, Pacific Medical College and Hospital, Rajasthan, India

Corresponding Author
Dr. Samrity Gandhi,
PG Resident, Department of Ophthalmology, Pacific Medical College and Hospital, Rajasthan, India

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ABSTRACT
Aim: To compare various intraocular lens power calculation formulae to achieve emmetropia following Cataract surgery by phacoemulsification. **Materials and Methods:** The present prospective study was conducted in the department of Ophthalmology, Pacific Medical College & Hospital among 240 patients undergoing cataract surgery at this centre from January 2018 –June 2019. Comparative analysis was performed using Optical Coherence Biometry (Zeiss IOL master) to measure IOL power and compare residual postoperative spherical refraction after topical Phacoemulsification using four different formulae. After 6 weeks, the analysis was completed. For the purposes of this investigation, postoperative refraction was taken at 6 weeks for all four groups of patients implanted with IOLs using four different equations. For all formulas, an optimised lens constant and an IOL with a standardised "A" constant were utilised. The IOL Master offers automatic measurement, automatic right/left detection, a graphical user interface with the most commonly used IOL power calculation formulas (SRK/T, Hoffers Q, Holladay, and Haigis), and data transfer. **Results**: Mean AL and ACD was higher in SRK-T group in comparison to other groups and this was statistically significant. Mean residual SRE among small eyes was higher in Hoffer Q group followed by Holladay, SRK-T and Haigis groups. **Conclusion**: After analysis of results, we found that over all in all eyes Hoffers Q Formula is coming as most accurate. In Small eyes as well as in Normal eyes Hoffer Q IOL formula is most accurate followed by Holladay formula, SRK-T formula and Haigis formula and In case of Large eyes Holladay formula is coming better followed by Hoffer Q, Haigis and SRK-T formula.
Keywords: Cataract, IOL, Emmetropia, Accuracy

INTRODUCTION

After the age of 50, cataract affects nearly 9–12 million Indians annually, which is more than glaucoma, macular degeneration, and diabetic retinopathy combined. Cataract removal is a much more frequent surgical procedure in India, which has a success rate of around 98% and great visual recuperation.[1,2] Every year, more than one million intraocular lenses (IOLs) are implanted.[2] Cataract surgery has advanced to the point of accuracy where it is now a kerato-refractive technique, and complete visual rehabilitation in terms of distant and near visual acuity, contrast sensitivity, and depth of focus is anticipated.

A miscalculation of the IOL's power is the most frequent cause of a subpar surgical outcome, making it the most important aspect of the preoperative workup. The search for an IOL formula that can produce post-surgical emmetropia and can be used with all types of eyes and circumstances has been on-going.[3]

Since Harold Ridley implanted the first IOL in 1949 and was surprised to acquire a postoperative refraction of 18DS/+6DC/20°, formulas for calculating IOL power have developed.[3] Since the natural lens had a power of 23D, he implanted an IOL with the same power. Since then, ophthalmologists have worked hard to develop a trustworthy IOL formula. According to how they were derived, IOL equations can be categorised as either (a) theoretical formulae, (b) formulae based on regression analysis, or (c) a combination of both. Different generations have been used to describe various stages of the evolution of IOL power Formulae. The patient's preoperative refraction was considered while using a power estimating approach at first. Later, a more precise calculation based on biometric parameters was developed from this.[3]

After cataract surgery, selecting among the wide range of IOL power equations can be difficult in order to achieve emmetropia. Prior to cataract surgery, the anatomical and optical characteristics of the eye must be taken into account when choosing an IOL. Most of the time, our goal is to attain emmetropia, but occasionally, depending on the unique requirements of each patient, ametropia may occur and some residual myopia may be necessary.[4]

Ocular AL is one of the most crucial factors when determining IOL power. ACD, lens thickness, and vitreous cavity depth are all factors that go towards calculating AL. Up to 2.5 to 3 Dioptres of IOL power can be changed using it (D). The corneal radius of curvature, which is measured by keratometry (K), is another significant metric. About two thirds of the eye's total refractive power is contained in the cornea, the transparent portion of the eye that covers the iris, pupil, and anterior chamber.

The power of the IOL can be changed by variations in corneal refractive power in a ratio of almost 1:1. In addition to AL and K, preoperative ACD and corneal white-to-white distance (WTW; sometimes known as the horizontal corneal diameter) may also be necessary parameters, depending on the type of formula utilized. The WTW distance is the horizontal distance between the borders of the corneal limbus, and the anterior chamber is the fluid-filled area between the iris and the innermost surface of the cornea.[5]

AIM

A comparative analysis of various intraocular lens power calculation formulae to achieve emmetropia following Cataract surgery by phacoemulsification.

OBJECTIVES

To compare the accuracy of four IOL power calculation formulae by comparing the postoperative residual objective spherical refraction.

1. SRK/T- The third generation formulae and comparing with other formulae.
2. HOFFER Q- Third generation IOL formulae and comparing with other IOL formulae.
3. HAIGIS- The fourth generation formulae and comparing it with other IOL formulae.
4. HOLLADAY- The fourth generation formulae and comparing it with other IOL formulae.

MATERIALS AND METHODS

The present prospective study was conducted in the department of Ophthalmology, Pacific Medical College & Hospital among the patients undergoing cataract surgery at this centre from January 2018 – June 2019. Comparative analysis was performed using Optical Coherence Biometry (Zeiss IOL master) to measure IOL power and compare residual postoperative spherical refraction after topical Phacoemulsification using four different formulae. After 6 weeks, the analysis was completed.

Sample size estimation: Sample size was calculated with the following information:

Standard deviation (σ), Precision required (Relative 15%), Probablity of type I error = 0.05

$$n= (z^2 (1- \alpha/2) \sigma^2) /d^2$$

By using the formula, the sample size calculated for the current study is:

- Considering: (σ)- is 1.15 as per previous studies
- Relative precision (d)= 15 %
- Sample size = 183
- Assuming non-response rate= 15%
- Sample size is 211.
- (Target sample size is approx. 240 in order to have adequate numbers for sub group analysis)

For the current study, a sample size of 240 was divided into four groups of 60 each.

INCLUSION CRITERIA

1. All age related cataract patients undergoing cataract surgery by PKE

EXCLUSION CRITERIA

1. Any history of ocular trauma.
2. History of previous ocular surgery
3. Pre-operative astigmatism of more than 0.5 D in order to rule out effect of major astigmatism in postoperative result.
4. Glaucoma
5. Corneal opacities/dystrophies.
6. Any involvement of the macula compromising vision
7. Posterior capsular rent during surgery or complications.

STUDY TECHNIQUE

All patients receiving PKE cataract surgery at this centre were evaluated, and an IOL power estimate was performed using the Zeiss IOL master with the following parameters: AXL, anterior chamber depth, keratometry, and lens thickness. 60 patients were randomly randomised to four groups, each of which had PKE with IOL implantation performed by a single surgeon using one of four equations. For the purposes of this investigation, postoperative refraction was taken at 6 weeks for all four groups of patients implanted with IOLs using four different equations. For all formulas, an optimised lens constant and an IOL with a standardised "A" constant were utilised.

The results were also analysed using AL, with eyes classified as Short (22mm), Normal (22-24mm), and Long (>24mm).

INTROCULAR LENS POWER CALCULATIONS AND FORMULAE

In this work, four equations were employed to calculate IOL Power: SRK-T, Holladay, Hoffer-Q, and Haigis. The first generation formulas rely on a single constant to predict the postoperative position of the IOL (ACD), but the second generation formulae employ ACD as a variable that fluctuates with the AL. Third generation equations (Holladay I, SRK/T) integrated the influence of corneal curvature to improve IOL location prediction. The fourth generation formula (Haigis formula) does not take into account a proportional relationship between the distance from the cornea to the IOL location and the AL. Instead, three constants are used to determine the position and shape of a power prediction curve. The Zeiss IOL Master is programmed with the most well-known contemporary formulae, including SRK-T, Holladay, Hoffer-Q, and Haigis. Our study objectives were to test the accuracy of IOL power calculation in terms of anticipated and actual spherical equivalents in emmetropes, hyperopes, and myopes utilising SRK/T, Hoffers Q, Haigis, and Holladay IOL equations and compare results with postoperative spherical refraction.

The IOL Master offers automatic measurement, automatic right/left detection, a graphical user interface with the most commonly used IOL power calculation formulas (SRK/T, Hoffers Q, Holladay, and Haigis), and data transfer.

PARAMETERS TO BE STUDIED

Primary outcome measurement: Postoperative refraction after surgery done manually and confirmed with auto refraction

Secondary outcome measurement: Unaided Visual acuity

STATISTICAL ANALYSIS

Data were entered into a Microsoft Excel spreadsheet for statistical analysis and subsequently analysed using SPSS (version 24.0; SPSS Inc., Chicago, IL, USA) Independent or unpaired samples were used in two-sample t-tests for a difference in mean. Paired t-tests were a type of blocking test that had more power than unpaired tests. The one-way analysis of variance (one-way ANOVA) technique was used to compare the means of three or more numerical data samples. A chi-squared test (or 2 test) was any statistical hypothesis test in which the test statistic's sampling distribution is a chi-squared distribution when the null hypothesis is true.

RESULTS

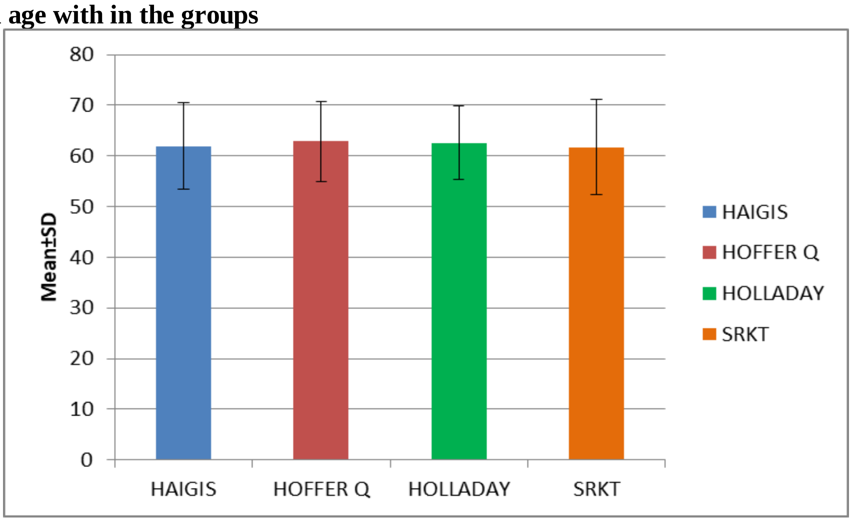
In this study, Haigis groups had 13 (21.7%) female patients and 47 (78.3%) male patients, while Hoffer Q groups had 19 (31.7%) female patients and 41 (68.3%) male patients. In the Holladay group, 24 (40.0%) of the patients were female, while 36 (60.0%) were male. In SRKT, 3 (5.0%) patients were female, while 57 (95.0%) were male. Gender association within subgroups was statistically significant (p=0.0001) as shown in table 1. The mean age distribution within groups was not statistically significant (p=0.8827). [graph 1]

Table 1: Gender Variations with in the Sub groups

Gender	HAIGIS	HOFFER Q	HOLLADAY	SRK-T	TOTAL
Female	13	19	24	3	59
Male	47	41	36	57	181
Chi Square	22.02				
p value	0.0001*				

*: statistically significant

Graph 1: Mean age with in the groups



The patients in the HAIGIS group had a mean axial length of 22.96±0.62. The mean AL of the patients in the HOFFERQ group was 22.93 0.62. The mean AL of the patients in the HOLLADAY group was 23.20±0.62. The mean AL of the patients in the SRK-T group was 23.27±0.76. The mean AL distribution in the groups was statistically significant (p=0.0099). The mean ACD group of the patients in the HAIGIS group was 1.98±.2249. The mean ACD group of the patients in the HOFFER Q group was 2.00±.26. The mean ACD group of the patients in the HOLLADAY group was 2.05±.38. The mean ACD group of the patients in the SRK-T group was 2.15±.44. The mean ACD group distribution within groups was statistically significant (p=0.0358). [Table 2]

Table 2: Distribution of mean AL and ACD with in groups

		Mean	SD	Minimum	Maximum	Median	p-value
Axial Length	HAIGIS	22.96	0.62	21.32	24.05	22.91	0.009*
	HOFFER Q	22.93	0.62	20.93	24.11	22.84	
	HOLLADAY	23.20	0.62	21.79	24.11	23.31	
	SRK-T	23.27	0.76	20.93	24.84	23.25	
ACD	HAIGIS	1.98	0.22	1.00	3.00	2.00	0.036*
	HOFFER Q	2.00	0.26	1.00	3.00	2.00	
	HOLLADAY	2.05	0.38	1.00	3.00	2.00	
	SRK-T	2.15	0.44	1.00	3.00	2.00	

*: statistically significant

The mean refractive error of the patients in the HAIGIS group was -0.33±0.80. The mean refractive error of the patients in the HOFFER Q group was 0.05±0.78. The mean refractive error of the patients in the HOLLADAY group was 0.21±0.73. The mean refractive error of the patients in the SRK-T group was 0.39±.62. The mean residual SRE distribution within groups was statistically significant (p=0.0001). [Table 3]

Table 3: Distribution of Mean Residual Spherical Refractive Error (SRE) with in Groups

		Mean	SD	Minimum	Maximum	Median	p-value
SRE	HAIGIS	-0.33	0.80	-1.87	1.75	-0.50	<0.001*
	HOFFER Q	0.05	0.78	-1.57	1.50	0.25	
	HOLLADAY	0.21	0.73	-1.25	1.75	0.50	
	SRK-T	0.39	0.62	-1.25	1.50	0.5000	

*: statistically significant

The mean residual SRE small eye of the patients in the HAIGIS group was 0.68±0.26. The mean residual SRE small eye of the patients in the HOFFERQ group was -0.62±.17. The mean residual SRE small eye of the patients in the HOLLADAY group was 0.83±.14. The mean residual SRE small eye of the patients in the SRK-T group was 0.75±.00. The mean small eye distribution within groups was statistically significant (p=0.0008).The mean residual SRE in the normal eye of the patients in the HAIGIS group was -0.36±0.80. The mean residual SRE in the normal eye of the patients in the HOFFERQ group was 0.07±0.80. The mean residual SRE in the normal eye of the patients in the HOLLADAY group was 0.19±.75. The mean residual SRE in normal eyes of individuals in the SRK-T group was 0.31±0.63. The mean normal eye distribution within groups was statistically significant (p0.0001). [Table 4]

Table 4: Distribution of Mean Spherical Residual Ref. error in small eye Mean Residual Spherical Ref. error in normal eye with in Group

		No.	Mean	SD	Minimum	Maximum	Median	p-value
Small Eyes (<20mm)	HAIGIS	2	0.68	0.26	0.50	0.87	0.68	0.008*
	HOFFER Q	2	-0.62	0.17	-0.75	-0.50	-0.62	
	HOLLADAY	3	0.83	0.14	0.75	1.00	0.75	
	SRK-T	2	0.75	0.00	0.75	0.75	0.75	
Normal Eyes (20-24mm)	HAIGIS	57	-0.36	0.80	-1.87	1.75	-0.57	<0.01*
	HOFFER Q	56	0.07	0.80	-1.57	1.50	0.25	
	HOLLADAY	51	0.19	0.75	-1.25	1.75	0.50	
	SRK-T	47	0.31	0.63	-1.25	1.50	0.50	

*: statistically significant

The patients in the HAIGIS group had a mean residual SRE in the large eye of -0.50 0.00. The mean spherical residual refractive error in the large eye of the patients in the HOFFER group was 0.25 0.00. The mean spherical residual refractive error in the large eye of the patients in the HOLLADAY group was 0.12 0.64. The mean residual spherical refractive error in the large eye of patients in the SRK-T group was 0.68 0.54. The mean large eye distribution within groups was not statistically significant (p=0.1189). [Table 5]

Table 5: Distribution of Mean Residual Spherical Ref. error in large eye with in Groups

		Number	Mean	SD	Minimum	Maximum	Median	p-value
Large Eyes (>24 mm)	HAIGIS	1	-0.50	0.00	-0.50	-0.50	-0.50	0.12*
	HOFFER Q	2	0.25	0.00	0.25	0.25	0.25	
	HOLLADAY	6	0.12	0.64	-0.50	1.00	0.00	
	SRK-T	11	0.68	0.54	-0.50	1.25	1.00	

*: statistically significant

DISCUSSION

Holladay 1, SRKT (T for theoretical), and Hoffer Q were popular 3rd generation equations that helped boost accuracy even further. Each of these equations, based on the K and/or AL, calculates the position of the IOL within the eye and produces more precise results. As a result, the use of older regression equations in clinical practise has decreased significantly. In order to improve accuracy, 4th generation equations that incorporate additional biometric characteristics were developed: Haigis formula requires ACD and ELP, Holladay 2 formula requires ACD, ELP, lens thickness, preoperative refraction, and patient's age. A prospective study was conducted to examine the accuracy of four formulae for determining IOL power by calculating the difference between expected and final refraction after PKE using each formula. The PCI-based Zeiss IOL master was used to calculate AL, anterior chamber depth, keratometry, lens thickness, and postoperative refraction for all groups of patients implanted with IOLs using four different equations. After 6 weeks, biometric data was entered into each of the IOL power calculation equations and the results were compared to the final refraction. In this work, the following four equations were utilised to calculate IOL Power: SRK-T, Holladay, Hoffer-Q, and Haigis. A total of 240 eyeballs were divided into four groups of 60.

In this study, gender distribution in all subgroups revealed male predominance, which was statistically significant across all groups (p=0.0001). The mean age distribution within groups was not statistically significant (p=0.8827). In this study; mean AL and ACD was higher in SRK-T group in comparison to other groups and this was statistically significant (p=0.0358). In our study Gender, AL and ACD distributions with in the subgroups showed statistically significant difference in spite of adequate randomization. This may have bearing on the final results.

In a study done by **Fam HB et al[6],** the mean absolute error achieved using the Hoffer Q method was (0.75+/-0.52 D), Holladay was (0.75+/-0.62 D), in SRK-T it was (0.76+/-0.60 D) and with SRK-T formula, 51.4% of eyes were within +/-0.50 D of emmetropia and 67.6% of eyes were within +/-1.00 D. In the Holladay group the highest percentage (81.1%) of eyes within +/-1.00 D and 45.9% of the eyes in this group were within +/-0.50 D. In our study least mean residual SRE was found in Hoffer Q (0.05) followed by Holladay (0.21), SRK-T(0.39) and Haigis formula (-0.33).

In the present study, mean residual SRE among small eyes was higher in Hoffer Q group followed by Holladay, SRK-T and Haigis groups. This difference was statistically significant (p=0.0008).

In a study done by **Gavin EA et al[7],** it was found that the Hoffer Q formula showed a mean prediction error of 0.61 D while SRK-T showed a mean prediction error of 0.87 D. A paired *t*-test found that the Hoffer Q was significantly more accurate than the SRK-T formula (*P*<0.001). Our study has also shown a similar result and has found Hoffer Q formula to be more accurate than the SRK-T formula in small eyes. Hoffer Q was more accurate than Holladay, SRK-T and Haigis formula.

Another study done by **Karabela Y et al[8]**, Haigis formula provided most accurate results & Hoffer *Q* was also found to be comparable and could be used as an alternative. However, in a study by **Moschos MM et al[9]** Haigis formula had statistically significant smaller mean residual refraction in comparison to Holladay, Hoffer Q, and SRK/T. The Haigis formula predicted more eyes with residual within ±0.5 D and ±1.0 D of predicted SRE compared to other formulae. This was in contrast to our study in which Hoffer Q were most accurate with lowest mean refractive error followed by Holladay, SRK-T and Haigis in smaller eyes.

In our study, in normal eyes (AL 20 to 24mm) in Haigis group the mean residual SRE was -0.36 ± 0.80, in Hoffer Q group mean residual SRE was 0.07±0.80, in Holladay group it was 0.19 ± 0.75 and in SRK-T group mean residual SRE was 0.31±.63. This was statistically significant (p<0.0001). In normal sized eyes Hoffers Q emerged the most accurate formula followed by Holladay, SRK-T and Haigis. A study by Bai L et al[10] found that Hoffer Q formula appeared to be more accurate when measuring ALs with A-Scan, whereas Haigis formula was more accurate when combined with IOL Master (0.37 +/- 0.14). For selection of IOL formula in eyes with high hyperopia, Haigis formula would be the most accurate using IOL Master analysis, but the Hoffer Q was better when using A-scan.

In their study Mansour MN et al[9] found that the accuracy of SRK/T and Haigis formulae used for intraocular lens (IOL) power calculation was significant in eyes with an AL of more than 25 mm. The proportion of patients having a prediction error within ±0.50 of SRK/T formula (54.29%) was comparable to those of Haigis (55.71%). In another study done by Doshi D et al[11] it was found that in eyes with AL more than 24.5 mm Hoffer Q, Holladay, SRK/T and Haigis formulae were equally accurate. Karabela Y et al[12] found that in eyes ≥24.6 mm the SRK/T formula performs well and shows good predictability in eyes with long ALs. In our study Holladay formula was found better in long eyes followed by Hoffers Q, Haigis and SRK-T but distribution of mean large eye with in groups was not statistically significant (p=0.1189).

LIMITATIONS

The notable short comings of this study are:

1. Distributions of eyes are not equal in different subgroups of eyes (small, normal and large) because samples were taken randomly.
2. Age was matched in this study but gender was not matched in our study.
3. The limitation of this study was the small number of eyes which was randomly taken Further studies requires more eyes to further assess the accuracy of variable formulae for the subgroups.

CONCLUSION

There are multiple techniques and methods to measure corneal power and AL necessary for different IOL calculation formulae existing at present time. In this Prospective study after analysis of results we found that over all in all eyes Hoffers Q Formula is coming as most accurate.

In Small eyes as well as in Normal eyes Hoffer Q IOL formula is most accurate followed by Holladay formula, SRK-T formula and Haigis formula and In case of Large eyes Holladay formula is coming better followed by Hoffer Q, Haigis and SRK-T formula.

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