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Original Research Article

Analysis of Various Intraocular Lens Power Calculation Formulae to Achieve Emmetropia Following Cataract Surgery by Phacoemulsification: A Comparative Analysis

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Abstract

Aim: The aim of the present study was comparative analysis of various intraocular lens power calculation formulae to achieve emmetropia following Cataract surgery by phacoemulsification.

Methods: After obtaining clearance from ethical committee of the institute, the study was conducted in the Department of Ophthalmology, Darbhanga Medical College and Hospital, Darbhanga, Bihar. All patients undergoing cataract surgery by PKE in this centre were taken and an IOL power calculation was done using Zeiss IOL master utilising parameters; AXL, anterior chamber depth, keratometry and lens thickness. 40 Patients were randomly assigned to 4 groups each were underwent PKE with IOL implantation by a single surgeon using one of the 4 formulae.

Results: We found in our study a total of 160 eyes were studied and subdivided into 4 groups as per IOL Formulae were taken for the study. 40 Patients were randomly assigned to 4 groups each were underwent PKE with IOL implantation by a single surgeon using one of the 4 formulae. In our study distribution of mean AL in the groups was statistically significant (p=0.0099). Distribution of mean residual SRE with in the groups was statistically significant (p<0.0001). It was found that difference of mean small eye and normal eye with in groups was statistically significant but difference of mean large eye with in groups was not statistically significant.

Conclusion: We found that aver 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: Intraocular Lens Power, Formulae, Cataract Surgery , Phacoemulsification

Introduction

Cataract surgery comprises of the major proportion of surgeries performed in ophthalmology. With advanced technology and procedures, the newer Intraocular Lenses (IOL) aim towards achieving highly defined vision along with emmetropia. [1] The achievement of emmetropia in cataract surgery depends highly on accurate determination of IOL power, which depend on the various variables in biometry such as average corneal refractive power (keratometry), Anterior Chamber Depth (ACD), Axial Length (AL) and the refractive index of lens material (A constant).

It is challenging for the surgeon to select appropriate intraocular lens (IOL) power calculation formulae for axial myopic eyes, especially for the highly axial myopic eyes. [2,3] Three main sources of errors in IOL power calculation of axial myopic eyes are the AL measurement error, anterior chamber depth (ACD) measurement error and effective lens position (ELP) error. With the introduction of optical biometry, the accuracy of AL and ACD measurement has been significantly improved. Now, the main source of predictive refraction error of IOL power calculation in axial myopic eyes is ELP error which is determined by IOL formulae. [4]

IOL formulae have been proposed more than 40 years to calculate IOL power after cataract surgery. [3] Over the past few decades, the third- or fourth generation formulae (traditional formulae) still were the most common method used in IOL power calculation. [5]

Formulae for calculation of IOL power have evolved since Harold Ridley implanted the first IOL in 1949 and was surprised to get a postoperative refraction of −18DS/+6DC/20°. [6] He implanted an IOL of power 23D since that was the power of the natural lens. Since then the ophthalmologists have strived to arrive at a reliable IOL formula. The evolution of IOL formulae can be classified on the basis of their derivation as (a) theoretical formulae, (b) those based on regression analysis, and (c) a combination of both principles. Various phases of IOL power Formulae evolution have been labelled as various generations. Initially, a power estimation method was used, and the patient's preoperative refraction was taken into account. Later, this evolved into a more specific calculation based on biometric parameters. First-generation formulae, such as SRK (Sanders, Retzlaff and Kraff) were based on the regression to estimate power of the lens which was based on cornea (K), axial length (AL), and A- Constant for the specific IOL to estimate power for IOL. They were found to be accurate in average sized eyes, but for shorter or longer eyes these formulae were not reliable. In second generation formulae, SRK II, a modification was made. [7]

In order to achieve emmetropia after cataract surgery, choosing from this plethora of IOL power formulae remains a challenge. For selection of IOL before cataract surgery the anatomical and optical parameters of eye have to be considered. In most of the cases we aim to achieve emmetropia but in some cases, depending on the specific needs of the individual patients, ammetropia may result and some residual myopia may be required. In calculating IOL power, one of the most important parameters is ocular AL. AL is a combination of anterior chamber depth (ACD), lens thickness and vitreous cavity depth. It can change the IOL power by up to 2.5 to 3 Dioptres (D). Another important parameter is the corneal curvature and keratometry (K) is the measurement of the corneal radius of curvature. The cornea is the transparent part of the eye that covers the iris, pupil and anterior chamber and it accounts for around two thirds of the eye's total refractive power. Changes in corneal refractive power can alter the IOL power in a ratio of nearly 1:1. Other than AL and K, other parameters that may be also required depending on the type of formula used are the preoperative ACD and the corneal white-to-white distance (WTW; also called the horizontal corneal diameter). The anterior chamber is the fluid-filled space between the iris and the innermost surface of the cornea and the WTW distance is the horizontal distance between the borders of the corneal limbus. [8]

For the purpose of study the eyes are divided into following subgroups depending on the formulae used

- SRK/T
- HOFFER Q
- HOLLADAY
- HAIGIS

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

Methods

Patients were undergoing cataract surgery at the centre Department of Ophthalmology, Darbhanga Medical College and Hospital, Darbhanga, Bihar, India.

Study Technique

After obtaining clearance from ethical committee of the institute, the study was conducted in the Department of Ophthalmology, Darbhanga Medical College and Hospital, Darbhanga, Bihar. All patients undergoing cataract surgery by PKE in this centre were taken and an IOL power calculation was done using Zeiss IOL master utilising parameters; AXL, anterior chamber depth, keratometry and lens thickness. 40 Patients were randomly assigned to 4 groups each were underwent PKE with IOL implantation by a single surgeon using one of the 4 formulae.

Postoperative refraction for all 4 groups of patients implanted with IOL using four different formulae at 6 weeks was taken for the purpose of this study. An optimized lens constant and an IOL with a standardised ―A‖ constant was used for all formulae. Results were also analysed according to AL, with eyes classified as Short Eyes (<22mm), Normal Eyes (22-24 mm), and Long Eyes (>24mm)

Statstical Analysis

For statistical analysis data were entered into a Microsoft excel spreadsheet and then analyzed by SPSS (version 24.0; SPSS Inc., Chicago, IL, USA) and GraphPad Prism version 5. Data had been summarized as mean and standard deviation for numerical variables and count and percentages for categorical variables. Two-sample t-tests for a difference in mean involved independent samples or unpaired samples. Without other qualification, 'chi-squared test' often is used as short for Pearson's chi-squared test. Unpaired proportions were compared by Chi-square test or Fischer's exact test, as appropriate. p-value ≤ 0.05 was considered for statistically significant.

Results

Table 1: Distribution of mean in four groups

		No.	Mean± SD	Min.	Max.	Median	p-value
Age	HAIGIS	40	61.98±8.51	39.00	80.00	62.00	0.8820
	HOFFER Q	40	62.85±7.88	42.00	76.00	64.00	
	HOLLADAY	40	62.56 ±7.24	44.00	76.00	62.50	
	SRK-T	40	61.76 ±9.43	32.00	87.00	62.00	
Axial length	HAIGIS	40	22.96 ±0.62	21.32	24.05	22.91	0.0088
	HOFFER Q	40	22.93 ±0.62	20.93	24.11	22.84	
	HOLLADAY	40	23.20 ±0.62	21.79	24.11	23.31	
	SRK-T	40	23.27 ±0.76	20.93	24.84	23.25	
Axial Length group	HAIGIS	40	1.98 ±0.22	1.00	3.00	2.00	0.0360
	HOFFER Q	40	2.00 ±0.26	1.00	3.00	2.00	
	HOLLADAY	40	2.05 ±0.38	1.00	3.00	2.00	
	SRK-T	40	2.15 ±0.44	1.00	3.00	2.00	
SRE	HAIGIS	40	0.33 ±0.80	-1.87	1.75	-0.50	
	HOFFER Q	40	0.05 ±0.78	-1.57	1.50	0.25	<0.0001

	HOLLADAY	40	0.21 ±0.73	-1.25	1.75	0.50	
	SRK-T	40	0.39 ±0.62	-1.25	1.50	0.500	
Small Eyes (<20 mm)	HAIGIS	2	0.68 ±0.26	0.50	0.87	0.68	0.0008
	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	<0.0001
	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	
Large Eyes (>24 mm)	HAIGIS	1	-0.50 ±0.00	-0.50	-0.50	-0.50	01120
	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	

We found in our study a total of 160 eyes were studied and subdivided into 4 groups as per IOL Formulae. In this study Haigis groups 13 (21.7%) patients were female and 47 (78.3%) patients were male, Hoffer Q groups 19 (31.7%) patients were female and 41(68.3%) patients were male. In Holladay group, 24(40.0%) patients were female and 36(60.0%) patients were male. In SRKT, 3 (5.0%) patients were female and 57(95.0%) patients were male. Association of gender within the subgroups was statistically significant (p=0.0001).

Our study showed that in HAIGIS group the mean age of the patients was 61.98 ± 8.51 years. In HOFFERQ group the mean age of the patients was 62.85 ± 7.88 years. In HOLLADAY group the mean age of the patients was 62.56 ± 7.24 years. In SRK-T group the mean age of the patients was 61.76 ± 9.43 years. Distribution of mean age with in groups was not statistically significant (p=0.8820). In our study we showed that HAIGIS group the mean. Axial length of the patients was 22.96 ± 0.62. In HOFFERQ group the mean AL of the patients was 22.93 ± 0.62. In HOLLADAY group, the mean AL of the patients was 23.20 ± 0.62. In SRK-T group the mean AL of the patients was 23.27 ± 0.76. Distribution of mean AL in the groups was statistically significant (p=0.0088). We found in HAIGIS group the mean AL group of the patients was 1.98 ±0.2249. In HOFFER Q group the mean AL group of the patients was 2.00 ± 0.26. In HOLLADAY group the mean AL group of the patients was 2.05 ± 0.38. In SRK-T group the mean AL group of the patients was 2.15 ± 0.44. Distribution of mean AL group with in. groups was statistically significant (p=0.0360). In our study we showed HAIGIS group the mean refractive error of the patients was -0.33 ± 0.80. In HOFFER Q group the mean refractive error of the patients was 0.05 ± 0.78. In HOLLADAY group the mean refractive error of the patients was 0.21 ± 0.73. In SRK-T group the mean refractive error of the patients was 0.39 ± 0.62. Distribution of mean residual SRE with in the groups was statistically significant (p<0.0001).

Our study showed that in HAIGIS group the mean residual SRE small eye of the patients was 0.68 ± 0.26. In HOFFERQ group, the mean residual SRE small eye of the patients was -0.62 ± 0.17. In HOLLADAY group the mean residual SRE small eye of the patients was 0.83 ± 0.14. In SRK-T group the mean residual SRE small eye of the patients was 0.75 ± 0.00. Distribution of mean small eye with in groups was statistically significant (p=0.0008). In HAIGIS group the mean residual SRE in normal eye of the patients was -0.36 ± 0.80.In HOFFERQ group, the mean residual SRE in normal eye of the patients was 0.07 ±0.80. In HOLLADAY group the mean residual SRE in normal eye of the patients was 0.19 ± 0.75. In SRK-T group the mean residual SRE in normal eye of the patients was 0.31 ± 0.63. Distribution of mean normal eye with in groups was statistically significant (p<0.0001). In our study we showed that HAIGIS group the mean residual SRE in large eye of the patients was -0.50 ± 0.00. In HOFFER group the mean spherical residual refractive error in large eye of the patients was 0.25 ± 0.00. In HOLLADAY group the mean spherical residual refractive error in large eye of the patients was 0.12 ± 0.64. In SRK-T group the mean residual spherical refractive error in large eye of the patients was 0.68 ± 0.54. Distribution of mean large eye with in groups was not statistically significant (p=0.1120).

Discussion

One of the essential elements to achieve postoperative emmetropia in cataract surgery is an accurate measurement of axial length. The principle of signal reflection is used to measure the axial length of the eye. The time taken for the signal to reflect back is measured and divided by two and multiplied into the speed of the signal to give the axial length. [9] A 1 mm error in axial length measurement results in a refractive error of approximately 2.35 D error. The two types of biometry used currently are optical and ultrasonic biometry. This study makes an effort to compare the swept source Optical Coherence Tomography (OCT) optical biometry and ultrasonic biometry using two formulae (SRK-II and Holladay I).

In Haigis group, the mean residual Spherical Refractive Error (SRE) of the patients was -0.33 ±0.80, in Hoffer Q group residual SRE was 0.05 ± 0.78, in Holladay group mean residual SRE was 0.21 ± 0.73 and in SRK-T group mean residual SRE was 0.39 ± 0.62. The lowest mean residual SRE was found in Hoffer Q followed by Holladay, SRK-T and Haigis. This association was statistically significant (p<0.0001).In a study done by Fam HB et al [10] (2008) in 37 eyes of 37 patients IOL power was calculated using the formulae :(SRK), SRK-T , Holladay , Hoffer Q, The calculated IOL power was compared and used to determine the mean error and mean absolute error of refractive outcome for each eye. 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 lest 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 small eyes (< 20mm), in Haigis group, the mean residual SRE was 0.68 ± 0.26, in Hoffer Q group mean residual SRE was -0.62 ± 0.17, in Holladay group it was 0.83 ± 0.14 and in SRK-T group mean residual SRE was 0.75 ± 0.00. Mean residual SRE in 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 [8] IOL power was calculated using SRK-T and Hoffer Q formulae. Refractive outcome was measured and the accuracy of the two formulae were compared in 41eyes with an AL <22 mm. 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 [11] compared the predictability of different IOL power calculation formulae using (SRK) II, SRK-T, Haigis, Hoffer Q in eyes with AL <22 mm using IOL master. Here 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 [12] 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.

A study by Bai L et al [13] 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 our study using IOL Master, Hoffers Q formula was the most accurate in Normal eyes followed by Holladay, SRK-T and Haigis and the difference was statistically significant ($p<0.0001$). Distribution of mean residual refractive error in large eye with in groups was not statistically significant ($p=0.1120$).

Karabela Y et al [14] 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 ($p=0.1120$). In this Prospective study after analysis of results we found that in all eyes Hoffers Q Formula is coming as most accurate. [15]

Conclusion

At present, cataract surgery is one of the most frequently performed and successful operations in the world. As cataract surgery technology and intraocular lens technology have improved remarkable and become safe; the patients have been expecting better postoperative refractive results, which are determined by the precise intraocular lens power calculation. 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 aver 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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