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Research Article

Comparative study of various intra ocular lens formulae by IOL master

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ABSTRACT

Background: The aim and objective of the study was to calculate intraocular lens power with IOL master in 100 eyes of 100 patients with long axial lengths between 25mm to 32mm.To analyse and compare the results of various formulae by postoperative auto refractometry and corrected distance visual acuity and to know the most accurate formula for highly myopic eyes (Axial length more than 25.00 mm).
Methods: Patients coming to Sarojini Devi Eye Hospital from December 2012-September 2014 for cataract surgery were considered in this study. All patients with visually significant cataract having fundus findings within normal limits were included in this study and patients of complicated cataract due to trauma, uveitis, Glaucoma and any corneal pathology were excluded from the study.
Results: The Mean AL was 27.25 ± 1.25 mm, the Mean keratometric value was 43.62 ± 1.45 D, and the Mean Absolute Error (MAE) calculated by the Haigis was 0.07 DD. Compared to the MAEs generated by the other formulae, the MAE generated by the Haigis was comparable to that by the SRK/T (0.231 D), and significantly lower than those by the Hoffer Q (0.481 D) and Holladay (0.864 D).
Conclusions: The Mean post-operative refractive error (spherical equivalent) was found to be the least with Haigis formula followed by SRK/T for eyes with long axial length.
The HAIGIS formula has a better predictability and accuracy. The postoperative hyperopic shift was comparable between HAIGIS and SRK-T formulae the least postoperative hyperopic shift with Haigis formula compared to other formulae.

Keywords: Haigis, SRK-T, Holladay

INTRODUCTION

The current study is intended to measure the accuracy of IOL power calculation by IOL Master and comparing various formulae in eyes with long axial length.[1]

The ultra-high precision of partial coherence interferometry seems promising in terms of improved accuracy in intraocular lens power calculation.[2] The fast developing corneal topographic technology and the introduction of ray tracing and light interference techniques may aid in providing extended diagnostic data[3] in measuring ocular biometry for cataract surgeries.

The aim and objective of the study was to calculate intraocular lens power with IOL master in 100 eyes of 100 patients with long axial lengths between 25 mm to 32 mm. To analyse and compare the results of various formulae by postoperative auto refractometry and corrected distance visual acuity and to know the most accurate formula for highly myopic eyes (Axial length more than 25.00 mm).

IOL master

The IOL Master (Figure 1) is a combined biometry instrument for the measurement of data of the human eye needed to calculate the power of an implanted Intraocular lens. The Axial length measurement is based on partial coherence interferometry (PCI) principles (Figure 2) based on the Michelson interferometer and takes about 0.4 seconds to measure.

METHODS

Patients coming to Sarojini Devi Eye Hospital from December 2012-September 2014 for cataract surgery were considered in this study.

Inclusion criteria

All patients with visually significant cataract having fundus findings within normal limits.

Exclusion criteria

Complicated cataract due to trauma, uveitis, Glaucoma and any corneal pathology.

Procedure

100 eyes of 100 patients undergoing cataract surgery with IOL implantation were included in the study. A detailed history was taken in every case and each case selected according to the conditions of the inclusion and exclusion criteria. All patients underwent a complete ophthalmic examination, namely Best -corrected visual acuity which was recorded using a Snellen's chart, Intraocular pressure measurement using Goldman applanation tonometry, Gonioscopy with Goldman three mirror lens, fundus examination with slit lamp biomicroscoy. Refraction was performed with automated refractometer.

IOL master was used for keratometry, axial length, anterior chamber (ACD) measurements and Intra ocular lens power calculation. Patients were divided into four groups of 25 in each group. In group 1 patients Haigis formula was used to calculate the Intra ocular lens power, group 2 with SRK/T, group 3 with Holladay and in group 4 with HofferQ formula was used. All the patients underwent Phacoemulsification with Foldable Intra ocular lens implantation. All of them were evaluated for Refraction and best corrected visual acuity on postoperative day 1, 6 and 6 weeks. Spherical Equivalent and MAE (Mean absolute error) was calculated from their refraction.

Statistical analysis

The absolute error was calculated from the formula-predicted refractive error and the actual postoperative refractive error. The data obtained was used to produce a Mean with a standard deviation following which a Student paired test was used to know the statistically significant difference in the MAE between the aforementioned groups

RESULTS

The study undertaken included one hundred cases. All the patients underwent phacoemulsification with a primary posterior chamber intraocular lens implantation.

Table 1: Sex distribution.

Sex of the patient	No of cases	Percentage of cases
Male	40	40
Female	60	60
Total	100	100

The results were analysed during the post-operative period (i.e. one and a half months following surgery) and the following observations were made.

Table 2: Age distribution.

Age group of the patient in years	No of cases	Percentage
40-50	22	22
51-60	28	28
61-70	37	37
71-80	13	13

Table 1 shows the sex distribution in which 40% were males and 60% were females.

Table 3: Axial length distribution.

No	Axial length	No. of cases
1	25.00-26.00	32
2	26.01-27.00	19
3	27.01-28.00	16
4	28.01-29.00	19
5	29.01-30.00	2
6	30.01-31.00	12

Table 2 shows age distribution of the patients studied.

Table 3 shows the axial length distribution.

Table 4: Range of parameters.

NO	Parameters	Minimum	Maximum
1	Axial length	25mm	30.78mm
2	Keratometry	41.90D	45.80D
3	IOL Power	+1.00D	+18.00D

Three important parameters utilized in the study included the axial length of the eye, average keratometric reading and intraocular lens power (Table 4).

The study showed that the range of the axial length of the eyes was between 25mm to 30.78mm. The range of the Keratometric readings were between 41.90D to 45.80D and the power of the intraocular lens implanted ranged from +1.00D to +18.00D.

Table 5: Formula predicted refractive error.

No	Haigis	SRK-t	Holladay	Hoffer Q
1	-0.25	-0.75	1.00	0.25
2	0.30	0.25	0.50	0.25
3	0.10	0.25	0.25	-0.25
4	0.10	0.20	0.25	0.25
5	0.00	-0.10	1.00	0.00
6	0.25	0.25	-0.25	0.00
7	0.25	0.20	0.25	0.25
8	0.25	-0.20	-0.25	0.25
9	0.00	0.50	0.50	-0.25
10	-0.10	-0.25	0.25	0.25
11	0.00	-0.25	-0.25	0.25
12	0.00	-0.25	0.50	0.25
13	0.10	0.05	1.00	-0.25
14	0.10	0.25.	-0.50	-0.50
15	0.00	0.25	-0.25	-0.25
16	-0.25	-0.25	0.00	0.00
17	0.00	0.50	-0.50	0.50
18	0.00	0.25	1.00	0.25
19	0.10	0.20	-0.20	0.25
20	0.10	-0.20	-0.25	0.25
21	0.25	-0.20	0.00	0.25
22	0.00	0.10	1.00	-0.50
23	0.00	0.25	0.25	0.25
24	-0.10	0.25	0.25	0.25
25	-0.25	0.25	0.05	0.25

Table 5 shows the refractive error calculated with various formulae.

Table 6 shows the post-operative residual refractive error by refraction (Autorefractometry followed by subjective correction) one and half months post-operatively. Post-operative refractive error showed a Mean of + 0.06D in Haigis, +0.32D in SRK-T, +0.72D in Holladay and +0.62D in Hoffer Q. Postoperative refractive error showed a standard deviation of 0.224D in Haigis, 0.481D in SRK/T, 1.089D in Holladay and 1.246D in Hoffer Q

Table-7 shows the comparison of post-operative spherical refractive equivalent error with different formulae.

Maximum hypermetropic refractive error in Haigis is +0.50D.

Maximum myopic refractive error in Haigis is -0.50D.

Maximum hypermetropic refractive error in SRK/T is +1.00D.

Maximum myopic refractive error in SRK/T is -0.75D.

Maximum hypermetropic refractive error in Holladay is +2.00D.

Table 6: Actual post-operative spherical equivalent.

SE	Haigis	SRK-t	Holladay	Hoffer Q
1.	-0.25	-0.75	+1.25	+0.75
2.	+0.50	+1.00	+1.00	+1.25
3.	_	+0.50	+0.75	-0.50
4.	+0.12	_	+1.25	+1.75
5.	_	-0.25	+2.00	+1.00
6.	+0.25	_	-0.25	-0.25
7.	+0.25	_	+0.50	+1.25
8.	+0.25	-0.25	-0.75	+0.25
9.	_	+1.00	_	-1.50
10.	-0.25	-0.75	+0.75	+0.75
11.	_	-0.75	-1.50	+1.25
12.	_	-0.50	+1.5	+1.75
13.	+0.25	+0.25	+2.00	-0.75
14.	+0.25	_	-1.50	-0.5
15	-	-	-1.25	-1.75
16.	-0.50	-0.50	+0.25	+2.00
17.	_	+1.00	+1.75	+2.00
18.	_	+0.75	+2.00	+1.25
19.	+0.25	_	-0.25	-1.75
20.	+0.25	-0.25	-0.50	+1.50
21.	+0.25	-0.25	+1.25	+1.50
22.	_	_	+1.75	-1.00
23.	_	+0.50	+0.50	+2.00
24.	-0.25	+0.75	+1.25	+1.75
25.	-0.25	+1.00	+0.75	+1.50

Maximum myopic refractive error in Holladay is -1.50D.

Maximum hypermetropic refractive error in Hoffer Q is +2.00D.

Table 7: Comparison of post-operative spherical refractive equivalent error with different formulae.

IOL formula	Hypermetropia	Emmetropia	Myopia
Haigis	10	10	05
SRK-t	09	07	09
Holladay	17	01	07
Hoffer q	17	0	08

Maximum myopic refractive error in Hoffer Q is -1.75D.

The Mean AL was 27.25 ± 1.25mm, the mean keratometric value was 43.62 ± 1.45D, and the MAE calculated by the Haigis was 0.07D (Table 10). Compared to the MAEs generated by the other formulae, the MAE generated by the Haigis was comparable to that by the SRK/T (=0.231D), and significantly lower than those by the HofferQ (0.481D) and Holladay (0.864D).

Table 8: Statistical comparison of postoperative spherical equivalent of all formulae using anova.

	Haigis	SRK/t	Holladay	Hoffer Q
N	25	25	25	25
Mean	0.04	0.1	0.58	0.62
Variance	0.05	0.32	1.18	1.55
Std. Deviation	0.224	0.572	1.08	1.24
Std. Error	0.044	0.114	0.217	0.249
Median Absolute Error	0.25	0.5	0.75	0.5
Mean absolute error	0.1618	0.4512	0.8904	1.0664

Table 9: Absolute error of different formulas.

No.	Haigis	SRK-t	Holladay	Hoffer Q
1	0	0	0.25	0.50
2	0.20	0.75	0.50	1.00
3	0.1	0.25	0.50	-0.25
4	0.02	0.2	1.00	1.50
5	0	-0.15	1.00	1.00
6	0	0.25	-0.50	-0.25
7	0	0.20	0.25	1
8	0	0.05	-.0.5	0
9	0	0.5	0.5	-1.25
10	0.15	-0.5	0.5	0.5
11	0.15	0.5	-1.25	1
12	0	0.2	1	1.5
13	0.25	0.25	1	-0.5
14	0	0.25	1	0
15	0	-0.25	1	-1.5
16	0.15	0.5	0.25	2
17	0.15	0.25	1.25	1.5
18	0	0.2	1	1
19	0	-0.05	-0.05	-1.5
20	0	0.05	-0.25	1.25
21	0.15	0.1	1.25	1.25
22	0	0.25	0.75	-0.5
23	0.15	0.5	0.25	1.75
24	0	0.75	1	1.5
25	0	-0.5	0.70	1.25

DISCUSSION

The IOL Master is a non-contact, user- and patient-friendly, partial coherence interferometry device for Axial Length determination and Intra ocular lens planning[1]. The IOL Master has high precision of all the currently available diagnostic instruments in routine use for measuring AL[2]. The corneal radius measured by the IOL Master and the automatic keratometer match closely. Optical biometry has improved the refractive results of cataract surgery patients and is more accurate than applanation ultrasound biometry.[3-8] Intra ocular lens power calculation formulae used optical biometry data obtained from assessments in eyes with long AL.

Table 10: Statistical comparison of absolute errors of all formulae using ANOVA.

No		Haigis	SRK/t	Holladay	HofferQ
1	N	25	25	25	25
2	Mean	0.058	0.182	0.498	0.67
3	Median	0	0.25	0.5	1.00
4	Variance	0.006	0.101	0.391	0.904
5	SD	0.082	0.318	0.625	0.951
6	Se	0.016	0.063	0.125	0.190
7	Mae	0.07	0.231	0.481	0.864

In the present study 100 patients were included, the mean AL was 27.25 ± 1.25mm, the mean keratometric value was 43.62 ± 1.45D, and the Mean Absolute Error calculated by the Haigis were 0.07D, SRK/T (0.231D), Holladay (0.864D) and HofferQ (0.481D).

Table 11: Intraocular lens power calculation table with various formulas by optical biometry (n = 100).

No		Median	Mean ± SD	P
1	Axial length (mm)	27.25	27.25 ±1.25	
2	Keratometric Value (D)	43.68	43.62 ±1.45	
3	Absolute error-Haigis(D)	0	0.05 ±0.01	
4	Absolute error-Hoffer Q(D)	1	0.67 ±0.19	0.05
5	Absolute error-Holladay 1	0.5	0.49 ±0.125	0.001
6	Absolute error-SRK/T (D)	0.25	0.18 ±0.06	0.04

In the present study, the predictive accuracy of the formula was analysed by comparing the mean difference between the actual and predicted postoperative SE; that is, the Mean absolute error (MAE). Mean absolute error (MAE) of Haigis formula was 0.07 D, was least when compared to SRK/T (0.231D) and Holladay (0.48D) and Hoffer Q (0.864 D). The Intra ocular lens power calculated using the Haigis formula predicted the best refractive outcome in long eyes (AL more than 25.00 mm).

Mean axial length of our study was 27.25 mm with a standard deviation of 3.50. The mean of axial length in the study done by katrin petermeier et al was 31.39mm with a standard deviation of 2.14.[9] Our study showed had a Mean axial length of 27.25 mm with a SD of 1.32 with when compared to the Mean axial length in the study done by Jia-Kang WANG which has value of 28.03mm with SD 1.22.[10]

Since absolute errors are not a Gaussian distribution we have also included the median values. The Median value of our study for the axial length was 27.25mm whereas the study done by JIA KANG WANG was 28.09 mm.[10] Their study included 75 cases and ours has 100. This demographic seems to be fairly comparable. In another study done by katrin petermeier et al, the mean axial length of the study was 31.15 mm with a SD of 1.69 for the positive dioptre IOL group.

Our study has an age keratometric value of 43.62D with a SD deviation of 1.45. The Median value being 43.68. The study done by Jia Kang Wang had a Mean of 44.64 with a standard deviation of 1.97.[10] It had a median of 43.62D and the study katrin petermeier had a Median value of 7.56mm (44.64D) with a SD of 0.28mm.

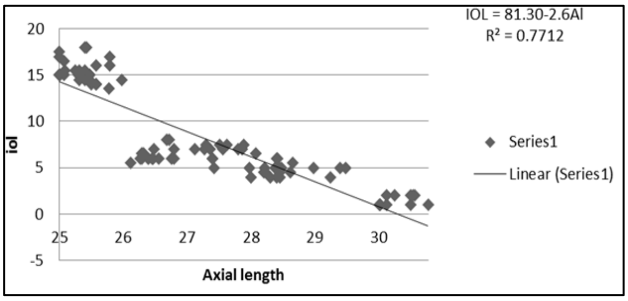

Figure 1: Regression analysis of axial length versus IOL power implanted.

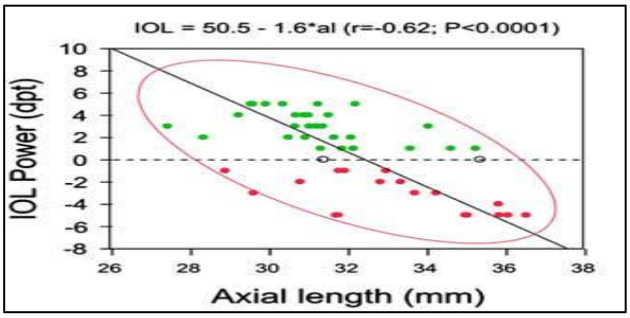

Figure 2: Regression analysis of axial length vs. IOL power implanted.

The linear regression analysis done for axial length and Intra ocular lens power implanted in the eye in our study showed that for every one unit increase in the axial length led to the increase Intra ocular lens power calculated by 2.6D with the R square value being 0.77 this correlation could be explained with reasonable certainty with the above equation. This finding of our seems to correlate with the study done by katrin petermeier which documented a regression analysis showing a corresponding value of 1.6D.[9] We attribute this difference to the fact that their study included a population of axial length having a wider range starting from 21 mm and extended up to 31mm. We can thus draw from this that the increase in value corresponding with the axial length is not uniform over its entire range. The corresponding values increase in a much logarithmic fashion in the range of higher axial lengths.

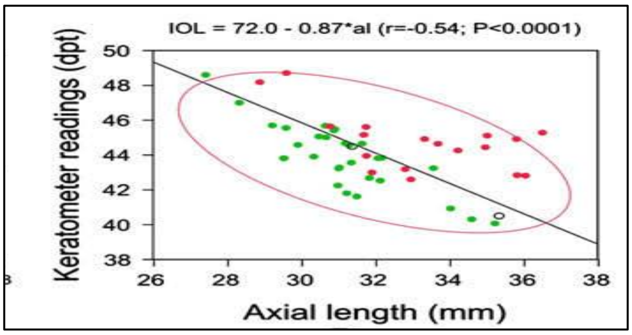

Figure 3: Regression analysis of keratometry readings vs. axial length.

Regression analysis of IOL power and corneal power with AXL in katrin petermeier study[9]

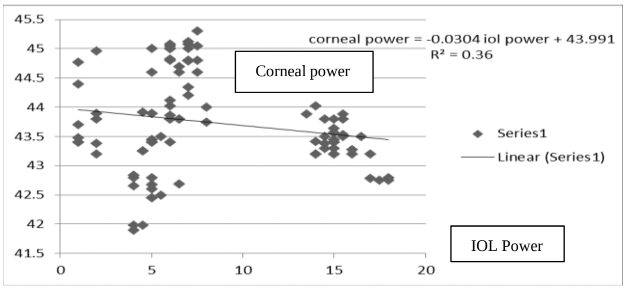

Figure 4: Regression analysis of corneal power versus IOL power.

Our regression analysis between keratometry readings and the Intra ocular lens power implanted during surgery correlated poorly with an R square value of only 0.36. This means the correlation between the two parameters could be explained with no greater probability than 36%. This can be explained by the fact that the prevalence of curvature myopia is documented to be a minority when the myopia population is considered at large.

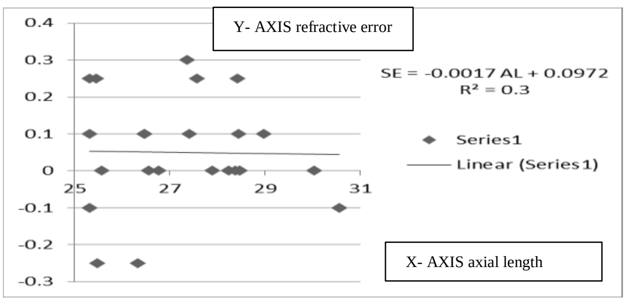

Figure 5: Regression analysis between refractive errors versus axial length in Haigis formula.

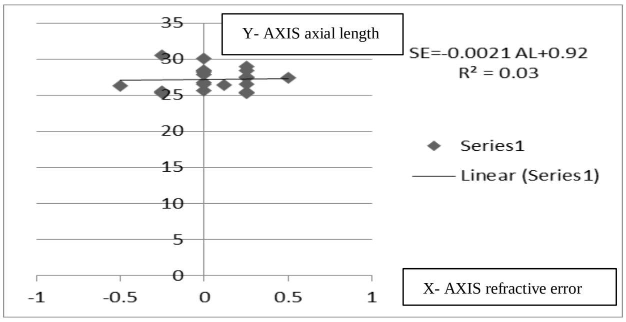

Figure 6: Regression analysis between axial lengths versus refractive errors in Haigis formula.

The above two graphs show a regression analysis between refractive errors versus axial length when Haigis formula was used for calculating the Intra ocular lens power. The analysis suggests, the poor correlation between the variables suggests that the residual power for correction didn't not depend on the axial length of the eyes. Rather other intangible factors like capsule shrinkage and surgical technique could be considered as possible reasons. What is interesting is to find that the preoperative prediction of Haigis formula correlates well the post-operative refractive errors noted. Thus our analysis points towards HAIGIS formula being more predictable and accurate for calculating the Intra ocular lens power when compared to the other contemporary formula available. Our study also correlated with the study done by Katrin petermeier, germany[9] who found a variance of 0.8 with HAIGIS formula whereas SRK-T showed 0.92. We believe this higher value of the variance using HAIGIS is because the study population in their study included axial length of a wide range. In the study conducted by Amanda Tang, 81% of eyes had refractive error within 1.0 D of predicted 54% were within 0.5 D of predicted using the Haigis formula. In contrast, 59.5% of eyes were within 1.0 D of predicted and 29.7% were within 0.5 D of predicted using the SRK/T formula. We found that these findings correlate with our study.

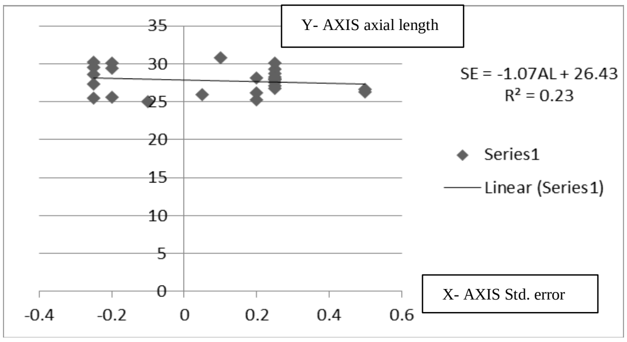

Figure 7: Regression analysis between SE versus axial length in SRK-t formula.

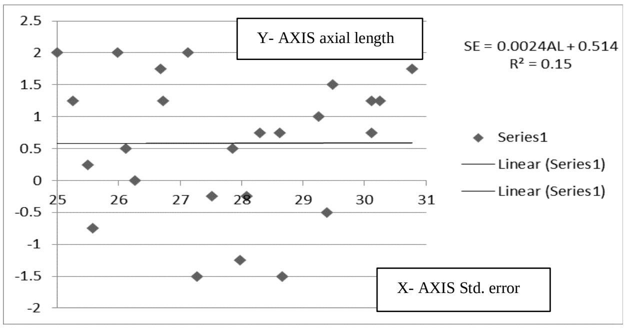

Figure 8: Regression analysis between se versus axial length in SRK-t formula.

The above 2 graphs show the linear regression between SE and axial length using SRK-T formula. The analysis shows poor correlation although the expected error is less when compared to the actual error recorded. A unit rise of axial length from 25mm to 26mm, we would expect an error of 0.06D but we found that the error is around 0.4D. The ANOVA analysis also points us in the same direction with an MAE of 0.1D for SRK-T. This value for HAIGIS was only 0.04. The analysis for HOLLADAY and HOFFER Q showed 0.58 and 0.62 respectively.

Figure 9: IOL master.

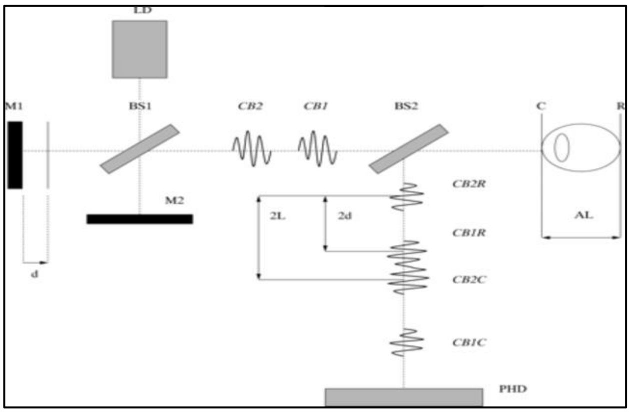

Figure 10: Principal of IOL master.

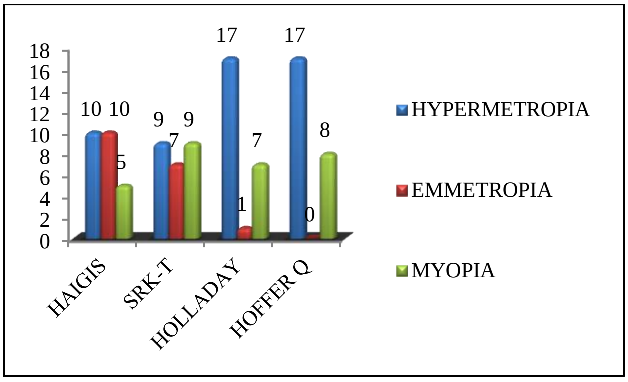

Figure 11: Graph post-operative spherical refractive equivalent error with different formulae.

In the study done by A Saad etc. the mean preoperative spherical equivalent (SE) was −17.52D (range, −12.25 to −30.50D).[11] After surgery, the mean spherical equivalent was −0.8 ± 0.83D (range, +1.25 to −3.75D).They too found that HAIGIS formula, when used for long axial length eye ball resulted in a post op error of within 1D. Their study also found that the other formulas had a tendency towards hyperopic shift postoperatively indicating probable false low axial length calculation. We too found this tendency in our study where cases in which HAIGIS formula was used had a lesser tendency towards a hyperopic shift.

What is the reason behind the last leap of quest towards attaining emmetropia still seemed to be answered. Other intangible factors like capsular bag shrinkage and development of better A-constants by using large normative data's and better adjustment factors could be the way ahead. With the increase in the advent of better ocular imaging facilities the post-operative condition of the capsular bag both in its position and in its other structural modifications that might affect the eventual Intra ocular lens position might help us understand the errors in the formulae better. We have found 10 cases out of the 25 cases that were operated with an eventual postoperative period we suggest to stay on the myopic side of correction as a choice for Intra ocular lens power selection. This hyperopic shift was found to be in a higher percentage of cases with other formulae although SDRK-T formula in our study showed a hyperopic shift in only 9 patients. The hyperopic shift was even higher in HofferQ and HolladaY formulae. The findings in our study thus suggest higher reliability of Haigis formula when compared to SRK-T and other formulae.

CONCLUSION

In the present study the Mean post-operative refractive error (spherical equivalent) was found to be the least with Haigis formula followed by SRK/T for eyes with long axial length we believe that normal axial lengths correlate better with SRK-T formula. The HAIGIS formula has a better predictability and accuracy in present study when compared to the other contemporary formulae. The postoperative hyperopic shift was comparable between HAIGIS and SRK-T formulae although myopic shift in the error post operatively was lesser with HAIGIS formula. The other formulae had higher hyperopic shift. The limitation of present study could be that present study population did not include cases with negative power Intra ocular lens. These type of cases could show a variation from the group with positive power Intra ocular lens, a question that needs further study. The results with Holladay and HofferQ were comparable and the Mean absolute errors were not only unpredictable but also consistently higher than for patients in whom HAIGIS formula was used. The present study showed the least postoperative hyperopic shift with Haigis formula compared to other formulae.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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