DOI: 10.7860/JCDR/2022/54834.16477

Original Article

Ophthalmology Section

# Comparison of Intraocular Lens Power Estimation by Optical Biometry and Ultrasound Biometry in Cataract Surgery

GAYATREE MOHANTY[1], HIMANSU RAJGURU[2], KHUSHI AGARWAL[3]




## ABSTRACT

**Introduction:** The evolution of modern technologies for cataract surgery has made it crucial for aiming emmetropia with highly defined vision. The key factor responsible for postoperative emmetropia is an accurate biometry, along with various other factors. Ultrasonic biometry is the gold standard method of Intraocular Lens (IOL) power calculation but the corneal indentation with the probe underestimate the axial length and result in a myopic shift which is overcome by the newer optical biometry devices, including swept source optical coherence biometry which uses infrared light to measure the ocular distances.

**Aim:** To determine the precision and accuracy of IOL power calculation by ultrasound A-scan and optical IOL master and their refractive outcomes.

**Materials and Methods:** This prospective and observational study was conducted between September 2019 to February 2021 in 155 patients with cataract undergoing phacoemulsification in Kalinga Institute of Medical Sciences, KIIT University, Bhubaneswar, Odisha, India. All subjects underwent comprehensive ocular examination and biometry with two formulae {Sanders-Retzlaff-Kraff (SRK) and Holladay-I}. Biometry included corneal curvature (keratometry), axial length, anterior chamber depth, IOL power calculation, predicted refractive error.

There were two broad groups. One group underwent biometry by ultrasound A-scan and the other group underwent optical biometry by IOL Master 700. The IOL power was calculated with the two formulae in both the groups. Comparisons between variables measured using the IOL master and A-scan were done using paired t-test. The p-values <0.05 were considered statistically significant.

**Results:** In 18 months period, 155 eyes were consecutively enrolled in the study. The mean age of all enrolled patients was 62.1±8.65 years (range 34-80 years) with male:female ratio of approximately 1.25:1. The mean axial length measured by IOL master was higher (23.15±0.85) than that by A-scan (22.96±0.81 diopters) with a mean difference of 0.197±0.35 mm (p-value <0.001, paired t-test). The mean predicted IOL power was 20.81±1.84 diopters by IOL master and 21.13±1.62 by A-scan by SRK-II formula (p-value <0.001). While mean predicted IOL power with Holladay-I by IOL Master 700 was 20.61±1.92 and 21.44±1.98 diopters by A-scan with a mean difference (-0.82±0.76 diopters) with a significant p-value <0.001. Bland-Altman analysis plots showed almost perfect agreement between both methods regarding predicted IOL power.

**Conclusion:** The swept source Optical Coherence Tomography (OCT) based IOL master 700 proved to be a faster non contact device to use with a shorter learning curve, higher accuracy in average axial length eye and less refractive surprises.


**Keywords:** Axial length, Phacoemulsification, Refractive error, Swept source optical tomography, Visual acuity

## 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).

The other factors which may alter the postcataract surgical refractive status are the type of wound, wound healing and the placement of IOL. Ultrasound biometry (A-scan) is the most frequently used method for IOL power estimation but the corneal indentation caused by contact with ultrasound probe causes shortening of the axial length of the eye, thus leading to underestimation of true axial length and myopic shift of the postoperative refraction. This drawback is overcome by the non contact optical biometry devices [2]. Modern optical biometry devices works on the principle of partial coherence inferometry or swept source optical tomography. Secondly, light has a shorter wavelength sound, thus the laser light of the optical biometry devices gives a better resolution and accuracy.

The advance models can measure IOL power also in patients of dense cataracts and other media opacities unlike the previous models [2,3]. The previous studies have documented either comparision between ultrasonic biometry and the Partial Coherence Inferometry (PCI) type of optical biometry or partial coherence inferometry and swept-source optical tomography biometry but not the ultrasonic biometry with the swept source optical tomography type of optical biometry. Thus, the aim of this study was to determine and compare the IOL power estimated by ultrasound A-scan and optical IOL master 700. The refractive outcomes were also compared.

## MATERIALS AND METHODS

This was a prospective, and observational study conducted between September 2019 to February 2021 among 155 patients in Kalinga Institute of Medical Sciences, KIIT University, Bhubaneswar, Odisha, India. The random consecutive sampling was used in the study. The study was conducted in accordance with the tenets of the Declaration of Helsinki and was approved by the Institutional Ethics Committee (KIIT/KIMS/IEC/109/2019). A written informed consent was taken from all the patients.

**Inclusion criteria:** All patients with cataract undergoing phacoemulsification were included in the study.

**Exclusion criteria:** The patients with ophthalmic conditions which could affect vision or axial length measurement like mature cataract, corneal pathology, vitreous hemorrhages, retinal pathology, glaucoma and history of trauma or prior ocular surgeries and paediatric age group subjects were excluded from the study.

The demographic profile and clinical history, visual acuity, slit lamp examination and fundus findings were recorded in detail. All patients underwent thorough clinical evaluation in Outpatient Department of Ophthalmology.

### Study Procedure

All the patients were subjected to biometry performed by both the techniques using IOL Master 700 (Carl Zeiss Meditec AG, Jena, Germany) and the A-scan (Sonomed Escalon, VuPad Model number BUA, Sonomed Inc., NY, USA) ultrasound unit.

- The optical biometry was measured by having the patient seated with the chin rested on the chin rest in the IOL Master 700 machine and fixate on the target.
- For ultrasonic A-scan, the patient was anaesthetized topically with proparacaine 0.5% eye drops. The 10 MHz probe was placed on the cornea while asking to fixate with the other eye to record the axial length and the other variables.

The corneal curvature (keratometry), axial length, anterior chamber depth, IOL power calculation, predicted refractive error were recorded. The predicted refractive error is the difference between the attempted target refraction and the achieved postoperative refraction.

Both Sanders-Retzlaff-Kraff II (SRK) and Holladay I formula, with the appropriate A-constant for both the types of biometry, aiming postoperative emmetropia were used [4]. All the measurements were taken by an experienced optometrist familiar with both the instruments to avoid interpersonal differences as a confounding factor.

All the subjects underwent phacoemulsification through a 2.8 mm superior corneal incision with hydrophobic acrylic intraocular lens implantation. Patients were followed-up after one month for refraction.

## STATISTICAL ANALYSIS

Consecutive patients were enrolled and data collected was coded and recorded in Microsoft Excel. The statistical program Statistical Package for Social Sciences (SPSS IBM Corp.) version 23.0 was used for statistical data analysis. The descriptive statistics were elaborated in the form of mean±standard deviations, median and interquartile range for continuous variable, and frequency and percentage (relative frequency) for categorical variables. Comparisons between variables measured using the IOL master and A-scan were done using paired t-test. The p-values <0.05 were considered statistically significant. Data was presented in graphical manner wherever appropriate for data visualisation using bar charts for categorical data. The agreement between both the devices with respect to the difference in axial length were analysed using Bland-Altman plot. The interdevice measurement differences were plotted against the means and the 95% limits of agreement (1.96 standard deviation) determined. This plot was used to examine if there was any over-estimate and variability of the difference between both the devices.

## RESULTS

The study was carried out on 155 eyes with immature cataract. Optical biometry and ultrasonic applanation biometry were carried out in 83 and 72 eyes, respectively. Out of the 83 eyes which underwent optical biometry, 31 eyes were implanted with IOLs according to the minimum predicted values of SRK-II formula while 52 eyes were implanted with IOLs according to the minimum predicted values of Holladay-I. While 43 eyes out of the 72 eyes which underwent using ultrasound A-Scan were implanted with IOLs according to the minimum predicted values of SRK-II formula and 29 eyes according to the minimum predicted values of Holladay-I.

The mean age of all enrolled patients was 62.1±8.65 years (range 34-80 years) with male: female ratio of approximately 1.25:1.

The average mean horizontal keratometry was 44.11±1.65 mm (range: 40-49.78 mm) and average mean vertical keratometry was 44.93±1.74 mm (range: 40.7-51.2 mm). The mean anterior chamber depth was 3.15±0.32 mm and mean lens thickness was found to be 4.13±0.62 mm. White to white diameter mean was 12.04±0.48 [Table/Fig-1].

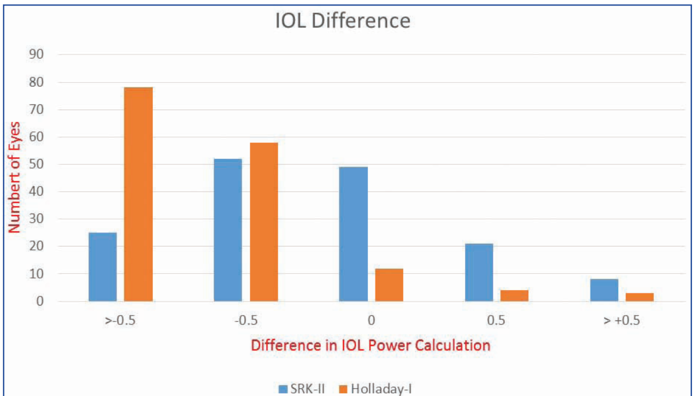
| Variables | Values |
|---|---|
| Mean age (years) | 62.1±8.65 |
| Mean horizontal keratometry | 44.11±1.65 |
| Mean vertical keratometry | 44.93±1.74 |
| Mean anterior chamber depth (mm) | 3.15±0.32 |
| Mean lens thickness | 4.13±0.62 |
| Mean white to white | 12.04±0.48 |

**[Table/Fig-1]:** Demographics.

The mean axial length measured by IOL master 700 was higher (23.15±0.85 mm) than that measured by ultrasonic A-scan (22.96±0.81 mm) with a mean difference of 0.197±0.35 mm, which was statistically significant (p-value <0.001). The mean predicted IOL power was greater by A-scan than with IOL Master 700 by using either formula and the difference was found to be statistically significant (p-value <0.001). There was no statistically significant difference in the mean predicted error in IOL power calculation using either of the formulae. The Bland-Altman plot also showed agreement between both the devices with respect to axial length with 95% limit of agreement (Cronbach's $\alpha$=0.995 for the mean difference of both parameters). Linear regression analysis showed that there was no proportional bias for the axial lengths by the two instruments (t-score=-1.07) [Table/Fig-2-4].

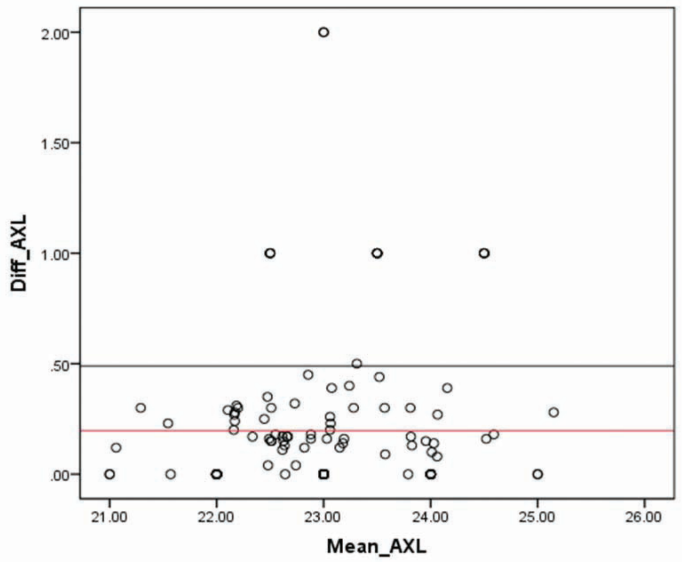
| Biometric data | IOL Master 700 (Mean±SD) | Ultrasonic A-scan (Mean±SD) | Mean difference | p-value (Two-tailed) |
|---|---|---|---|---|
| Axial length (mm) | 23.15±0.85 (21-25.29) | 22.96±0.81 (21-25.01) | 0.197±0.35 | <0.001 |
| **Sanders-Retzlaff-Kraff II (SRK)** | | | | |
| Intraocular lenses (diopters) | 20.81±1.84 (16-25) | 21.13±1.62 (17-25) | -0.32±0.72 | <0.001 |
| Predicted error (Diopter) | 0.0027±0.11 (-0.5-1.0) | 0.00129±0.81 (-0.4-0.2) | 0.0014±0.13 | 0.896 |
| **Holladay I** | | | | |
| Intraocular lenses (diopters) | 20.61±1.92 (16-25) | 21.44±1.98 (17-26) | -0.82±0.76 | <0.001 |
| Predicted error (Diopter) | -0.0032±0.10 (-1.0-0.17) | 0.0013±0.08 (-0.17-0.7) | -0.0045±0.13 | 0.67 |

**[Table/Fig-2]:** Biometric data obtained from ultrasonic A-scan and IOL Master 700.



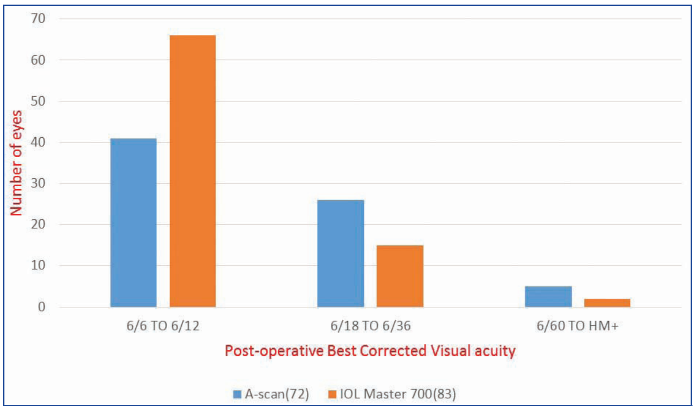

**[Table/Fig-3]:** Difference in IOL power calculation by ultrasonic A-scan and intraocular lenses Master 700 (SRK-II and Holladay-I).

Of all the patients implanted with IOL power calculated from IOL Master 700, 5 (6.02%) eyes of 83 eyes needed spherical corrections,



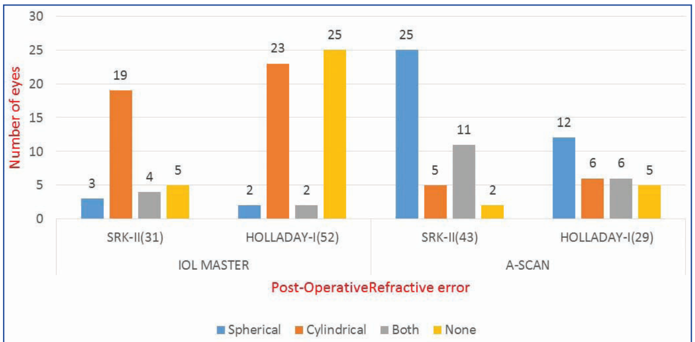

**[Table/Fig-4]:** Bland-Altman plot for agreement between the A-scan and intraocular lenses Master 700 with respect to the difference in axial length (AXL).

42 (50.6%) eyes needed astigmatic correction, 6 (7.22%) need both and 30 (36%) eyes were emmetropic. On the other hand, 37 of the 72 eyes which were implanted with IOL power calculated by A-scan required spherical correction, 11 (15.2%) eyes required astigmatic correction, 17 (23.6%) required both spherical and astigmatic correction and 7 (9.72%) of the eyes were emmetropic [Table/Fig-5].




**[Table/Fig-5]:** The postoperative best corrected visual status with implantation of intraocular lenses power calculation by ultrasonic A-scan and IOL Master 700.

Further analysed, 25 eyes out of the 52 eyes (48%) implanted with IOLs calculated by Holladay-1 on IOL master 700 required no refractive corrections in comparison to only 16.1% of the eye (n=51) with IOL power calculated by SRK-II formula. While 17.2% (n=5) and 4.6% (n=2) of the eyes needed no refractive correction in eye calculated by Holladay-1 and SRK-II formulae, respectively on ultrasonic A- scan. The postoperative refraction was most desirable in eyes in implanted with Holladay-I formula on IOL master among the four modalities [Table/Fig-6].




**[Table/Fig-6]:** The postoperative best corrected visual status with implantation of IOL power calculation by ultrasonic A-scan and IOL Master 700 (SRK-II and Holladay-1).

The best corrected visual acuity in patients implanted with IOL power calculated on IOL Master 700 achieved 6/6 to 6/9 in 66 (79.5%), 6/9 to 6/12 in 15 (18.07%) and 6/18 to 6/24 in 2 (2.40%); while the patients implanted with IOL power calculated by ultrasonic A-scan achieved 6/6 to 6/9 in 41 (56.9%), 6/9 to 6/12 in 26 (36.11%) and 6/18 to 6/24 in 5 (6.94%).

## DISCUSSION

One of the essential element 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 [3]. 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).

The most common formulae used on these devices are SRK II and Holladay I. The SRK II is the widely used regression formula which calculates the IOL power using the keratometry and axial length as the variables. Holladay I is a third generation two-variable vengence formulae, which uses the anterior chamber depth along with the axial length and keratometry to calculate the IOL power. The third generation formulae attempt to express a mathematical relation between anterior chamber depth and axial length to achieve more accurate IOL power and more improved visual outcomes. The newer artificial intelligence assisted formulae claim to have more accurate outcomes [2,4].

The optical biometry is a non contact technique based on Partial Coherent Inferometry (PCI) or swept source optical coherence tomography. It has been documented to have a more precise estimate of axial length and intraocular lens power calculation. It measures the axial length along the visual axis from the anterior corneal surface to the retinal pigment layer. The machine also measures the corneal curvature, corneal thickness and anterior chamber depth apart from calculating the IOL power [2,5]. Partial coherent inferometry uses dual beam inferometer to reduce the error due to longitudinal movements. Two beams infrared light of short coherence are projected into the eye. The tissue interfaces reflect the light to produce partial coherent inferometry signals [5,6]. The swept source OCT (IOL Master 700) device uses a laser wavelength of 1050 nm. It has a scan depth of 44 mm and a scan width of 6 mm. Its tissue resolution is 22 μm. It measures 2000 A-scans per second. It has enhanced penetration in dense cataracts in comparison to PCI based optical biometry devices [7,8]. On the other hand, in ultrasonic biometry which is the most preferred technique, the axial length is measured using a 10 Hz probe with a resolution of 200 microns with accuracy of 100-150 microns. The ultrasonic A-scan measures the distance from the corneal vertex to the Internal Limiting Membrane (ILM), which theoretically should measure a shorter axial length than the optical type by 130 microns. But, errors due to non alignment of the optical axis with visual axis or corneal indentation may arise as well [2,5].

The mean axial length difference between both the methods was statistically significant in the present study. The axial length produced on IOL master 700 was longer than the ultrasonic A -scan, which was consistent with previous studies done in other parts of the world [3,5,9,10]. While on the other hand, there are studies which did not find any significant difference in the axial length in both the methods [11]. The difference found in the present study can be attributed to the corneal indentation and improper alignment of the A-scan probe as discussed earlier by previous studies. The mean predicted IOL power was significantly less using the IOL master 700 with a mean difference of -0.41 with both the SRK II and Holladay I, similar to previous documentations who have used different formulae for IOL power prediction. The difference between predicted error by both the formulae were not significant. Similar results have been documented in a recent study in 2017 but no significant difference in the mean predicted errors [5,11-14]. The difference between IOL power calculation by both the formulae were not significant.

Most of the patients had a best-corrected vision of 6/6. Total 50% percent patients of the IOL Master 700 biometry group and 23.6% patients of the A-scan biometry group required astigmatic correction. The astigmatism was attributed to the pre-existing astigmatism and surgically-induced astigmatism. Post- operative spherical refractive error were seen in only five patients of IOL Master 700 group in contrast to 37 patients of A-scan group. The difference between the postoperative refractive status SRK-II and Holladay-1 formulae on both devices were significant on IOL Master 700 not A-scan. Previous studies have proven the Holladay formula needs to be the preferred formula for short and longer eyes though no significant difference in mean absolute error has been seen in medium length eyes [2,15].

There has been no previous documentation of comparison of four variables together (two devices and two formulae) in this region of the country. The present study compared the mean predictive IOL power and the final refractive errors between the four variables.

Further studies must be carried out considering pre-existing astigmatism and the precision of IOL Master 700 in Toric IOLs, precision of IOL power calculation by IOL Master 700 in various materials of IOLs and the difference and precision of IOL power calculation using various formulae for the different axial lengths (short, medium and long).

### Limitation(s)

The sample size was less due to the prevailing pandemic situation. Some of the study subjects were lost on follow-up due to the same. The pre-existing astigmatism, toric IOLs and the various IOL materials were not used or included in the study to avoid confounding factors. The difference in axial length measurements in both the devices and formulae according to short, medium or long eyes have not been considered in this study.

## CONCLUSION(S)

The swept source optical coherence tomography based IOL master 700 proved to be a faster device to use with a shorter learning curve. It provided a non contact technique with no risk of infection or corneal abrasion and was most accepted by patients. It produced more accurate IOL power calculation than ultrasound biometry in eyes with average axial length because of higher penetrability. Thus, less refractive surprises and more patient satisfaction could be achieved. However, there exist certain conditions where only the A-scan is useful like hypermature cataract.

## REFERENCES


[1] Sharma A, Sharma AV. Comparison of accuracy between ultrasound B scan and partial coherence interferometry (IOL master) in IOL (intraocular lens) power calculation. Indian Journal of Clinical and Experimental Ophthalmology. 2018;4(4):492-98.

[2] Mohan P, Chakrabarti A. Intraocular lens power calculation in 2019: The cutting edge. Kerala J Ophthalmol. 2019;31:191-201.

[3] Nakhli FR. Comparison of optical biometry and applanation ultrasound measurements of the axial length of the eye. Saudi J Ophthalmol. 2014;28(4):287-91.

[4] Xia T, Martinez CE, Tsai LM. Update on Intraocular Lens Formulas and Calculations. Asia Pac J Ophthalmol (Phila). 2020;9(3):186-93.

[5] Eleftheriadis H. IOLMaster biometry: Refractive results of 100 consecutive cases. Br J Ophthalmol. 2003;87:960-63.

[6] Hitzenberger CK, Drexler W, Leitgeb RA, Findl O, Fercher AF. Key Developments for Partial Coherence Biometry and Optical Coherence Tomography in the Human Eye Made in Vienna. Invest Ophthalmol Vis Sci. 2016;57(9):OCT460-74.

[7] Yang CM, Lim DH, Kim HJ, Chung TY. Comparison of two swept-source optical coherence tomography biometers and a partial coherence interferometer. PLoS One. 2019;14(10):e0223114.

[8] Hirnschall N, Varsits R, Doeller B, Findl O. Enhanced Penetration for Axial Length Measurement of Eyes with Dense Cataracts Using Swept Source Optical Coherence Tomography: A Consecutive Observational Study. Ophthalmol Ther. 2018;7(1):119-24.

[9] Wang XG, Dong J, Pu YL, Liu HJ, Wu Q. Comparison axial length measurements from three biometric instruments in high myopia. Int J Ophthalmol. 2016;9(6):876.

[10] Rose LT, Moshegov CN. Comparison of the Zeiss IOL master and applanation A-scan ultrasound: Biometry for intraocular lens calculation. Clin Exp Ophthalmol. 2003;31:121-24.

[11] Fontes BM, Castro E. Intraocular lens power calculation by measuring axial length with partial optical coherence and ultrasonic biometry. Arq Bras Oftalmol. 2011;74:166-70.

[12] Gaballa SH, Allam RS, Abouhussein NB, Raafat KA. IOL master and A-scan biometry in axial length and intraocular lens power measurements. Delta J Ophthalmol. 2017;18:13-19.

[13] Ellakwa AF, Abd Elaziz MS, Zaky MA, Nagy WM. Predictability of intraocular lens power calculation in eyes with average axial lengths: Optical versus ultrasonic biometry. Delta J Ophthalmol. 2019;20(2):68.

[14] Tehrani M, Krummenauer F, Kumar R, Dick HB. Comparison of biometric measurements using partial coherence interferometry and applanation ultrasound. J Cataract Refract Surg. 2003;29(4):747-52.

[15] Aristodemou P, Knox Cartwright NE, Sparrow JM, Johnston RL. Formula choice: Hoffer Q, Holladay 1, or SRK/T and refractive outcomes in 8108 eyes after cataract surgery with biometry by partial coherence interferometry. J Cataract Refract Surg. 2011;37(1):63-71.



**PARTICULARS OF CONTRIBUTORS:**

1. Associate Professor, Department of Ophthalmology, Kalinga Institute of Medical Sciences, Bhubaneswar, Odisha, India.
2. Professor, Department of Ophthalmology, Kalinga Institute of Medical Sciences, Bhubaneswar, Odisha, India.
3. Postgraduate Student, Department of Ophthalmology, Kalinga Institute of Medical Sciences, Bhubaneswar, Odisha, India.

**NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:**
Dr. Gayatree Mohanty,
HIG-1, Maritu Villa, Magnetix Square, P.O: K.I.I.I,
Bhubaneswar-751024, Odisha, India.
E-mail: mgayatree@gmail.com



**PLAGIARISM CHECKING METHODS:** [Jain H et al.]
- Plagiarism X-checker: Jan 12, 2022
- Manual Googling: Feb 25, 2022
- iThenticate Software: Mar 08, 2022 (7%)

**ETYMOLOGY:** Author Origin

**AUTHOR DECLARATION:**
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Jan 08, 2022**
Date of Peer Review: **Feb 01, 2022**
Date of Acceptance: **Mar 10, 2022**
Date of Publishing: **Jun 01, 2022**