Original Article

Comparative Study between Optical and Ultrasonic Measurement of Axial Length and Anterior Chamber Depth in Normal, Long and Short Eyes

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Key Words:
Axial length, anterior chamber depth, swept source optical biometry, applanation biometry.

Abstract:

Purpose: *The aim of the study is to evaluate and analyze the difference between optical and ultrasonic measurement regarding axial length (AL) and anterior chamber depth (ACD) in normal, long and shorts eyes.*

Methods: *A prospective study conducted on 145 patients enrolled for cataract surgery. Total 145 eyes have been tested. The eyes were divided into three groups depending on their AL; normal eye (22mm – 25mm), long eye (>25mm) and short eye (< 22mm) groups. The eyes have been measured by both Swept Source Optical biometry and Applanation Ultrasoundbiometry.*

Results: *Statistical analysis of the sub groups showed, mean axial length was 23.68mm and 23.59mm by optical and applanation biometry with standard deviation of 2.34mm and 2.30mm. The mean of anterior chamber depth was 3.14mm by optical and 3.12mm by ultrasonic method with standard deviation of 0.48mm and 0.44mm. The sample size was 145. The correlation statistics between the methods was 0.995 and 0.934 with mean difference of 0.08 and 0.02 for AL and ACD respectively. The eyes were divided into normal eye (22mm-25mm), long eye (>25mm) and short eye (<22mm) groups according to the measurement of axial length. There was no statistically significant difference in axial length and anterior chamber depth measurement by optical method (P=0.52) and ultrasonic method (P= 0.17). So, it can be said that, there is good agreement between the two methods regarding measurement.*

Conclusion: *There is no significant difference in measurement of axial length and anterior chamber depth by optical and ultrasonic method of biometry.*

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Introduction

For achievement of desired refractive outcome, precise biometry is one of the major key factors for accurate intra ocular lens power calculation in cataract surgery. Refractive status after successful cataract surgery depends on various factors specially measurement error of axial length and estimation of anterior chamber depth.[1] According to some study, 54% of error in predicted refraction after intra ocular lens implantation took place due to variability of axial length measurement. Variability in anterior chamber depth measurement causes 38% of predicted refraction error.[2] Axial length means the length of optical path, from the corneal anterior surface to the retinal pigment epithelium. Anterior chamber depth extends from the corneal vertex to the internal limiting membrane.[3] Both of these parameters can be measured by optical and ultrasound method of biometry. The optical and ultrasound method utilize the principle of signal reflection to measure the distance between various ocular structures.[4] Over a decade ago, optical biometer, the IOL Master was introduced in ophthalmic practice. Optical biometry utilizes a laser for signal transmission through the ocular structures.[4] The updated IOL Master 700 (Carl Zeiss meditec, Germany) is a popular swept source optical tomography based optical biometer.[5] This SS-OCT is capable of obtaining multiple measurements in a single capture and generate AL abd ACD values with perfect alignation of subject's visual axis.[5] It uses a rapid-cycle, tunable wavelength laser to scan the eye, which improves the tissue penetration and image quality.[6] The ultrasound biometry using 10-MHz ultrasound waves to measure axial length and anterior chamber depth. It is performed by applanation of the ultrasonic probe to the corneal surface after applying the surface anesthesia.[3] Applanation ultrasound is the common method to measure axial length and anterior chamber depth worldwide, especially in developing countries due to its familiarity with the technique and cost effectiveness.[4] After introduction of highly repeatable and reproducible optical method, due to its consistency and high resolution in measurement IOL Master became a method of choice for most of the surgeons now a days.[3] More over IOL Master is quick, easy to use, non-contact method which doesn't need any anesthesia or pupillary dilatation. It believes to be 10 times better than ultrasound method of biometry.[7] Previous comparative studies between optical biometryandapplanationultrasound show equal or better result with optical biometry.[4] We make a hypothesis that; different axial length subgroup may influence the measurement consistency of optical method. The aim of the study is to analyze the comparative measurement of axial length and anterior chamber depth both by optical and applanationultrasound method of different axial length subgroup, namely, normal, long and short eye.

Materials and method

A prospective study was conducted on 145 patients enrolled for cataract surgery in a tertiary level eye hospital located in a busy area. As per the setting of the pre-operative procedure, all the patients who enrolled for cataract surgery need to do pre phaco investigation. Measurement of axial length and anterior chamber depth by both optical and ultrasound applanation method are included in the pre- operative investigation. But as per research ethics a written consent was taken from all the patients who have been selected to include in the study.

Out of 145 patients, 62 were male and 83 were female. Mean age was 59.03 yrs with standard deviation of 11.73yrs. There were some inclusion and exclusion criteria for the study patient selection. The inclusion criteria include , patient need to have a visually significant cataract in one or both eyes, normal findings of slit lamp and fundoscopy, patient underwent uneventful phacoemulsification and in bag intra ocular lens implantation.The exclusion criteria include thepatients with history of ocular trauma, patient havingprevious history of ocular surgery for any ophthalmic condition other than cataract that may affect vision or intraocular parameters measurement, patient with ocular infective pathology such as retinal detachment, retinitis pigmentosa, patients who cannot be positioned satisfactorily for optical tests and patients who have nystagmus or poor fixation.

Among the methods optical biometry was performed first followed by ultrasonic measurement. This order is necessary to get perfect result from both methods as saline shell can hamper corneal integrity while doing immersion method.

The measurements with both devices were performed based on manufacturer's recommendation and standard protocol. All the tests by both devices were done at least 3 times and by a single experienced technician in a dark room. First, patient's data was entered, and then the fixation light and illumination lights were switched on. The patient was asked to place the chin on the chin rest and press the forehead against the forehead strap. The patient's eyes were aligned along the visual axis by a central fixation light. The axial length from cornea to retina was measured using a single refractive index. All IOL Mastersmeasure with a signal-to-noise ratio greater than 2which are acceptable for data analysis. The anterior chamber depth was measured by image analysis of the distance between anterior corneal pole and anterior surface of the crystalline lens. Measurement of anterior chamber depth was automatically generated by means of lateral slit illumination.Ultrasound biometry was done by instillation of topical anesthesia proparacaine hydrochloride 0.5%. The patient was asked to sit comfortably in an upright position and look straight. A 10 MHz probe from the scan unit was brought forward to touch the cornea without intending it. The probe's position should be aligned along the visual axis to get proper spikes on the screen. One hand was holding the lids and the other hand hold the probe in a perpendicular position with the corneal steep to exhibit the measurement which automatically calculated by the instrument for AL and ACD value.The measurements were taken from there.

After taking the measurements with both devices the patient's eyes were divided into three sub groups based on their axial length measurement. The sub groups are, normal eye group (22mm – 25mm), long eye group (>25mm) and short eye group (<22mm).

Statistical analysis

Comparison and correlation was analyzed between opticaland ultrasonic measurements of axial length and anterior chamber depth of three sub group's eyes. The statistical analysis of the data was done by SPSS version 23.0. Differences in measurement between two methods were evaluated by paired two-tailed t-test. The inter-device agreement was analyze by Bland-Altman plots. The correlation among the methods was calculated with 95% confidence interval. A p value of <0.05 indicates statistical significant value.

Result

A total number of 145 patients were enrolled as sample for the study. Informed written consent was taken from the patients after random selection. Among 145 patients62 were male and 83 were female. The mean age of the patient was 59.03, with standard deviation of 11.73. The age range of the patients was 34 years to 56 years.

Table-I

Characteristics of study group by gender

Gender		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	62	42.8	42.8	42.8
	Female	83	57.2	57.2	100.0
	Total	145	100.0	100.0	

Table-II

Age distribution of the study group.

		Gender	Age
N	Valid	145	145
	Missing	0	0
	Mean		59.03
	Std. Deviation		11.73
	Variance		137.60
	Range		56
	Minimum		34
	Maximum		90

The patients were divided into three groups according to their axial length measurement. They were long, normal and short eye group. According to the biometry normal eye present with axial length within 22-25mm , long eye group have axial length >25mm, and short eye shows axial length <22mm. Normal eye group had 75 patients , long eye group consist of 29 patients and there were 41 patients in short eye group.

In total sample of 145 patients, mean axial length by optical biometry was 23.68mm with standard deviation of 2.34mm. By ultrasound biometry the mean of axial length was measured 23.59mm with standard deviation of 2.30mm. The mean of difference between the two methods was 0.089 ±0.22 (p= 0.00). For anterior chamber depth, by optical method the measurement mean was 3.14mm with standard deviation of 0.48mm. By ultrasound biometry method the measurement mean was 3.12mm with standard deviation of 0.44mm. The mean of difference here was 0.015 ±0.17 (p=0.29) which is not significant.

Table-III

Optical and ultrasonic measurement of AL and ACD

	N	Mean	Std. Deviation
Optical Axial Length	145	23.68	2.34
Ultrasonic Axial Length	145	23.59	2.30
Optical Anterior Chamber Depth	145	3.14	0.48
Ultrasonic Anterior Chamber Depth	145	3.12	0.44
Valid N (listwise)	145		

Abbreviations: N total number of patients

Immersion Axial Length

The correlation between optical and ultrasonic method for axial length measurement with 95% confidence interval showed0.995 (p=0.00) and anterior chamber depth measurement was 0.934 (p=0.00). So, the Bland- Altman plot showsa quite strong agreement between these two methods of biometry.

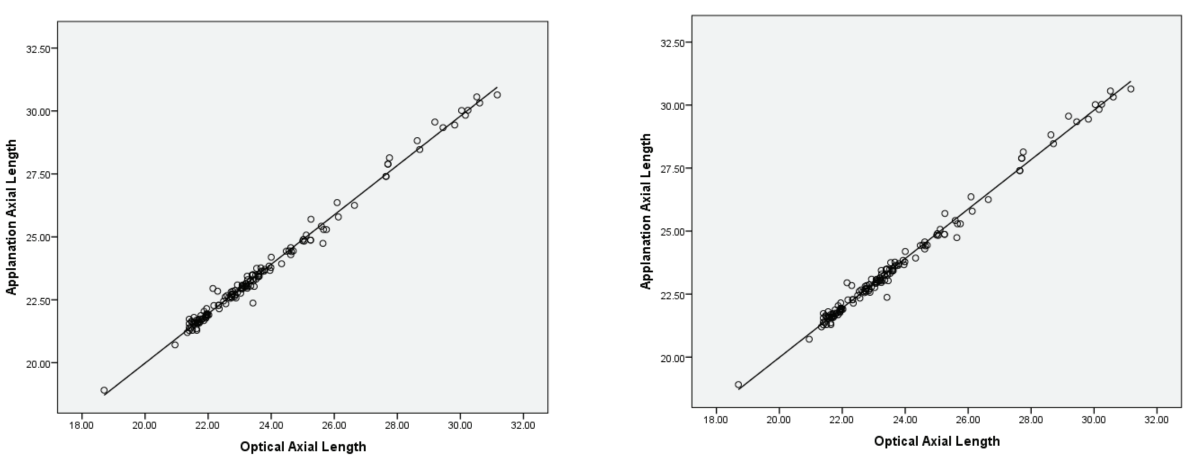

Fig.-1: *Scatterplot of correlation between AL and ACD measured by optical and ultrasound biometry*

According to sub group analysis, for normal eye group, by optical biometry the mean of axial length measurement was 23.29mm ±0.65mm and was recorded 23.20mm ±0.61mm by ultrasonic biometry. The mean of difference between the measurements by two methods were 0.09mm ±0.22mm (p=0.00). Similarly, for anterior chamber depth, the mean of optical biometric measurement was 3.14mm ±0.48mm and ultrasonic biometric measurement was 3.13mm ±0.44mm. The mean of difference between the two measurement methods were 0.01mm ±0.13mm (p=0.51) which is not significant.

For long eye group, the mean of axial length measurement by optical biometry was 27.56mm ± 2.07mm and by ultrasonic method it was 27.42mm ±2.11mm. The mean difference between two method was 0.14mm ±0.31mm (p=0.02). The mean of anterior chamber depth measured by optical biometry was 3.43mm±0.27mm and byultrasonic biometry was 3.42mm±0.26mm. The mean difference between these two methods were 0.01mm ±0.12mm (p=0.75), which is not significant.

For short eye group, the mean axial length measurement by optical biometry was 21.60mm±0.52mm and by ultrasonic biometry it was21.57mm±0.50mm. The mean of difference was 0.03mm±0.15mm (p=0.21) which is not significant. For anterior chamber depth, the mean by optical method was 2.94mm±0.58mm and by ultrasonic method it was 2.90mm±0.52mm. The mean value of difference between these two methods was 0.03mm ±0.26mm (p=0.32) which is not significant as well.

Table-IV

Correlation between AL and ACD measurement by optical and ultrasound methods of biometry

	N	Correlation	p value
Optical AL&UltrasonicAL	145	.995	<0.01
Optical ACD&UltrasonicACD	145	.934	<0.01

Abbreviations: AL axial length, ACD Anterior chamber depth

Table-V

Difference between optical and ultrasound measurement of AL and ACD

	Paired Differences					t	df	p value
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
OpticalALUltrasonicAL	0.08	0.22	.02	.05	.12	4.43	144	<0.01
OpticalACDUltrasonicACD	0.02	0.17	.01	.04	.01	1.06	144	0.29

Abbreviations: AL axial length, ACD Anterior chamber depth

Table-VI

AL and ACD sub group measurement by optical and ultrasound method of biometry

Axial Length of the Eye		N	Mean	Std. Deviation
Normal Eye	Optical AL	75	23.29	0.65
	Ultrasonic AL	75	23.20	0.61
	Optical ACD	75	3.14	0.42
	Ultrasonic ACD	75	3.13	0.43
	Valid N (listwise)	75		
Long Eye	Optical AL	29	27.56	2.07
	Ultrasonic AL	29	27.42	2.11
	Optical ACD	29	3.43	0.27
	Ultrasonic ACD	29	3.42	0.26
	Valid N (listwise)	29		
Short Eye	Optical AL	41	21.60	0.52
	Ultrasonic AL	41	21.57	0.50
	Optical ACD	41	2.94	0.58
	Ultrasonic ACD	41	2.90	0.44
	Valid N (listwise)	41		

Abbreviations: AL axial length, ACD Anterior chamber depth

To analyze the correlation between optical biometry and ultrasound biometry among the sub groups paired t test has been done with 95% confidence interval. For normal eye, correlation between two methods for axial length measurement was 0.943 (p=0.00) and for anterior chamber depth was 0.957 (p=0.00). In case of long eye the correlation of measurement between two methods for axial length was 0.989 (p=0.00) and for anterior chamber depth was 0.898 (p=0.00). At last for short eye group, the correlation between the two methods of biometry was measured 0.959 (p=0.00) for axial length and 0.909 (p=0.00) for anterior chamber depth. The Bland-Altman Plot analysisalso showed strong agreement between the optical and ultrasound methods of biometry.

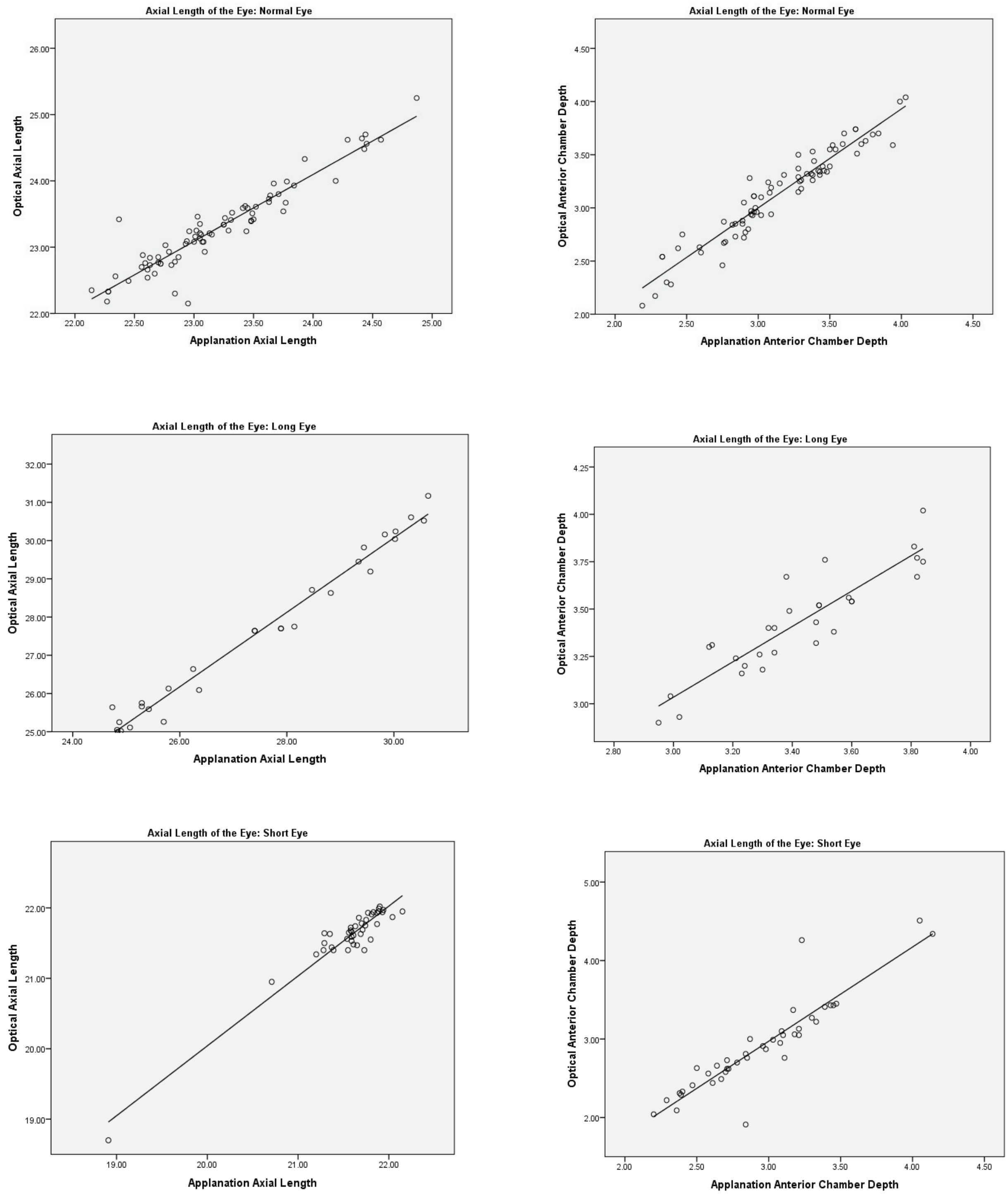

Fig.-2.*Scatterplot between AL and ACD measured by 2 methods of biometry in normal, long and short eye group*

Table-VII

Correlation of AL and ACD by two methods in normal, long and short eye group.

Axial Length of the Eye		N	Correlation	p value
Normal Eye	Optical AL & Ultrasonic AL	75	.943	<0.01
	Optical ACD & Ultrasonic ACD	75	.957	<0.01
Long Eye	Optical AL & Ultrasonic AL	29	.989	<0.01
	Optical ACD & Ultrasonic ACD	29	.898	<0.01
Short Eye	Optical AL & Ultrasonic AL	41	.959	<0.01
	Optical ACD & Ultrasonic ACD	41	.909	<0.01

Abbreviations: AL axial length, ACD Anterior chamber depth

Table VIII

Comparative difference of AL and ACD measurements by 2 methods in different axial length eye group

Axial Length of the Eye		Paired Differences					t	df	p value
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Normal Eye	Optical ALU ltrasonic AL	0.09	0.22	0.03	0.04	0.14	3.55	74	<0.01
	Optical ACD- Ultrasonic ACD	0.01	0.13	0.01	0.04	0.02	0.67	74	0.51
Long Eye	Optical AL Ultrasonic AL	0.14	0.31	0.06	0.02	0.26	2.46	28	0.02
	Optical ACD Ultrasonic ACD	0.01	0.12	0.02	0.04	0.05	0.31	28	0.76
Short Eye	Optical AL- Ultrasonic AL	0.03	0.15	0.02	0.02	0.07	1.27	40	0.21
	Optical ACD Ultrasonic ACD	0.04	0.26	0.04	0.12	0.04	1.00	40	0.32

Abbreviations: AL axial length, ACD Anterior chamber depth

Discussion

With increasing demand of more exact postoperative refractive outcome and higher patient expectation, cataract surgery consider as refractive vision restoration surgery now a days. To achieve more accurate IOL power calculation more precise, user and patient friendly optical biometry became the method of choice.[7] Since its introduction in 2000, it was evaluated repeatedly for its accuracy and applicability in compare to other traditional method.[8] The optical most advanced biometry machine IOL Master is a non-contact, non-invasive imaging technique that uses laser inferometry technology for more accurate and reliable result.[8] As this optical method provides an image based measurement, it allows a surgeon to view the complete longitudinal section of the eye.[9] IOL Master measures the axial length from corneal vertex to retinal pigment epithelium with the help of red fixation beam.[10] Anterior chamber depth is measured by calculating the distance between cornea and the lens surface.[10] Although optical method have some advantages like less observer dependency, non-contact approach, accuracy and reliability it still has got some limitations.[8] Optical biometry cannot work in some conditions like dense media opacity that occurs in hard cataract, high axial myopia and poor fixation.[11] The ultrasound technique measures the axial length from the cornea to vitreo retinal interface. The advantage of ultrasound measurement is the ability to perform in unclear optical media, less time consuming and inexpensive in compare to optical method. On negative side, ultrasound biometry requires trained and experienced observer.[12] There are some differences between the optical and ultrasonic biometry method. First of all, the laser light used in optical method has short wave length compare to sound wave used in ultrasound method. Secondly, the starting point of measurement for ultrasound method is corneal apex and for optical method it is second principal plane of the cornea.[4] At last, the optical method works along the visual axis and the ultrasound method works along the anatomic axis.[13]

After statistical analysis of the data collected from 145 patients enrolled for cataract surgery we found that, the axial length measurement by optical biometry is 0.083mm ± 0.22mm higher than the measurement by ultrasonic biometry. Study by Nemeth et al reveals similar result in his study with IOL Master and ultrasonic biometer.[13] In his study axial length was 0.39mm±0.36mm longer then ultrasonic biometry. Gopi et al did the study with IOL Master as well and reveals 0.11mm±0.36mm longer measurement of axial length by IOL Master then ultrasound biometry method.[2] Goel et al have done the study with Lenstar and reported significantly higher measurement of axial length from ultrasonic method.[14] Bjelos Roncevic et al and Buckhurst et al both in their study reported the axial length by optical method 0.25mm±0.27mm and 0.14mm±0.15mm respectively.[15,16] This shortening of axial length by ultrasonic method could be due to indentation of the cornea by the saline inside the shell by an average of 0.1 to 0.3mm.[13] The higher level of axial length by optical method is due to the axis of measurement by an ophthalmic assistant and not dependent on any trained and experienced observer.[10]

For anterior chamber depth measurement, our study reveals closely correlated measurement by two methods. Here optical measurement is only 0.02mm±0.17mm higher than ultrasonic biometric value. Similar outcome observed from the study of Santodomingo-Rubido et al and Elbaz et al.[17,18,19] According to their study anterior chamber depth measured by optical biometry is 0.06mm±0.25mm longer than immersionultrasound biometry measurement.[20] Other studies done by Kriechbaum et al all show longeranterior chamber depth measurement by optical biometry then ultrasound biometry.[21] They have explained the cause of lesser value by ultrasound method by a number of factors like, experience of the operator, probe tip handling, and lack of pupil dilatation and different setting of ultrasound velocity.[2, 21] They also claim that this different methodical measurement can also be due to IOL Master's slit source. As the light is always coming from the temporal side, the measurement is higher from temporal side then from the middle.[10] It seems that this was the factor to influence the anterior chamber depth measurement in our study.Our study also shows a strong agreement between the methods of biometry. The mean difference shows negligible values with significant p value ($p<0.01$) of correlation coefficient, which indicates both methods can be used interchangeably.

According to sub group data analysis, normal, long and short eye group shows longer axial length measurement by optical biometry and similarly higher anterior chamber depth measurement by optical method of biometry. They have very good positive correlation with no significant difference between them. Both optical and ultrasonic methods show strong agreement in intraocular biometric measurements. Studies conducted by Gopi et al, Dong et al, Higashiyama et al, and Fouad et al also divide their study subjects into different axial length group.[2,4,18,22]]They found the measurements difference by two methods in almost all cases. But they all shared a common finding of excellent correlation between the biometry methods. They calculate their negligible difference in mean of axial length like 0.03mm in short AL group, 0.05mm in long AL group.[22] In our study we found the result as, .03mm in short AL group and 0.14 mm in long AL group. Similarly study conducted by Bai et al reveals the mean difference of anterior chamber depth as 0.36mm with correlation coefficient of 0.823.[11] According to our study this mean difference came up as 0.009mm with correlation coefficient of 0.959. So it can be said that, Axial length and anterior chamber depth measurement for normal. Long and short eye have statistically significant difference in measurement and the difference between the two devices are clinically negligible.

Conclusion

After detailed data analysis, the optical biometry seemed to gives lightly improved refractive results in compare to applanation ultrasound biometry [23].At the same time they show excellent positive correlation and strong agreement with appalnation ultrasound measurement. Once optimization of IOL constant is done in IOL power calculation formula, both optical and applanation method give improved refractive results after cataract surgery [24,25].So, from this study it can be said that, both optical and ultrasonic methods can be used interchangeably for accurate preoperative biometric measurements in normal, long and short eyefor calculation of précised IOL power.

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