Original Article

Ocular biometry characteristics and corneal astigmatisms in cataract surgery candidates at a tertiary care center in North-East India

Tanie Natung, Wakaru Shullai, Benjamin Nongrum, Lanalyn Thangkhiew, Prasenjit Baruah[1], Mary L Phiamphu[1]

Purpose: The purpose of this study is to determine the ocular biometry characteristics and corneal astigmatisms using partial coherence laser interferometry in patients aged 40 years or above undergoing cataract surgery in a medical college in North-East India. **Methods:** In a hospital-based cross-sectional study, ocular biometry characteristics such as axial length (AL), anterior chamber depth (ACD), white-to-white (WTW) diameter, corneal power (K), and corneal astigmatisms (D) of consecutive eligible cataract patients in a medical college in North-East India between January 2015 and December 2017 were determined using the intraocular lens (IOL) master. Height and weight were also measured. **Results:** A cross-sectional study evaluated ocular biometry characteristics of 641 eyes in 641 eligible patients. The mean age was 64.04 ± 10.81 years. The mean AL, ACD, WTW, corneal power, IOL power, and body mass index (BMI) were 23.34 ± 1.12 mm, 3.12 ± 0.39 mm, 11.92 ± 0.54 mm, 44.41 ± 1.50 diopter (D), 20.53 ± 2.79 D, and 26.12 ± 4.32, respectively. Against-the-rule, with-the-rule, and oblique astigmatisms were 48.4%, 33.2%, and 18.4%, respectively. Corneal astigmatism of ≥1 D was found in 292 eyes (45.55%) and >1.5 D in 182 eyes (28.39%). AL had statistically significant correlation with ACD, WTW, K, IOL power, height and weight but not with age. By multivariate analysis, AL was found to be associated with ACD, WTW, K and IOL power ($P \leq 0.05$). The mean AL was negatively correlated with the mean K (R-square 0.138). **Conclusion:** This study is likely to provide the initial normative data for ocular biometry values in Indian adults 40 years or above, because such data is lacking in Indians using the IOL master. This will also help ophthalmologists in planning and improving the quality of surgical outcomes in phacoemulsification and phacorefractive surgeries by choosing the appropriate IOL and incision location.

Key words: Cataract surgeries, corneal astigmatisms, North-East India, ocular biometry, phacoemulsification

Access this article online
Website: www.ijo.in
DOI: 10.4103/ijo.IJO_1353_18
Quick Response Code:

Cataract surgery is rapidly becoming a lens-based refractive surgery by correcting the refractive errors including astigmatisms and presbyopia, while at the same time replacing the cataractous lens with a premium intraocular lens (IOL).[1] Therefore, very precise assessment of axial length (AL), corneal power, and anterior chamber depth (ACD) is very important to calculate the exact IOL power to achieve the desired refractive power and to minimize the postoperative astigmatism.[2,3] This is especially required in patients opting for premium IOLs such as trifocal or toric or trifocal-toric IOLs. This will reduce spectacle dependence of the patients undergoing cataract surgery.

Partial coherence interferometry (PCI) is the gold standard for measuring the ocular biometry characteristics.[4] Using the PCI, few studies have been done to find the ocular biometry characteristics in the Asian eyes.[3,5-11] However, there is no data available, to the best of our knowledge, on the pattern of ocular biometric values and astigmatisms of Indian subjects undergoing cataract surgery by using PCI. Using the ultrasonography (USG) contact method, only one study from Central India has tried to find the association of AL with other ocular and systemic parameters in an adult Indian population.[11] Hence, the biometry pattern using the PCI in Indian eyes is not known.

Therefore, the aim of our study was to determine the distribution of ocular biometric parameters and corneal astigmatisms in Indian patients undergoing cataract surgery at this medical college of North-East India.

Methods

It was a prospective, cross-sectional, hospital-based study. The study was conducted at the Department of Ophthalmology of a medical college in North-East India between January 2015

Departments of Ophthalmology and [1]Optometry, North Eastern Indira Gandhi Regional Institute of Health and Medical Sciences, P.O. Mawdiangdiang, Shillong, Meghalaya, India

Correspondence to: Dr. Tanie Natung, Department of Ophthalmology, North Eastern Indira Gandhi Regional Institute of Health and Medical Sciences (NEIGRIHMS), P.O. Mawdiangdiang, Shillong, Meghalaya, India. E-mail: natungtanie@gmail.com

Manuscript received: 23.08.18; Revision accepted: 25.04.19

Cite this article as: Natung T, Shullai W, Nongrum B, Thangkhiew L, Baruah P, Phiamphu ML. Ocular biometry characteristics and corneal astigmatisms in cataract surgery candidates at a tertiary care center in North-East India. Indian J Ophthalmol 2019;67:1417-23.

and December 2017. Institute's ethics clearance was taken for the study and we adhered to the tenets of Declaration of Helsinki. Written informed consent was taken from every patient undergoing cataract surgery.

We included patients 40 years or above undergoing cataract surgery were included in the study. Dense cataract interfering with the measurement with PCI, cataract surgery for secondary IOL-like scleral fixated IOL, corneal diseases, and ocular surface disorders and post-traumatic cataract patients were excluded from the study.

The place of study was a hill station with an altitude of approximately 550 m above sea level. Because of higher altitude of the place and low population, the prevalence of cataract is low in this place. During the study period 641 consecutive cataract candidates were enrolled. The ocular biometry before the cataract surgery was performed using PCI with an infrared diode laser at a 780 nm wavelength (IOL Master, Carl Zeiss Meditec AG, 07745 Jena, Germany, 2014). The parameters measured were keratometry, AL, ACD, white-to-white (WTW), and the IOL formulas of SRK II, SRK/T, Holladay, Hoffer Q and Haegis formulas, and IOL power. The place of study has many central government establishments such as the eastern headquarters of Indian Army, Indian Air Command, Border Security Force, Assam rifle, Indo-Tibetan Border Police, Geological and Botanical Survey of India, a central university, and many science and humanity colleges. These centers have many central government officers from different states of India posted at this place. So, apart from the patients from the state and the nearby states, this medical college caters to many patients from all over India.

Because IOL master is a noncontact biometer, the AL was measured as the distance from the tear film to the retinal pigment epithelium. Similarly, the ACD was measured as the distance from the anterior corneal surface to the anterior lens surface. Corneal power (keratometry – K) was measured in both the flat (K1) and steep K (K2). The final K value was taken as the mean of K1 and K2. For calculation of astigmatism, difference between K1 and K2 were taken and for the axis of astigmatism the axis of the steeper power, i.e., K2 was taken. The refractive index value used by PCI was 1.3375. The SRK T formula (as per the AL) was used for the statistical analysis of the theoretical IOL powers, and the target refraction was set as 0.00 diopter (D). The A constant was set as per the IOL chosen. The IOL master was calibrated every Monday of the week.

Apart from the patients' details, height and weight were also measured using standard instruments. The height was measured using a standard height measuring device (Floor Model Height Scale Model No: WS0011, Prestige Weighing Scales, Hardik Meditech, New Delhi). Similarly, weight was measured using a standard weighing machine (Microgene Bathroom weighing scale, BR9201, Ghaziabad, India). These equipments were calibrated every Monday.

Statistical analysis

Data were recorded in Microsoft Excel spreadsheets and then transferred to SPSS software for analysis. Continuous variables were expressed as the mean ± standard deviation for the data showing normal distribution. Data were analyzed using the Kolmogorov–Smirnov test to see whether they were normally distributed or not. Student's *t*-test was used to compare the means of characteristics between the male and female groups. Univariate analyses of the associations between AL and other ocular parameters were determined. Then, multivariate regression analyses of the associations between AL and other parameters were performed. One-way analysis of variance and the Kruskal–Wallis test were applied for the comparison of variance for normally and non-normally distributed data among the different age groups, respectively. Statistical analysis was performed using the SPSS software package (SPSS for Windows, version 22.0; SPSS, Inc., Chicago, IL, USA). P values <0.05 were considered statistically significant.

For statistical purpose, the patients were divided into six subgroups on the basis of age as: 40–50, 51–60, 61–70, 71–80, and ≥81 years. All the eyes were subdivided into four groups based on AL measurements as shorter than 22.0, 22.0–24.5, 24.51–26.0, and longer than 26.0 mm. Type of astigmatism was defined as with-the-rule (WTR) if the steeper meridian lies between 60 and 120; against-the-rule (ATR) if it lies between 0 and 30 or 150 and 180; and oblique astigmatism if it lies between 30.01 and 59.99 or 120.01 and 149.99. ACD was divided into ≤2.8, 2.81–3.5, and ≥3.51 mm. The amount of corneal astigmatism was divided into 0–1, 1.01–2.00, 2.01–3.00, 3.01–4.00, 4.01–5.00, 5.01–6.00, and ≥6.01.

Results

Data were analyzed from a total of 641 eligible patients. The distribution of age, ocular biometric parameters, and BMI by sex is given in Table 1. The distribution of ocular biometric parameters by age group and sex are given in Table 2 and in the Figs. 1-4. State-wise distribution of participants from different Indian states is given in Table 3.

The mean age of the participants was 64.04 ± 10.81 years. There were 334 males and 307 females in the study. There was no statistically significant difference in age between the male and female (P = 0.951).

The mean AL of the participants was 23.34 ± 1.12 mm. The mean AL in males (23.58 ± 0.99 mm) was longer than the females (23.07 ± 1.19 mm) and was statistically significant (P = 0.00). Fifty-seven participants (8.9%) had

Table 1: Distribution of age, ocular biometric parameters, and BMI in males and females

Sex (Eyes)	Mean±SD								
	Age	AL	ACD	WTW	Corneal power (D)			IOL power	BMI
					K1	K2	K		
Male (334)	64.07±11.15	23.58±0.99	3.18±0.39	11.99±0.53	43.56±1.46	44.81±1.65	44.19±1.46	20.34±2.35	25.98±4.05
Female (307)	64.01±10.45	23.07±1.19	3.05±0.39	11.84±0.54	44.01±1.62	45.29±1.65	44.65±1.52	20.73±3.20	26.29±4.61
All (641)	64.04±10.81	23.34±1.12	3.12±0.39	11.92±0.54	43.78±1.55	45.04±1.67	44.41±1.50	20.53±2.79	26.13±4.33

Table 2: Distribution of ocular biometric parameters by age group and sex

Age (years)/Sex	Eyes (*n*)	AL (mm)	ACD (mm)	WTW (mm)	Keratometry			IOL power
					K1	K2	K	
40-50								
Male	51	23.76±1.12	3.38±0.32	12.21±0.50	43.69±1.55	45.07±1.88	44.38±1.62	20.08±2.56
Female	38	23.17±1.06	3.25±0.39	11.94±0.60	43.54±1.38	45.12±1.64	44.3334±1.15383	20.38±3.07
51-60								
Male	75	23.53±1.06	3.22±0.36	12.01±0.50	43.58±1.58	44.83±1.58	44.21±1.48	20.25±2.84
Female	69	23.33±2.01	3.15±0.46	11.90±0.56	43.96±1.92	45.34±1.91	44.65±1.78	19.86±5.17
61-70								
Male	123	23.57±0.87	3.19±0.40	11.97±0.56	43.59±1.30	44.68±1.56	44.11±1.33	20.61±1.89
Female	120	22.95±0.77	2.99±0.33	11.76±0.47	44.18±1.48	45.36±1.59	44.77±1.47	20.87±2.25
71-80								
Male	65	23.33±0.71	3.04±0.33	11.84±0.48	43.54±1.54	44.86±1.65	44.20±1.52	20.44±1.88
Female	69	22.93±0.73	2.96±0.36	11.84±0.56	44.20±1.51	45.40±1.49	44.80±1.41	21.41±1.76
81-90								
Male	20	24.17±1.49	2.99±0.48	12.00±0.60	43.30±1.4	44.68±1.77	43.99±1.56	19.27±3.27
Female	11	23.28±0.79	2.86±0.19	11.96±0.71	42.84±1.75	44.14±1.41	43.49±1.49	21.72±2.12
Total	641	23.34±1.12	3.12±0.39	11.92±0.54	43.78±1.55	45.04±1.67	44.41±1.50	20.53±2.79

Mean±SD

Table 3: State-wise distribution of participants

States	Number	Percentage
Meghalaya	207	32.3
Assam	195	30.4
Manipur	67	10.5
Nagaland	42	6.6
Bihar	32	5
Arunachal Pradesh	29	4.5
Mizoram	24	3.7
Uttar Pradesh	8	1.2
Punjab	6	0.9
Tripura	5	0.8
West Bengal	4	0.6
Rajasthan	3	0.5
Himachal Pradesh	3	0.5
Sikkim	3	0.5
Uttarakhand	3	0.5
New Delhi	2	0.3
Orissa	2	0.3
Haryana	2	0.3
Andhra Pradesh	2	0.3
Tamil Nadu	1	0.2
Kerala	1	0.2
Total	641	100

AL <22 mm, 521 (81.3%) had between 22 and 24.5 mm, 48 (7.5%) had between 24.51 and 26 mm, and 15 (2.3%) had >26 mm [Table 1]. The mean AL decreased initially and then increased with the increase in age (*P* for trend = 0.004) [Fig. 1].

The mean ACD was 3.12 ± 0.39 mm. The mean ACD in males (3.18 ± 0.39 mm) was deeper than the females (3.05 ± 0.39 mm) and was statistically significant (*P* = 0.00). A total of 138 (21.5%) patients had ACD ≤2.8 mm, 403 (62.9%) had between 2.81 and 3.5 mm, and 100 (15.6%) had >3.5 mm [Table 1]. The mean ACD decreased with the increase in the age (*P* for trend = 0.00) [Fig. 2].

The mean WTW was 11.92 ± 0.54 mm. The difference in the mean WTW (*P* = 0.00) between the males and females was statistically significant. It was more for males (11.99 ± 0.53 mm) than females (11.84 ± 0.54 mm). The mean WTW increased initially and then decreased with the increase in the age (*P* for trend = 0.007) [Fig. 3].

The mean K was 44.41 ± 1.50 D. The mean K in females (44.01 ± 1.62 D) was higher than the males (43.56 ± 1.46 D) [Table 1], and the difference was statistically significant (*P* = 0.00). The mean K increased initially and then decreased with the increase in age but the change was not statistically significant (*P* = 0.074) [Fig. 4].

Astigmatism Types

The proportion of WTR was more in the younger age group. However, with the increase in age, the proportion of ATR increased more than the WTR [Fig. 5] The amount of astigmatism decreased initially and then increased with age but the trend was statistically not significant (*P* for trend = 0.249). ATR, WTR, and oblique astigmatisms were 48.4, 33.2, and 18.4%, respectively. Corneal astigmatism of ≥1 D was found in 45.55% and >1.5 D in 28.39%. A total of 353 (55.1%) had astigmatism ≤1 D, 174 (27.1%) had between 1.01 and 2 D, 61 (9.5%) had between 2.01 and 3 D, 32 (5%) had between 3.01 and 4 D, 7 (1.1%) had between 4.01 and 5 D, 7 (1.1%) had between 5.01 and 6 D, and 3 (0.5%) had ≥6 D.

The mean IOL power in our study was 20.53 ± 2.79 D and the mean BMI was 26.12 ± 4.32. Male eyes had longer AL, deeper ACD, wider WTW, flatter K, greater height and weight (*P* = 0.00).

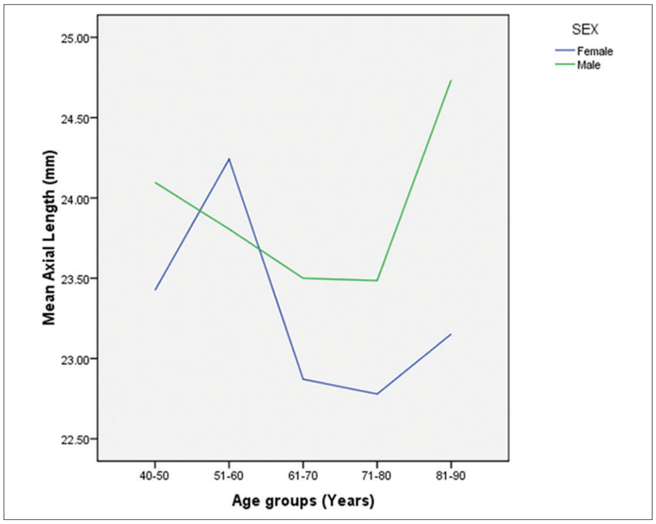

Figure 1: Relationship of mean AL with increasing age in males and females

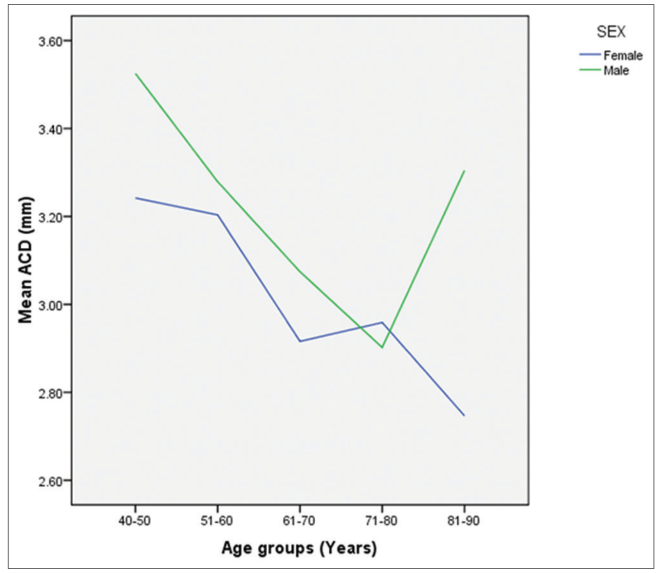

Figure 2: Relationship of mean ACD with increasing age in males and females

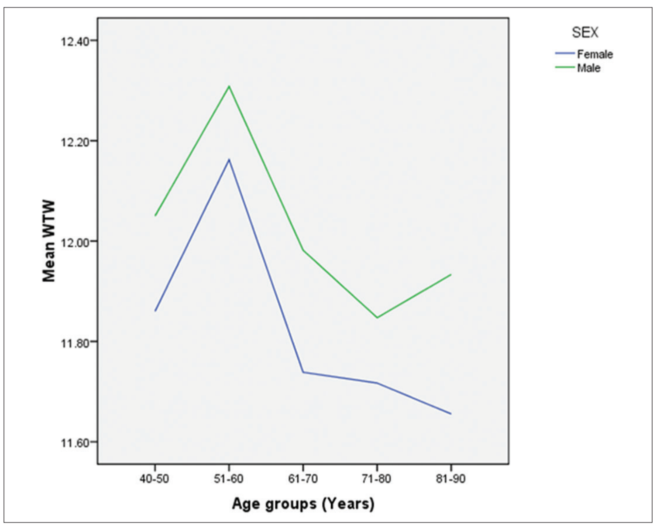

Figure 3: Relationship of mean WTW with increasing age in males and females

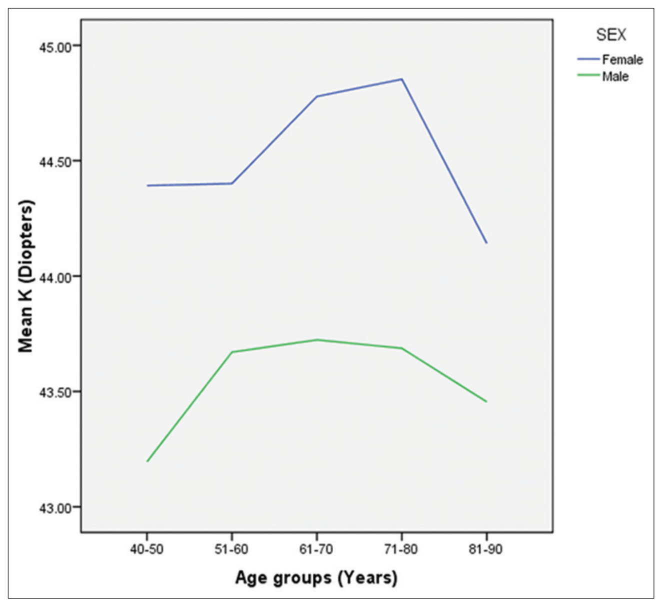

Figure 4: Relationship of mean keratometry with increasing age in males and females

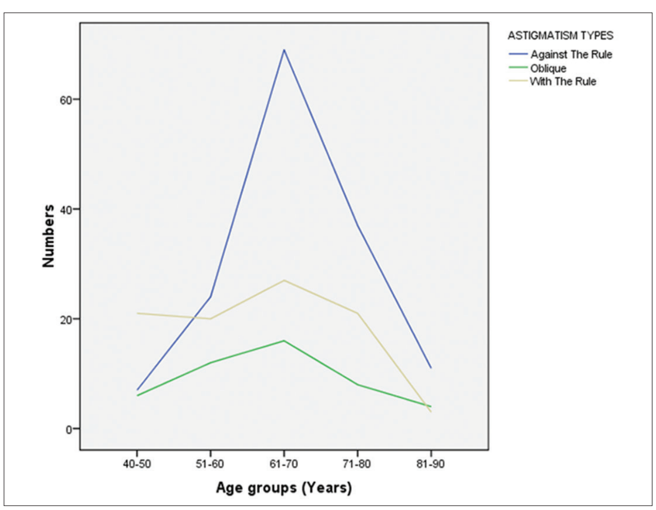

Figure 5: Distribution of astigmatism types with increasing age

Correlations

Age had statistically significant correlation with ACD, WTW, and BMI ($P = 0.00$) but not with AL and K. AL had statistically significant correlation with K, ACD, WTW, IOL power ($P = 0.00$) but not with age. AL, ACD, WTW, and K had statistically significant correlations with each other ($P = 0.00$), while IOL power had statistically significant correlation with AL, ACD, and BMI ($P = 0.00$). BMI had statistically significant correlation with age, ACD, and IOL power ($P = 0.00$).

Regression analysis

In the first step univariate analysis was performed where the association of AL, as the dependent variable, was tested with each of the rest of other variables taken individually as an

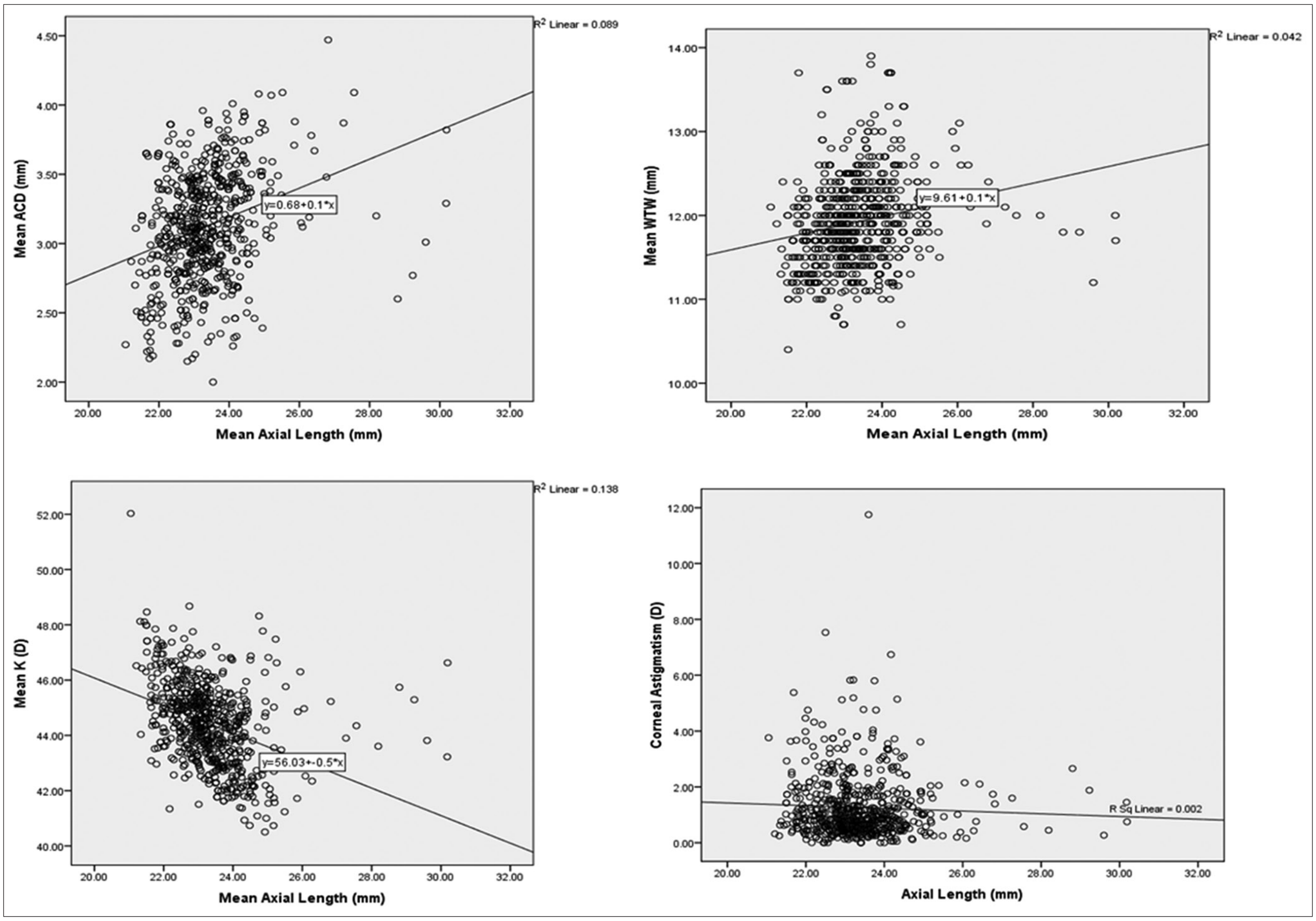

Figure 6: Scatter plots of mean ACD, WTW, keratometry, and corneal astigmatism in relation to mean AL

independent variable. It was found that AL had statistically significant association with K, ACD, WTW, IOL Power, height and weight individually but not with Age, Corneal Astigmatism and BMI [Table 4]. In the next step, multivariate regression analysis was performed with AL as the dependent variable and all other variables that were significantly associated with AL in the univariate analysis were taken together as the dependent variables. It was seen that only K, ACD, WTW and IOL power had statistically significant association but not height and weight [Table 4]. The mean AL was negatively correlated with the mean K (R-square linear 0.138) [Fig. 6].

Discussion

Our study could determine the ocular biometry characteristics and astigmatisms in the candidates of 40 years and above, undergoing cataract surgery in a medical college in North-East India. We could find the association of AL with other ocular parameters, and IOL power.

PCI is currently the gold standard for ocular biometry and IOL power calculations.[4] Because it is a noncontact technique, it is more accurate than the contact biometry measurement techniques and has less chance of corneal abrasions and infections. Moreover, it is easier to use and is reproducible. It can also predict the postoperative target refraction better than the manual biometer. However, it cannot be carried out in patients with very dense cataracts such as matured cataracts or dense posterior subcapsular cataract.

On comparing the studies for AL measurement, the mean AL in our study (23.34) was longer than the AL of Chinese population from Singapore and rural China,[5,6] Indians,[11] and Iranians.[12] It was shorter than the AL of Whites,[2,7,13-20] Chinese of Southern China,[3] Malay,[8] Singaporean Indians,[9] and Hispanics[21] [Table 5]. The mean AL in males was longer than the females and was statistically significant (P = 0.00). The AL decreased initially and then increased with the increase in age, which was statistically significant (P for trend = 0.004). The AL in our study was longer than that found in the Central India Eye and Medical study (22.6 ± 0.91), which, however, was done by USG method contact method.[11] It could be because the population in that study was mainly rural, whereas in our study the population was mainly from the urban area. Therefore, there could be a greater degree of axial myopia.[5,7,11,21]

Similarly, the mean ACD (3.12 ± 0.39) was deeper than the Chinese Mongoloids,[3,5,6] Whites,[7,12,15-17] and Malay Mongoloid.[8] It was less than the ACD found in the Caucasians,[2,13,14,18-20] Singapore Indians,[9] Hispanics and Indians.[22] The mean ACD in males was deeper than the females, which was statistically significant. The mean ACD decreased with the increase in the age (P for trend = 0.00).

Table 4: Univariate and multivariate regression analysis of ocular biometry parameters, corneal astigmatisms, and systemic parameters with AL

Variables	With	Univariate regression analysis			Multivariate regression analysis		
		Correlation coefficient β	95% CI of coefficient	*P*	Correlation coefficient β	95% CI of coefficient	*P*
AL	Age	−0.044	−0.013-0.004	0.267			
	K	−0.372	−0.331-−0.224	0.000	−0.294	−0.257-−0.182	0.000
	ACD	0.298	0.639-1.061	0.000	0.116	0.182-0.480	0.000
	WTW	0.205	0.266-0.580	0.000	0.090	0.080-0.292	0.001
	Corneal Astigmatism	−0.048	−0.122-0.029	0.228			
	IOL Power	−0.682	−0.297-−0.252	0.000	−0.644	−0.279-−0.239	0.000
	BMI	0.069	−0.002-0.038	0.080			
	Height	0.207	0.015-0.032	0.000	0.085	−0.026-0.046	0.595
	Weight	0.203	0.013-0.028	0.000	0.056	−0.040-0.052	0.809

Table 5: Comparison of ocular biometry characteristics of the present study with some other studies of the world

Author	Country	Race	Measurement method	AL (mm)			ACD (mm)			K (D)		
				Total	Males	Females	Total	Males	Females	Total	Males	Females
Nangia *et al.*	India	Indian	USG contact method	22.60	-	-	3.21	-	-	-	-	-
Cao *et al.*	China	Chinese	USG contact method	23.04	-	-	3.03	-	-	44.24	-	-
Hashemi *et al.*	Iran	Iranian	Lenstar	23.14	23.41	23.95	2.62	2.66	2.58			
Wong *et al.*	Singapore	Chinese	USG contact method	23.23	23.54	22.98	2.9	2.99	2.81	44.12	43.66	44.47
Shufelt *et al.*	USA	Hispanic	USG contact method	23.38	23.65	23.18	3.41	3.48	3.36	43.72	43.35	43.95
Knox *et al.*	United Kingdom	Caucasian	IOL Master	23.40	23.76	23.2	-	-	-	43.9	43.45	44.18
Hoffman *et al.*	Germany	Caucasian	IOL Master	23.43	23.77	23.23	3.11	3.12	3.02	43.89	43.44	44.12
Fotedar	Australia	Caucasian	IOL Master	23.44	23.75	23.2	3.1	3.16	3.06	43.42	43.01	43.74
Olsen	Denmark	Caucasian	IOL Master	23.45	-	-	-	-	-	-	-	-
Pan *et al.*	Singapore	Indian		23.45	23.68	23.23	3.15	3.19	3.1			
Jivrajka *et al.*	USA	Caucasian	USG contact method	23.46	23.76	23.27	2.96	3.05	2.9	-	-	-
Siahmed *et al.*	France	Caucasian	IOL Master	23.46	-	-	-	-	-	43.97	-	-
Lim *et al.*	Singapore	Malay	IOL Master	23.55	-	-	3.1	-	-	44.12	-	-
Hoffer	USA	Caucasian	USG Immersion	23.65	-	-	3.24	-	-	43.81	-	-
Lee *et al.*	USA	Caucasian	IOL Master	23.69	23.92	23.51	3.11	3.14	3.09	43.83	43.44	44.12
Ferreira *et al.*	Portugal	Caucasian	Lenstar	23.87	23.99	23.68	3.25	3.2	3.09	43.91	43.46	44.2
Cui *et al.*	China	Chinese	IOL Master	24.07	24.28	23.9	3.01	3.08	2.96	44.13	43.78	44.38
Olsen *et al.*	Finland	Caucasian	USG contact method	-	23.74	23.20	-	3.2	3.08	-	43.41	43.73
Present study	India	Indian	IOL Master	23.34	23.58	23.07	3.12	3.18	3.05	44.41	43.56	44.01

The mean K was 44.41 ± 1.50 D. There was statistically significant difference in the mean K between the males and the females ($P = 0.00$). It was more than all other studies who have reported the mean K.[3,5-8,14-16,18-21] The mean K increased initially and then decreased with the increase in age but the change was not statistically significant ($P = 0.074$).

The mean WTW was 11.92 ± 0.54 mm. The mean WTW decreased initially and then increased with the increase in the age (P for trend = 0.007). Other studies have not reported the mean WTW. Therefore, we cannot make a comparison of our mean WTW with other studies.

Age was correlated well with ACD, WTW, and BMI ($P = 0.00$) but not with AL and K. As in other studies, the mean AL was negatively correlated with the corneal power (R square linear 0.138).

Corneal astigmatism of ≥1 D was found in 292 (45.55%) and >1.5 D in 182 (28.39%) cases. This was similar to that found in the studies by Cui *et al.*[3] The amount of astigmatism decreased initially and then increased with age but was not statistically significant (P for trend = 0.249). ATR, WTR, and oblique astigmatisms were 48.4, 33.2, and 18.4%, respectively. As the age increases, the proportion of ATR becomes more than the WTR although initially the WTR is more than the ATR.

Conclusion

This study gives the characteristics of ocular biometry and corneal astigmatism using IOL master in patients undergoing cataract surgery in a medical college in North-East India. This will serve as the initial normative data for biometry values in Indian adults undergoing cataract surgery because such data is lacking in the Indian population. This data will also help the ophthalmologists in choosing the correct IOL and incision location, thereby improving the surgical outcome in phacoemulsification or phacorefractive surgeries.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Donaldson K, Fernandez-Vega-Cueto L, Davidson R, Dhaliwal D, Hamilton R, Jackson M, *et al*. Perioperative assessment for refractive cataract surgery. J Cataract Refract Surg 2018;44:642-53.
2. Olsen T. Improved accuracy of intraocular lens power calculation with the Zeiss IOL Master. Acta Ophthalmol Scand 2007;85:84-7.
3. Cui Y, Meng Q, Guo H, Zeng J, Zhang H, Zhang G, *et al*. Biometry and corneal astigmatism in cataract surgery candidates from Southern China. J Cataract Refract Surg 2014;40:1661-9.
4. Kaswin G, Rousseau A, Mgarrech M, Barreau E, Labetoulle M. Biometry and intraocular lens power calculation results with a new optical biometry device: Comparison with the gold standard. J Cataract Refract Surg 2014;40:593-600.
5. Wong TY, Foster PJ, Ng TP, Tielsch JM, Johnson GJ, Seah SK. Variations in ocular biometry in an adult Chinese population in Singapore: The Tanjong Pagar survey. Invest Ophthalmol Vis Sci 2001;42:73-80.
6. Cao X, Hou X, Bao Y. The ocular biometry of adult cataract patients on lifeline express hospital eye train in rural China. J Ophthalmol 2015;2015:171564.
7. Lee KE, Klein BK, Klein R, Quandt Z, Wong TY. Age, stature, and education associations with ocular dimensions in an older white population. Arch Ophthalmol 2009;127:88-93.
8. Lim LS, Saw SM, Jeganathan SE, Tay WT, Aung T, Tong L, *et al*. Distribution and determinants of ocular biometric parameters in an Asian population: The Singapore Malay eye study. Invest Ophthalmol Vis Sci 2010;51:103-9.
9. Pan C-W, Wong T-Y, Chang Lan, Lin X-Y, Lavanya R, Zheng Y-F, *et al*. Ocular biometry in an Urban Indian population: The Singapore Indian eye study (SINDI). Invest Ophthalmol Vis Sci 2011;52:6636-42.
10. Yu J, Zhong J, Mei Z, Zhao F, Tao N, Xiang Y. Evaluation of biometry and corneal astigmatism in cataract surgery patients from Central China. Invest Ophthalmol Vis Sci 2002;43:1408-13.
11. Nangia V, Jonas JB, Sinha A, Matin A, Kulkarni M, Panda-Jonas S. Ocular axial length and its associations in an adult population of central rural India: The Central India eye and medical study. Ophthalmology 2010;117:1360-6.
12. Hashemi H, Khabazkhoob M, Miraftab M, Emamaian MH, Shariati M, Abdolahinia T, *et al*. The distribution of axial length, anterior chamber depth, lens thickness, and vitreous chamber depth in an adult population of Shahroud, Iran. BMC Ophthalmology 2012;12:1-8.
13. Olsen T, Arnarsson A, Sasaki H, Sasaki K, Jonasson F. On the ocular refractive components: The Reykjavik eye study. Acta Ophthalmol Scand 2007;85:361-6.
14. Knox Cartwright NE, Jonhston RL, Jaycock PD, Tole DM, Sparrow JM. The cataract national dataset electronic multicentre audit of 55,567 operations: When should IOL Master biometric measurements be rechecked? Eye (Lond) 2010;24:894-900.
15. Hoffmann PC, Hutz WW. Analysis of biometry and prevalence data for corneal astigmatism in 23,239 eyes. J Cataract Refract Surg 2010;36:1479-85.
16. Fotedar R, Wang JJ, Burlutsky G, Morgan IG, Rose K, Wong TY, *et al*. Distribution of axial length and ocular biometry measured using partial coherence laser interferometry (IOL Mater) in an older white population. Ophthalmology 2010;117:417-23.
17. Jivrajka R, Shammas MC, Boenzi T, Swearingen M, Shammas HJ. Variability of axial length, anterior chamber depth, and lens thickness in the cataractous eye. J Cataract Refract Surg 2008;34:289-94.
18. Siahmed K, Muraine M, Brasseur G. Optic biometry in intraocular lens calculation for cataract surgery. Comparison with usual methods. J Fr Ophthalmol 2001;24:922-6.
19. Hoffer KJ. Axial dimension of the human cataractous lens. Arch Ophthalmol 1993;111:914-8. Erratum 1993;111:1626.
20. Ferreira TG, Hoffer KJ, Ribeiro F, Ribeiro P, O'Neill JG. Ocular biometric measurements in cataract surgery candidates in Portugal. PLoS One 2017;10:1-12.
21. Shufelt C, Fraser-Bell S, Ying-Lai M, Torres M, Varma R; Los Angeles Latino Eye Study Group. Refractive error, ocular biometry, and lens opalescence in an adult population: The Los Angeles Latino eye study. Invest Ophthalmol Vis Sci 2005;46:4450-60.
22. Jonas JB, Nangia V, Gupta R, Khare A, Sinha A, Agarwal S, *et al*. Anterior chamber depth and its associations with ocular and general parameters in adults. Clin Exp Ophthalmol 2012;40:550-6.