Original Article

A comparison of lens parameters in patients with various subtypes of primary angle-closure disease and the normal population: A prospective study

Keya Chakrabarti, Swati Samant, Ramesh Mohapatra, Suchismita Mishra, Suprava Das, Meena Chakrabarti[1]

Purpose: To assess the role of lens parameters in the detection and progression of primary angle-closure disease (PACD) by combining A-scan and A-scan optical coherence tomography (AS-OCT) parameters. **Methods:** A cross-sectional study was conducted in a tertiary health-care center in eastern India. A total of 91 study subjects including cases and controls were included in the study. The parameters studied were lens thickness (LT), lens axial factor (LAF), relative lens position (RLP), and lens vault (LV). Anterior chamber depth (ACD) and axial length (AL) were also analyzed using A-scan. **Results:** The LT was significantly more in all subtypes of PACD (from 4.24 ± 0.84 to 5.02 ± 0.18 mm) than in controls (4.04 ± 0.46 mm; $P < 0.01$). Similarly, LAF was significantly less among all subtypes of PACD compared to controls ($P < 0.001$). The RLP, calculated using the formula (ACD + 0.5 LT)/AL × 10, showed no significant difference ($P > 0.05$) between various study groups. The LV in acute angle-closure glaucoma (AcCG) patients was significantly higher compared to the control population ($P < 0.01$). Ocular parameters like ACD decreased, whereas LT and LAF increased from normal through primary angle closure (PAC) to primary angle-closure glaucoma (PACG). Logistic regression analysis found a significant association between a decrease in ACD and an increased risk of PACG (P-value was 0.0001) and an increase in LT and LAF with increased risk of PACG ($P = 0.040$ and $P = 0.006$, respectively). **Conclusion:** Inclusion of lens parameter assessment in the workup of a patient with PACD helps in detection and close monitoring of the progression from suspected to disease state.

Key words: Lens Axial Factor, lens parameters, lens thickness, lens vault, primary angle-closure disease, relative lens position

Access this article online

Website: www.ijo.in

DOI: 10.4103/ijo.IJO_3007_21

Quick Response Code:

Primary angle-closure glaucoma (PACG) is one of the leading causes of blindness.[1] Even though the incidence of open-angle glaucoma is more than that of angle-closure glaucoma, the amount of blindness created is the same owing to the greater morbidity of the latter.[1,2] According to a study in conjunction with the World Health Organization (WHO), the number of subjects suspected of having angle-closure glaucoma in 2010 was 0.69%. Females were more commonly affected than males.[2] By 2020, PACG was expected to cause blindness in almost 5.3 million people.[2,3] The blindness caused by angle-closure glaucoma can be prevented to a large extent by early detection, appropriate treatment, and regular follow-up.[4] One possible mechanism of primary angle closure (PAC) is based on ocular biometric characteristics. The biometric parameters that have been found to have a correlation with PAC diseases (PACDs) are axial length (AL) of the eyeball, anterior chamber depth (ACD), lens thickness (LT), vitreous depth (VD), lens vault (LV) as well as the anterior chamber angle parameters.[5] Among the ocular biometric parameters, the lens factors play an important role in the progression of the disease. It has been shown in several studies that eyes with PACG have a relatively thicker and more anteriorly positioned lens than normal eyes.[6]

Vitreous cavity depth was taken to rule out choroidal effusion associated with angle closure, as it is less in these cases. Other than that, it has no relevance in the context of the present study.[7] Even though many studies have been conducted to collect biometric parameters, a study of the ocular biometric parameters of the eastern Indian population has not been attempted.

The present study was conducted with an aim to determine the biometric characteristics of patients with various subtypes of PACDs who were attending the outpatient clinic of a tertiary-level hospital in India and to compare these parameters with those of normal population. We also tried to identify whether variation in any of the lens-related biometric parameters increased the risk of progression to acute angle-closure disease.

Methods

A cross-sectional study was conducted in the Department of Ophthalmology of a tertiary care center in eastern India from October 2018 to September 2020.

Institute of Medical Science and SUM Hospital, Kalinga Nagar, Ghatikia, Bhubaneswar, Odisha, [1]Chakrabarti Eye Care Centre, Trivandrum, Kerala, India

Correspondence to: Dr. Swati Samant, Institute of Medical Science and SUM Hospital, Bhubaneswar, Odisha, India. E-mail: drswati_s@soahospitals.com

Received: 01-Dec-2021 Revision: 01-Mar-2022
Accepted: 05-May-2022 Published: 29-Jul-2022

Cite this article as: Chakrabarti K, Samant S, Mohapatra R, Mishra S, Das S, Chakrabarti M. A comparison of lens parameters in patients with various subtypes of primary angle-closure disease and the normal population: A prospective study. Indian J Ophthalmol 2022;70:2889-94.

A total of 91 patients were included in the study, out of which 30 patients were diagnosed as PAC suspects (PACS), 12 had PAC, seven had PAC glaucoma (PACG), 12 had chronic angle-closure glaucoma (CACG), and seven were acute angle-closure glaucoma (AcCG) patients. Five of the fellow eyes of AcCG patients were also included. Eighteen patients with normal eyes were enrolled in the study for comparative analysis. Patients with no shallow anterior chamber, normal gonioscopy, and no previous intervention for any type of PACD were taken as controls. As majority of the older population had cataract, which could cause shallow angles, they were excluded from the study.

PACD was classified based on International Society Geographical & Epidemiological Ophthalmology (ISGEO) classification.[8,9] Patients in whom the angle of anterior chamber was apposed/closed in greater than 270° in all three quadrants were included in the study. If they were asymptomatic, they were considered PACS. If only intraocular pressure (IOP) was raised (more than 21 mmHg),[10] then the patients were considered PAC. Patients with peripheral anterior synechiae, raised IOP, and complaining only of occasional headache were included in the CACG category. Patients with visual field changes and glaucomatous disk changes were included in the PACG category. AcCG patients were those with visual field changes, glaucomatous disk changes, and acute onset of symptoms like headache, colored halos, and blurred vision. These patients were managed with interventions and were included in the study after 3 weeks of the acute attack. The fellow eyes of all such patients were also included.

Patients with other types of glaucoma, ocular anomalies (microcornea, coloboma, aniridia), prior intraocular surgery (including cataract surgery), ocular trauma, or any other ocular pathology including active infections were excluded. Patients who have had any interventions for PACD (miotics, laser peripheral iridotomy [Yttrium Aluminum Garnett [YAG PI]) were excluded from the study. An exception to this was acute angle-closure attack, where immediate medical intervention followed by YAG PI was necessary. In such patients, biometric parameters were collected 3 weeks after the medical intervention.

A detailed history of sociodemographic data such as name, age, gender, and history of illness including history of previous attacks was taken from each patient. A detailed examination of the patients was done, wherein visual acuity with Snellen's chart, refraction, detailed slit-lamp examination including van-Hericks, gonioscopy, and signs of current or previous acute angle-closure attacks were examined. The IOP was recorded using Goldmann Applanation tonometry. Central corneal thickness (CCT)-corrected IOP was also documented (corrected IOP = measured IOP – [CCT – 545]/50 × 2.5 mmHg).[11] Gonioscopy was performed using a Sussman's four-mirror lens, and assessment of the anterior chamber angle was carried out according to Schaffer's classification. Care was taken to not press the lens against the cornea, so that mild cases of PACS were not missed. Analysis of the visual fields and optic disk was done to categorize our patients into PACG and PAC. Visual fields and fundus examination were more important in assessing progression and for proper counseling of the patient.[8]

Once it was confirmed that the patient had a particular subtype of angle closure and met the inclusion and exclusion criteria, the biometric parameters of the right eye were taken for statistical analysis.

A scan machine (ophthalmic ultrasound scanner- Marvel II AB-Scan) was used to determine the LT, ACD, and AL, and these values were used to calculate the lens AL factor and relative lens position (RLP). Cirrus HD-OCT 500 was used to obtain biometric parameters like CCT for CCT-corrected IOP and LV.

The lens axial factor (LAF) was calculated by using the formula LAF = (LT/AL) × 10. The lens position was defined as the sum of ACD and one-half LT, that is, (ACD + 1/2 LT). RLP was calculated by using the formula LP divided by AL.[12,13]

LV is defined as the perpendicular distance between the anterior pole of the crystalline lens and the horizontal line joining the two scleral spurs on horizontal A-scan optical coherence tomography (AS-OCT) scans.[14] The lens parameters studied included LT, LV, RLP, and LAF. The study was conducted according to the Declaration of Helsinki and was approved by the Institutional Ethics Committee (Ref. no/DMR/IMS.SH/180108).

Statistical analysis

Data were analyzed using the computer software R. The analyzed data are expressed as frequency (f) and percentage (%), as well as mean (M) and standard deviation (SD). To elucidate the associations and comparisons between different groups, the Chi-square (χ^2) test (nonparametric test) and one-way analysis of variance (one-way ANOVA) (parametric test) were performed. To elucidate multiple comparisons between groups, Duncan's multiple range (DMR) test was also performed. For all statistical evaluations, a two-tailed probability of P value <0.05 was considered significant.

Results

The study population comprised 91 subjects diagnosed to have various subtypes of PACD and 18 normal eyes with open angles as the control population. Thirty patients were diagnosed as PACS, 12 patients as PAC, seven patients as PACG, and 12 patients as CACG. Five AcCG patients and their fellow eye (FeAcCG) were also included in the study. One patient had an acute attack simultaneously in both eyes. The general and ocular characteristics of the study population are given in Table 1. In our study, 40.70% of patients were between 50 and 59 years of age. Except for four out of 18 control group eyes of patients who were less than 30 years of age, the remaining study population was between 30 and 59 years of age. Also, 18.70% (17 patients) were older than 60 years. The mean age of the patients with various subtypes of PACD was comparable (range from 52.25 ± 7.85 to 59.71 ± 3.45) but significantly higher when compared to the mean age of the control population (39.33 ± 11.27; $P < 0.001$). The study population had a greater number of females (59 [64.80%]). The patients in the case group were mostly females (48.35%), except for the CACG group which had more males (Chi-square test: 24.199; $P < 0.001$). Most of the patients in our study had hyperopia (63.70%), while 8.80% who were myopic belonged to either the control group or were PACG suspects.

Table 2 shows the best corrected visual acuity (BCVA) of the study population. It was found to be lowest in the AcCG

Table 1: Details of the demographic characteristics of the study population

Criteria	PACS	PAC	PACG	AcCG	FeAcCG	CACG	Control	Total
Mean age *P*<0.001, Chi-square test: 52.208	54.17±7.78	52.25±7.85	59.71±3.45	56±7.05	52.80±5.45	53.33±6.61	39.33±11.27	109
Sex *P*<0.001, Chi-square test: 24.199								
M	12 (40%)	1 (8.30%)	2 (28.60%)	1 (14.30%)	1 (20.00%)	11 (91.70%)	4 (22.20%)	32 (35.20)
F	18 (60%)	11 (91.70%)	5 (71.40)	6 (85.70%)	4 (80%)	1 (8.30%)	14 (17.80%)	59 (64.80%)
REFR *P*<0.001, Chi-square test: 119.313								
E	6 (20%)	3 (25%)	-	-	2 (40%)	1 (8.30%)	13 (72.20%)	25 (27.50%)
H	18 (60%)	9 (75%)	7 (100%)	7 (100%)	3 (60%)	11 (91.70%)	3 (16.70%)	58 (63.70%)
M	6 (20%)	-	-	-	-	-	2 (11.10%)	8 (8.80%)
CCT *P*<0.001, Chi-square test: 24.353								
<535	7 (23.30%)	-	-	-	-	4 (33.30%)	3 (16.70%)	14 (15.40%)
535-565	14 (46.70%)	8 (66.70%)	4 (57.10%)	7 (100%)	5 (100%)	6 (50.00%)	15 (83.30%)	59 (64.80%)
>565	9 (30.00%)	4 (33.30%)	3 (42.90%)	-	-	2 (16.70%)	-	18 (19.80%)
Mean ACD	2.78±0.39	2.84±0.43	2.44±0.39	2.00±0.11	2.78±0.45	2.63±0.32	3.18±0.31	
Mean AL	22.15±0.91	21.74±1.12	20.74±1.25	19.60±0.50	21.58±1.18	22.38±0.52	22.67±0.57	

AcCG=acute angle-closure glaucoma, ACD=anterior chamber depth, AL=axial length, CACG=chronic angle-closure glaucoma, CCT=central corneal thickness, E=emmetrope, F=female, FeAcCG=fellow eye of acute angle-closure glaucoma, H=hypermetrope, M (in sex) = male, M=myope, PAC=primary angle closure, PACG=primary angle-closure glaucoma, PACS=primary angle-closure suspect

Table 2: Distribution of vision in the study population

BCVA Chi-square test: 119.313; *P*<0.001	Groups							Total
	Control	PACS	PAC	PACG	CACG	FeAcCG	AcCG	
6/6	14 (77.80%)	21 (70.00%)	5 (41.70%)	-	8 (66.70%)	1 (20.00%)	-	49 (53.80%)
6/9	3 (16.70%)	5 (16.70%)	4 (33.30%)	-	3 (25.00%)	3 (60.00%)	-	18 (19.80%)
6/12	1 (5.60%)	3 (10.00%)	2 (16.70%)	-	-	1 (20.00%)	-	7 (7.70%)
6/18	-	1 (3.30%)	1 (8.30%)	1 (14.30%)	1 (8.30%)	-	-	4 (4.40%)
6/36	-	-	-	2 (28.60%)	-	-	-	2 (2.20%)
6/60	-	-	-	3 (42.90%)	-	-	5 (71.40%)	8 (8.80%)
Hand movement	-	-	-	1 (14.30%)	-	-	2 (28.60%)	3 (3.30%)
Total	18	30	12	7	12	5	7	91

AcCG=acute angle-closure glaucoma, CACG=chronic angle-closure glaucoma, BCVA=best corrected visual acuity, FeAcCG=fellow eye of acute angle-closure glaucoma, PAC=primary angle closure, PACG=primary angle-closure glaucoma, PACS=primary angle-closure suspect

group (<6/60 in all patients) followed by PACG group. The ocular biometric parameters of the study population are shown in Table 3. Mean AL of AcCG patients was found to be the lowest (19.60 ± 0.50 mm) among all the subtypes of glaucoma in our study. A reciprocal relationship was observed between the AL and severity of disease (AcCG < PACG < FeAcCG < PAC < CACG < PACS < control). ANOVA showed very highly significant difference ($P < 0.001$) in AL in AcCG, when compared to PACS and controls. The AcCG group also had the shallowest ACD (2.00 ± 0.11mm). Hence, ACD also followed a reciprocal relationship with the severity of the disease (AcCG < PACG < CACG < FeAcCG = PACS < PAC < control). There was a very highly significant difference ($P < 0.001$) in ACD between the AcCG group and the control group. The mean LT was minimum in the control group (4.04 ± 0.46 mm) and comparable in PACG (5.02 ± 0.18 mm) and AcCG (4.95 ± 0.13 mm) groups. An increase in LT was directly proportional to the disease severity (PACG > AcCG > CACG > PAC > PACS > FeAcCG > control). The LTs of PACS and FeAcCG were also comparable. ANOVA showed a significant difference ($P < 0.01$) in LT between the control group and AcCG and the control group and PACG groups. The mean LAF values of AcCG (2.53 ± 0.10) and PACG (2.52 ± 0.19) were comparable and were the highest in the study population ($P < 0.001$). The mean RLP of patients was similar in the study groups and in the control population. There was no significant difference ($P > 0.05$) in RLP between the study groups. The mean LV was maximum in the AcCG group (1805.86 ± 89.95) followed by

Table 3: Validation of lens parameters using statistical analysis

Parameters	Group	Mean	±SD	*F*	*P*
A-scan: LT	Control	4.04[a]	0.46	4.319**	*P*<0.01
	PACS	4.42[a, b]	0.72		
	PAC	4.54[b, c]	0.51		
	PACG	5.02[c]	0.18		
	CACG	4.81[b, c]	0.61		
	FeAcCG	4.24[a, b]	0.84		
	AcCG	4.95[c]	0.13		
A-scan: LAF	Control	1.77[a]	0.20	8.875***	*P*<0.001
	PACS	1.99[a, b]	0.36		
	PAC	2.10[b]	0.34		
	PACG	2.52[c]	0.19		
	CACG	2.16[b]	0.24		
	FeAcCG	1.97[a, b]	0.46		
	AcCG	2.53[c]	0.10		
AS-OCT: LV	Control	1386.00[a, b]	173.94	3.406**	*P*<0.01
	PACS	1237.80[a]	422.02		
	PAC	1503.50[b]	336.37		
	PACG	1368.86[a, b]	499.80		
	CACG	1533.92[b]	288.40		
	FeAcCG	1200.00[a]	440.60		
	AcCG	1805.86[c]	89.95		
A-scan: RLP	Control	2.30[a]	0.17	0.849*	*P*>0.05
	PACS	2.26[a]	0.25		
	PAC	2.35[a]	0.25		
	PACG	2.39[a]	0.20		
	CACG	2.29[a]	0.26		
	FeAcCG	2.27[a]	0.14		
	AcCG	2.43[a]	0.16		

AcCG=acute angle-closure glaucoma, AS-OCT=A-scan optical coherence tomography, CACG=chronic angle-closure glaucoma, FeAcCG=fellow eye of acute angle-closure glaucoma, LAF=lens axial factor, LT=lens thickness, LV=lens vault, PAC=primary angle closure, PACG=primary angle-closure glaucoma, PACS=primary angle-closure suspects, RLP=relative lens position, SD=standard deviation. [a, b, c, d]Means with same superscript do not differ from each other (DMR test). *P>0.05, **P < 0.01, ***P<0.001

CACG (1533.92 ± 288.40) and PAC (1503.50 ± 336.37) groups. The mean LV values of the rest of the subtypes of PACG were comparable. The mean LV of FeAcCG was similar to PACS. ANOVA showed highly significant difference ($P < 0.01$) in the values of mean LV between the study groups. The mean LV values of the rest of the subtypes of PACG were comparable. With regard to ocular parameters, the ACD tended to decrease and the LT and LAF tended to increase from normal through PAC to PACG. The eyes of the PACG group had significantly shallower ACD ($P < 0.001$) and thicker lens ($P < 0.001$) than those of the PAC group.

Discussion

Several studies showed that the demographic factors associated with PACG risk are an older age group, female gender, and hyperopic refractive error.[9,15-17] Our present study also showed a similar result. Also, 63.70% of patients in our study, especially those in the cases cohort, were hyperopic. An association between hyperopia and a predisposition toward PACD was also seen in this study. The AL in our study was shorter in all the subgroups of angle-closure disease compared to the controls. Patients with AcCG had the shortest AL, which was 3.07 mm shorter (19.60 vs. 22.67 mm in controls) than in normal eye. ANOVA showed a highly significant difference in the AL between the subtypes of PACD. Other studies also showed similar results with regards to AL.[4,6,16,17,18-20] In contrast to our study, studies done by Mohamed-Noor *et al*. and Razeghinejad *et al*. concluded that there was no difference in AL among the subtypes of PACD.[4,15] Sihota *et al*.[18] stated that the AL was shorter in PACD patients, and their relatives also had shortness of AL. Thapa *et al*.[17] stated that the risk for developing angle-closure glaucoma increases with each millimeter decrease in AL ((odds ratio, 0.49; 95% CI, 0.36–0.67)). The mean ACD in our study was found to be the lowest in patients with AcCG (2.00 ± 0.11 mm). The ACD in all subtypes of PACD was lower than in the control population. The association between a shallow ACD and the risk of PACG has been documented in Inuit, Mongolians, Indians, and Australians.[21-24] There are many studies showing the correlation between shallow ACD and PACD.[6,15,16,17,19,20,25-28] In our study, ACD was also found to decrease with increasing age and was shallower in females when compared to males. In females, the ACD was shallower by 0.19–0.20 mm when compared to the male study population, and the age-related shallowing was also more (0.21 mm in females vs. 0.14 mm in males) when the age-matched subtypes of PACD were compared with respect to ACD after the age of 50 years (50–59 years group). In our study, the mean ACD of FeAcCG was 2.78 ± 0. 45 mm. This was more than the mean ACD of AcCG (2.00 ± 0.11), but much less than that of the control group (3.18 ± 0.31mm). There was also one patient who presented with an acute attack simultaneously in both her eyes and had comparable ACDs in both the eyes.

In the present study, the LT was more in all subtypes of PACD (from 4.24 ± 0.84 to 5.02 ± 0.18 mm) when compared to the control group (4.04 ± 0.46 mm), and this was found to be statistically significant ($P < 0.01$). This finding was comparable to other studies.[4,6,9,19] Saxena *et al*.[13] demonstrated that the odds of getting AcCG increased by 11% upon an increase in LT by 0.01 mm. A thicker, more anteriorly vaulted lens and a larger LAF have been shown to be predictive for angle closure in several population-based studies.[4,22,29]

On analyzing our data by stratifying the subjects into various age groups, it was also observed that there was a direct correlation between increasing age and increased LT, which again correlated directly with a shallowing of the anterior chamber. The onset of age-related lens change could also contribute to the increased LT and forward movement of the lens.[30-33]

The results of this study also showed than an increase in LT acted through shallowing of the ACD, but ACD shallowing could be either due to an increase in LT or due to other biometric variants.[13] The LAF values of AcCG (2.53 ± 0.10) and PACG (2.52 ± 0.19) were comparable and were the highest among all subtypes of PAC in our study. There was statistically significant difference between the LAF of AcCG, PACG, PAC, CACG, and the control group ($P < 0.001$). A similar study done by Hu *et al*.[34] in the Chinese population concluded that there was difference in LAF between AcCG and the other two groups ($P < 0.05$). Razeghinejad *et al*.[4] concluded that larger

LAF was predictive of AcCG. RLP did not show any significant correlation to the progression of the disease. Similar results were demonstrated by Sihota *et al*., Hu *et al*., Nongpiur *et al*., and Lim *et al*. in their studies on the influence of ocular biometric characteristics in the genesis of PACG.[9,34-36]

In the present study, the LV was highest in the AcCG group (1805.86 ± 89.95) compared to the control population (1386.00 ± 173.94). The FeAcCG (1200.00 ± 440.60) and PACS (1237.80 ± 422.00) groups had the lowest LV, which was lower even than the control. Thus,our study showed a direct correlation between high LV and the chance of acquiring PACD. This finding was statistically significant ($P < 0.01$). Nongpiur *et al*.[35] demonstrated a positive correlation among LV, LT, and PACD. The presence of a thicker lens with greater lens vaulting anteriorly could be one of the main pathogenic mechanisms for angle closure.[35] Moghimi *et al*.[37] compared the ocular biometric characteristics in different subtypes of PACD and observed the highest LV in AcCG.

Our study clearly showed an increased risk of PACDs with regard to female gender, increasing age, and the presence of hyperopia as refractive error. A shallower ACD ($P < 0.000$), thicker lens ($P = 0.047$), a higher LAF ($P = 0.040$), and a greater LV are the lens biometric parameters associated with the risk of progression in severity and the development of an acute congestive attack.

Limitations

- Sample size of certain subtypes of angle-closure disease was small for any relevant analysis.
- Although this study was prospective, the duration of the study was short, and hence, we cannot draw a direct cause–effect relationship between the biometric changes that we analyzed and the progression in the patient to acute congestive glaucoma.
- In acute congestive glaucoma group, the biometry was performed after laser PI, and hence, the ACD that we obtained could have been influenced by the widening of the angles that occur after laser PI. However, previous studies have shown that laser PI deepens the ACD only in the periphery and does not influence the depth of the AC in the center.

Conclusion

Based in a tertiary eye care center, this study analyzed ocular biometric features and their relationship to various subtypes of angle-closure disease. The results of the study showed that there is a definite correlation between biometric characteristics and PACD. A crowded anterior chamber with a thicker, anteriorly vaulted lens was seen across all subtypes of PACD and also in the fellow eye of patients with acute congestive attack.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Weinreb RN, Aung T, Medeiros FA. The pathophysiology and treatment of glaucoma: A review. JAMA 2014;311:1901-11.
2. Leite MT, Sakata LM, Medeiros FA. Managing glaucoma in developing countries. Arq Brasil Oftalmol 2011;74:83–4.
3. Rotchford AP, Kirwan JF, Muller MA, Johnson GJ, Roux P. Temba glaucoma study: A population-based cross-sectional survey in urban South Africa. Ophthalmol 2003;110:376–82.
4. Razeghinejad MR, Banifatemi M. Ocular biometry in angle closure. J Ophthalmic Vis Res 2013;8:17-24.
5. Moghimi S, Ramezani F, He M, Coleman AL, Lin SC. Comparison of anterior segment-optical coherence tomography parameters in phacomorphic angle closure and acute angle closure eyes. Invest Ophthalmol Vis Sci 2015;56:7611-7.
6. Lan Y-W, Hsieh J-W, Hung P-T. Ocular biometry in primary angle-closure glaucoma. J Med Ultrasound 2007;15:243–50.
7. Quigley HA, Friedman DS, Congdon NG. Possible mechanisms of primary angle-closure and malignant glaucoma. J Glaucoma 2003;12:167-80.
8. Foster PJ, Buhrmann R, Quigley HA, Johnson GJ. The definition and classification of glaucoma in prevalence surveys. Br J Ophthalmol 2002;86:238-42.
9. Sihota R, Gupta V, Agarwal HC, Pandey RM, Deepak KK. Comparison of symptomatic and asymptomatic, chronic, primary angle-closure glaucoma, open-angle glaucoma, and controls. J Glaucoma 2000;9:208-13.
10. Founti P, Topouzis F, Holló G, Cvenkel B, Iester M, Haidich AB, *et al*. Prospective study of glaucoma referrals across Europe: Are we using resources wisely? Br J Ophthalmol 2018;102:329-37.
11. Shih CY, Zivin JSG, Trokel SL, Tsai JC. Clinical significance of central corneal thickness in the management of glaucoma. Arch Ophthalmol 2004;122:1270–5.
12. Coh P, Moghimi S, Chen RI, Hsu CH, Masís Solano M, Porco T, *et al*. Lens position parameters as predictors of intraocular pressure reduction after cataract surgery in glaucomatous versus nonglaucomatous eyes. Invest Ophthalmol Vis Sci 2016;57:2593-9.
13. Saxena S, Agrawal PK, Pratap VB, Nath R. Anterior chamber depth and lens thickness in primary angle-closure glaucoma: A case-control study. Indian J Ophthalmol 1993;41:71-3.
14. Ozaki M, Mizoguchi T, Nongpiur ME, Aung T. Lens vault as a risk factor for angle closure in Japanese. Invest Ophthalmol Vis Sci 2011;52:6273.
15. Mohamed-Noor J, Abd-Salam D. Refractive errors and biometry of primary angle-closure disease in a mixed Malaysian population. Int J Ophthalmol 2017;10:1246-50.
16. Lavanya R, Wong TY, Friedman DS, Aung HT, Alfred T, Gao H, *et al*. Determinants of angle closure in older Singaporeans. Arch Ophthalmol 2008;126:686-91.
17. Thapa SS, Paudyal I, Khanal S, Paudel N, van Rens GH. Comparison of axial lengths in occludable angle and angle-closure glaucoma--The Bhaktapur Glaucoma Study. Optom Vis Sci 2011;88:150-4.
18. Sihota R, Ghate D, Mohan S, Gupta V, Pandey RM, Dada T. Study of biometric parameters in family members of primary angle closure glaucoma patients. Eye (Lond) 2008;22:521-7.
19. George R, Paul PG, Baskaran M, Ramesh SV, Raju P, Arvind H. Ocular biometry in occludable angles and angle closure glaucoma: A population based survey. Br J Ophthalmol 2003;87:399-402.
20. Congdon NG, Quigley HA, Hung PT, Wang TH, Ho TC. Screening techniques for angle-closure glaucoma in rural Taiwan. Acta Ophthalmol Scand 1996;74:113-9.
21. Alsbirk PH. Anterior chamber depth and primary angle-closure glaucoma. I. An epidemiologic study in Greenland Eskimos. Acta Ophthalmol (Copenh) 1975;53:89-104.
22. Lowe RF. Aetiology of the anatomical basis for primary angle-closure glaucoma. Biometrical comparisons between

normal eyes and eyes with primary angle-closure glaucoma. Br J Ophthalmol 1970;54:161-9.

23. Sihota R, Lakshmaiah NC, Agarwal HC, Pandey RM, Titiyal JS. Ocular parameters in the subgroups of angle closure glaucoma. Clin Exp Ophthalmol 2000;28:253-8.
24. Aung T, Nolan WP, Machin D, Seah SKL, Baasanhu J, Khaw PT, *et al*. Anterior chamber depth and the risk of primary angle closure in 2 East Asian Populations. Arch Ophthalmol 2005;123:527–32.
25. 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.
26. Foster PJ, Alsbirk PH, Baasanhu J, Munkhbayar D, Uranchimeg D, Johnson GJ. Anterior chamber depth in Mongolians: Variation with age, sex, and method of measurement. Am J Ophthalmol 1997;124:53-60.
27. Sihota R. An Indian perspective on primary angle closure and glaucoma. Indian J Ophthalmol 2011;59:S76–81.
28. Casson RJ, Marshall D, Newland HS, McGovern S, Muecke J, Tan EW, *et al*. Risk factors for early angle-closure disease in a Burmese population: The Meiktila Eye Study. Eye (Lond) 2009;23:933-9.
29. Friedman DS, Gazzard G, Foster P, Devereux J, Broman A, Quigley H, *et al*. Ultrasonographic biomicroscopy, Scheimpflug photography, and novel provocative tests in contralateral eyes of Chinese patients initially seen with acute angle closure. Arch Ophthalmol 2003;121:633-42.
30. Wickremasinghe S, Foster PJ, Uranchimeg D, Lee PS, Devereux JG, Alsbirk PH, *et al*. Ocular biometry and refraction in Mongolian adults. Invest. Ophthalmol Vis Sci 2004;45:776-83.
31. 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.
32. Lowe RF. Primary angle closure glaucoma: A review of ocular biometry. Australian and New Zealand J Ophthalmol 1977;5:9–17.
33. Lowe RF. Anterior lens displacement with age. Br J Ophthalmol 1970;54:117–21.
34. Hu J, Jiang B. Ocular biometric characteristics of acute and chronic primary angle-closure glaucoma in Chinese patients. J Central South University 2014;39:333-7.
35. Nongpiur ME, He M, Amerasinghe N, Friedman DS, Tay W-T, Baskaran M, *et al*. Lens vault, thickness, and position in Chinese subjects with angle closure. Ophthalmol 2011;118:474–9.
36. Lim MC, Lim LS, Gazzard G, Husain R, Chan YH, Seah SK, *et al*. Lens opacity, thickness, and position in subjects with acute primary angle closure. J Glaucoma 2006;15:260-3.
37. Moghimi S, Vahedian Z, Fakhraie G, Ghaffari R, Eslami Y, Jabarvand M, *et al*. Ocular biometry in the subtypes of angle closure: An anterior segment optical coherence tomography study. Am J Ophthalmol 2013;155:664-73.