

## Normative Distribution of Axial Length and Anterior Chamber Angle Parameters in an Adult Healthy Population

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### Abstract:

**Background:** Studies have documented considerable inter-individual variability in the anterior chamber angle, emphasizing differences attributable to age, ethnicity, refractive status, and other ocular and Systemic Factors.

**Aim and Objective:** To identify the normative distribution of anterior chamber angle (ACA) width and axial length (AL) in adult healthy individuals.

**Methods:** In this cross-sectional study, 2000 eyes of subjects aged  $\geq 18$ y were sampled at a tertiary care hospital of central India for 18 months. After a preliminary interview, the participants underwent optometric examinations including visual acuity and refraction measurement followed by slit lamp biomicroscopy. Finally, ocular imaging was done using the Sonomed Escalon 300A PacScan to measure AL and ZEISS CIRRUS HD-OCT 500 to measure ACA all four quadrants (superior, inferior, nasal, temporal) of both eyes.

**Results:** Out of 2000 eyes studied, 47.7% (n=954) were females and 52.3% (n=1046) were males. Mean age of the subjects was 44.6 years (19-79 y). 16.8% (n=335) was hyperopic, 21.6% (n=432) was myopic. The mean AL was  $23.45 \pm 0.37$  mm and mean ACA of superior, inferior, nasal, temporal quadrants was  $32.40^\circ \pm 0.94^\circ$ ,  $32.43^\circ \pm 0.92^\circ$ ,  $32.47^\circ \pm 0.92^\circ$  and  $32.49^\circ \pm 0.92^\circ$  respectively. In the multivariable model, after adjusting for the effect of both eyes, the maximum AL and ACA were seen in myopic, male and 18-40 y age group, and minimum in hyperopic, females,  $>60$  y age group subjects ( $p < 0.001$ ).

**Conclusion:** Normative value of AL, and ACA parameters are specific for each ethnicity, age and sex group. Any alteration in these parameters and their effect on refraction should be considered in this age group, especially in case of cataract surgery.

**Keywords:** Anterior Chamber Angle; Axial Length, Adult Healthy Population.

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### Introduction

The anterior chamber angle is the angular space between the iris and the cornea, bounded anteriorly by the corneal endothelium and posteriorly by the iris pigment epithelium [1]. It comprises of following anatomical landmarks: Schwalbe's line, anterior & posterior trabecular meshwork, scleral spur & 1 ciliary body band [2]. It is an important determinant of aqueous humor drainage and intraocular pressure regulation [3]. Studies have documented considerable inter-individual variability in the anterior chamber angle, emphasizing differences attributable to age, ethnicity, refractive status, and other ocular and Systemic Factors [4]. Researchers have employed a wide range of investigative approaches—from Gonioscopic evaluation, a histological analysis to modern imaging techniques such as anterior segment optical coherence tomography (AS-OCT) and Ultrasound Bio microscopy—to examine the

anatomical configuration and dynamic changes of this critical ocular structure [5]. Advances in imaging technologies have further revolutionized the study of the anterior chamber angle, offering high-resolution, quantitative assessments that were not possible with traditional methods. These innovations have not only enhanced diagnostic accuracy but have also facilitated the development of targeted therapeutic interventions aimed at mitigating disease progression [6]. Axial length is the distance between the anterior surface of the cornea and the posterior surface of the retina, measured along the visual axis [7]. Genetic factors significantly govern the baseline axial length, which in turn influences refractive error development. Moreover, differences in axial length across populations point to a combination of genetic background and lifestyle factors contributing to the global variation in refractive error prevalence [8].

Ultrasound A-Scan biometry, is a widely used scanning method, utilizes high-frequency sound waves to determine axial length, although it requires contact with the cornea (or immersion techniques), it remains an important tool, especially in cases where media opacities limit optical measurements [9]. The integration of these advanced scanning techniques has also enabled researchers to conduct large-scale epidemiological studies.

This study aims to establish normative values for anterior chamber angle configuration across different age groups, genders and refractive status, exclusively in adult and elderly populations within this region. By systematically analysing these biometric parameters, our goal is to provide valuable normative data that can aid in the early detection of angle-related ocular pathologies. The findings from this study are intended to inform clinical screening protocols and support more personalized approaches to ocular health assessment and management.

### Methods

We conducted an observational, cross-sectional study in the Department of Ophthalmology in a tertiary care center of central India for a period of 18 months, from May 2023 to October 2024. Participants for the study were briefed about the purpose and process of the study. Prior to data collection, informed consent and assent were taken from the respondents. All participants, for the research, were also assured about the confidentiality and anonymity of the information. After approval of the study protocol by the Institutional Ethics Committee of Gandhi Medical College, Bhopal, the study was initiated under Helsinki Ethical Guidelines. A total of 2000 eyes of all subjects of age group 18 years or above irrespective of gender were included in the study after explaining the procedure. Participants aged less than 18 years, participants with previous intraocular surgery or trauma, participants with any ocular pathology, ocular trauma or post operative patients or poor Participants cooperation were excluded from this study. Those who agreed to be part of the study were given the consent forms to sign which was also signed by the principal investigator. Detailed history was taken regarding presence or absence of refractive error and previous intraocular surgery or trauma. Assessment of visual acuity was done by using Snellen's letter chart with the subject seated at 6 meters from the chart, in a dark room, occluding one eye at a time in literate subjects and using the same procedure, and replacing the Snellen's Letter Chart with Landolt's Broken ring chart or Tumbling E chart in illiterate subjects. Anterior segment examination was done initially in torch light (gross). Detailed examination was done using Haag Streit Slit Lamp Biomicroscope, first using diffuse illumination to rule out any gross anomaly, then using Parallelepiped illumination to study the

corneal surface for changes in surface and curvature, and optic section to study the anterior chamber depth. A Scan was performed using Sonomed Escalon 300A PacScan A scan to calculate the axial length of the subjects by using contact (or applanation) method of biometry. After taking well informed consent from the subject, and anesthetizing the subject's eyes with topical proparacaine hydrochloride 0.5 % ophthalmic solution. Subject was made to sit in reclined position and the examiner was seated on an adjustable stool to the other side of the subject, while resting his/her arm in the patient's shoulder and side of his/her hand on the subject cheek. While the subject was instructed to look at a target affixed to the ceiling, the examiner gently placed the tip of A scan probe gently on the corneal vertex and directing the sound beam through the visual axis. An average of five readings was recorded. Anterior chamber angles were measured using ZEISS CIRRUS HD-OCT 500. All the participants underwent imaging using the anterior segment wide angle-to-angle scan mode and all four angles (superior, inferior, nasal, temporal) of both eyes were evaluated. Seated subjects were asked to fixate on the internal fixation light in the primary gaze position under dark room conditions. The operator had to pull the upper and lower eyelids to image the superior and inferior angles while avoiding inadvertent pressure on the globe. It was a self-funded study and also it was ensured that there was not any financial burden to the study participants at any stage of the study. There were no conflicts of interest related to this study. The collected data was compiled in a Microsoft Excel sheet and was subsequently statistically analysed. Descriptive and inferential statistical analyses were carried out in the present study. Results on continuous measurements were presented as Mean  $\pm$  standard deviation (SD; Min.–Max.), and results on categorical measurements were presented as number (%). The statistical software Statistical Package for the Social Sciences (SPSS) version 20 and MedCalc 19.5 were used for the analysis. The review and analyzed data were checked for antiplagiarism using Plagiarism Checker X.

### Results

A total of 2000 eyes of 1000 subjects were evaluated of whom 47.7% (n=954) were females and 52.3% (n=1046) were males. 41.2% belonged to the age group 18–40 years, 35.7% to 41–60 years, and 23.1% to >60 years. Of 2000 eyes, 21.6% (n=432) were myopic and 16.8% (n=335) were hyperopic.

Table 1 represents the normative distribution and Association of mean AL (mm) and mean ACA (degree) in superior, inferior, nasal and temporal quadrant among Age-Matched Groups, gender matched groups and refractive status matched group. The mean AL was  $23.45 \pm 0.37$  mm (23.12–24.76 mm), and mean ACA of superior, inferior, nasal,

temporal quadrants was  $32.40^\circ \pm 0.94^\circ$  ( $30.45^\circ - 34.84^\circ$ ),  $32.43^\circ \pm 0.92^\circ$  ( $31.43^\circ - 34.84^\circ$ ),  $32.47^\circ \pm 0.92^\circ$  ( $31.47^\circ - 34.84^\circ$ ) and  $32.49^\circ \pm 0.92^\circ$  ( $31.47^\circ - 34.86^\circ$ ), respectively.

According to Table 1, Males demonstrated significantly longer AL ( $23.46 \pm 0.31$  mm) compared to females ( $23.20 \pm 0.38$  mm), with a mean difference of 0.26 mm ( $p < 0.001$ ). Significant age-related decrease in AL was observed. Mean AL of emmetropic subjects was  $23.30 \pm 0.10$  mm. Myopic subjects had the longest AL ( $23.90 \pm 0.40$  mm; 0.60 mm longer than emmetropia) and hyperopic individuals had the shortest AL ( $22.21 \pm 0.11$  mm; 1.09 mm shorter than emmetropia), and the difference between these two groups of participants and emmetropic individuals was significant ( $p < 0.001$ ).

Table 1 present ACA at four meridians (superior, inferior, nasal, temporal) with mean ACA values ranging from approximately  $31.6^\circ$  to  $34.3^\circ$  depending on demographic group. Mean ACA was  $32.48 \pm 0.93^\circ$  in males and  $32.40 \pm 0.90^\circ$  in females ( $p = 0.052$ ). Age-Related Changes in ACA; 18-40 years:  $33.22 \pm 0.83^\circ$  (widest), 41-60 years:  $32.33 \pm 0.43^\circ$  (intermediate), >60 years:  $31.63 \pm 0.29^\circ$  (narrowest) is highly significant ( $p < 0.001$ ). Hyperopic subjects had the smallest ACA ( $31.82 \pm 0.42^\circ$ ) value compared to emmetropic ( $32.12 \pm 0.51^\circ$ ) and myopic ( $33.84 \pm 0.39^\circ$ ) individuals.

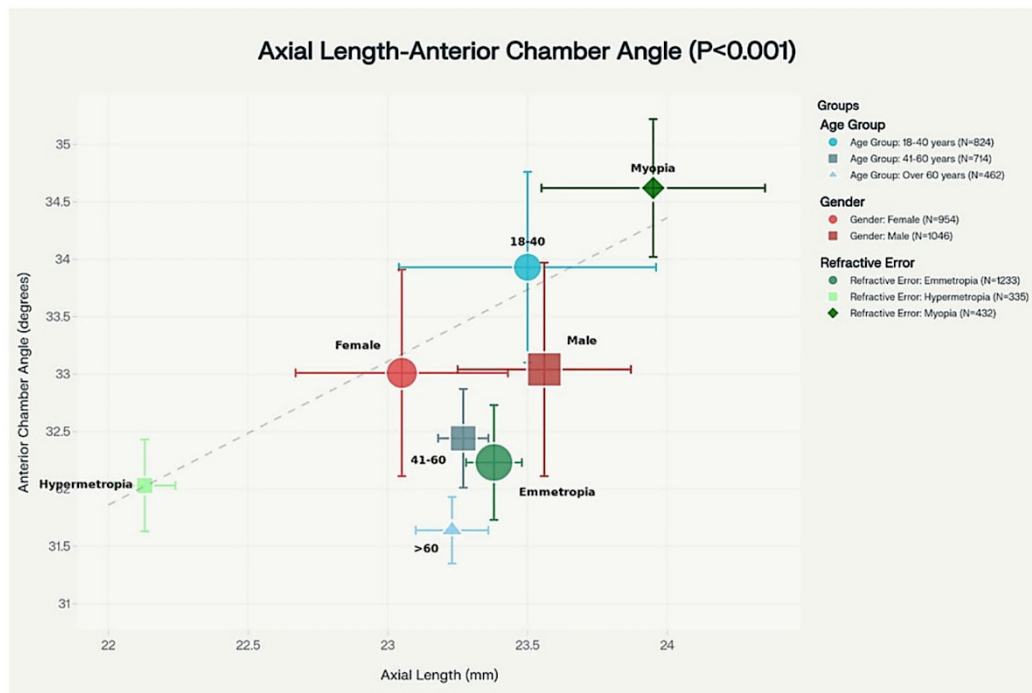
Figure 1 is scatter plot, reveals a highly significant positive correlation ( $p < 0.001$ ) between axial length (AL) and anterior chamber angle (ACA) across 2,000 eyes, stratified by age group, sex, and refractive error status.

**Table 1: Mean  $\pm$ SD of Axial Length and Anterior Chamber Angle Mean  $\pm$ SD of Axial Length (mm) and Mean  $\pm$ SD of Anterior Chamber Angle (degree) in superior, inferior, nasal and temporal quadrant among Age-Matched Groups, gender matched groups and refractive status matched groups.**

Parameters	No. of eyes	AL, mm		ACA, degree					
		Mean $\pm$ SD	p	Superior	Inferior	Nasal	Temporal	Mean $\pm$ SD	p
Total	2000								
Sex	<0.001 <sup>a</sup>		0.052 <sup>a</sup>						
Male	1046	23.46 $\pm$ 0.31		32.47 $\pm$ 0.93	32.44 $\pm$ 0.94	32.50 $\pm$ 0.93	32.52 $\pm$ 0.93	32.48 $\pm$ 0.93	
Female	954	23.20 $\pm$ 0.38		32.39 $\pm$ 0.90	32.36 $\pm$ 0.93	32.42 $\pm$ 0.89	32.44 $\pm$ 0.89	32.40 $\pm$ 0.90	
Age		<0.001 <sup>a</sup>	<0.001 <sup>a</sup>						
18-40	824	23.42 $\pm$ 0.46		33.21 $\pm$ 0.82	33.19 $\pm$ 0.83	33.23 $\pm$ 0.83	33.26 $\pm$ 0.81	33.22 $\pm$ 0.83	
41-60	714	23.35 $\pm$ 0.09		32.32 $\pm$ 0.44	32.29 $\pm$ 0.44	32.35 $\pm$ 0.43	31.60 $\pm$ 0.42	32.33 $\pm$ 0.43	
Above 60	462	23.33 $\pm$ 0.13		31.61 $\pm$ 0.26	31.58 $\pm$ 0.37	31.65 $\pm$ 0.25	32.30 $\pm$ 0.26	31.63 $\pm$ 0.29	
Refractive errors	<0.001 <sup>b</sup>		<0.001 <sup>c</sup>						
Emmetropia	1233	23.30 $\pm$ 0.1		31.84 $\pm$ 0.43	31.56 $\pm$ 0.52	32.40 $\pm$ 0.48	32.68 $\pm$ 0.51	32.12 $\pm$ 0.51	
Myopia	432	23.9 $\pm$ 0.4		33.66 $\pm$ 0.18	33.40 $\pm$ 0.12	34.06 $\pm$ 0.15	34.26 $\pm$ 0.16	33.84 $\pm$ 0.39	
Hyperopia	335	22.21 $\pm$ 0.11		31.62 $\pm$ 0.12	31.37 $\pm$ 0.10	32.02 $\pm$ 0.11	32.27 $\pm$ 0.13	31.82 $\pm$ 0.42	

<sup>a</sup>The P-value was calculate independent sample t-test with controlled the effect of both eyes using the GEE method, and other P-value was calculated with ANOVA; <sup>b</sup>After adjusting for the effect of age and sex using Bonferroni correction, the results showed

a significantly higher and lower AL values in myopic and hyperopic participants respectively. <sup>c</sup>The P-value calculated with Bonferoni correction after controlling age and sex effect.



**Figure 1: The scatter-plot provides a comprehensive multi-dimensional visualization of the relationship between axial length (AL) and anterior chamber angle (ACA), stratified simultaneously by age group, sex, and refractive error status.**

## Discussion

This study was conducted to evaluate the anatomical distribution of anterior chamber angle (ACA) configuration and axial length (AL) of the eye using high-resolution imaging modalities in adult patients aged 18 years and above.

The mean AL was  $23.45 \pm 0.37$  mm (23.12-24.76 mm) in the present study, which was slightly smaller than the values in subjects above 60y in studies by Chen et al [10], Fotedar et al [11], and slightly larger than the values reported by and Wickremasinghe et al [12] Hashemi et al [13].

Several studies have evaluated the factors affecting AL, reporting age and sex as the most important determinants [14]. Evaluation of the relationship between sex and AL in the present study showed that AL was longer in men ( $23.46 \pm 0.31$  mm) versus women ( $23.20 \pm 0.38$  mm), which is consistent with the studies where the longer AL in men has been attributed to their taller stature as well as physical differences between men and women [15-17].

Significant age-related decrease in AL was observed in present study. Evaluation of the role of age in AL changes showed a decrease in AL with age in the study population, which was consistent with the majority of the studies [18,19]. Since ageing is associated with some degrees of atrophy in ocular structures [20], ageing is expected to be associated with a decrease in AL.

Reduction in AL in the elderly is expected to be associated with an increase in hyperopia and a

decrease in myopia. This finding was consistent with a cohort study by Hashemi et al [21,22].

Analysis of the ACA across age groups and quadrants reveals a clear trend of ACA in our study. The temporal quadrant in young adults (18-40 years) demonstrated the widest angles, with a mean ACA of  $33.22^\circ \pm 0.83^\circ$ . In contrast, the narrowest angles were observed in the inferior quadrant of older adults (>60 years), with a mean ACA of  $31.63^\circ \pm 0.29^\circ$ . This pattern shows statistically significant differences ( $p < 0.001$ ). This pioneering study provides the first comprehensive analysis of anterior chamber angle (ACA) measurements across different age groups in all four quadrants. The findings reveal a clear and consistent pattern of age-related angle narrowing, with the most pronounced narrowing observed in the inferior quadrant of individuals over 60 years old. Conversely, the widest angles are found in the temporal quadrant among those aged 18-40 years. This level of detail in quadrant-specific, age-related changes has not been documented before, offering new insights into the anatomical variations of the anterior chamber angle. More studies are required to evaluate the relationship between ACA and age, gender and refractive status.

The analysis of gender-based differences in ACA measurements reveals marginally higher values in males (mean ACA  $32.40^\circ \pm 0.90^\circ$ ) compared to females (mean ACA  $32.48^\circ \pm 0.93^\circ$ ) across all quadrants, with P values not statistical significance ( $P > 0.05$ ).

One of the limitations of the present study was, it did not comprehensively account for other variables that could influence ACA and AL, such as lens thickness, anterior chamber depth, corneal curvature, systemic diseases, or medication use.

### Conclusion

Both AL and ACA decrease with advancing age, highest mean AL (23.42 mm) and ACA (33.22°) were observed in the 18–40 years age group. These values decreased in older age groups, with the 41–60 years group showing a mean AL of 23.35 mm and ACA of 32.63°, and the >60 years group showing a mean AL of 23.33 mm and ACA of 31.33° ( $p < 0.001$ ).

Males demonstrated higher mean values for both axial length (AL:  $23.46 \pm 0.31$  mm, +0.26 mm longer) and anterior chamber angle (ACA:  $32.48 \pm 0.93^\circ$ , +0.08° wider) compared to females (AL:  $23.20 \pm 0.38$  mm; ACA:  $32.40 \pm 0.90^\circ$ ), with all differences being statistically significant ( $p < 0.001$ ).

Myopic eyes exhibited the highest mean AL ( $23.92 \pm 0.40$  mm) and ACA ( $33.87 \pm 0.60^\circ$ ), followed by emmetropic eyes (AL:  $23.30 \pm 0.10$  mm, ACA:  $32.12 \pm 0.50^\circ$ ), and hypermetropic eyes (AL:  $22.21 \pm 0.11$  mm, ACA:  $31.83 \pm 0.40^\circ$ ) ( $p < 0.001$ ).

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