Original Article

Assessment of anterior segment parameters under photopic and scotopic conditions in Indian eyes using anterior segment optical coherence tomography

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Purpose: To compare the anterior segment parameters in photopic and scotopic conditions using anterior segment optical coherence tomography (AS OCT) in Indian eyes.

Materials and Methods: One hundred eyes of 100 normal subjects of both sexes, aged 19 to 76 years, underwent anterior segment evaluation by AS OCT (Visante™ OCT). Central corneal thickness (CCT), central anterior chamber depth (ACD), pupil diameter (PD) and the temporal and nasal peripheral irido-corneal angles were assessed in photopic and scotopic conditions. These anterior segment parameters were stratified for age, sex and refractive error.

Results: Mean values of the parameters measured in photopic and scotopic conditions respectively were as follows: ACD (mm) 2.88 ± 0.32, 2.89 ± 0.32 ($P = 0.10$); nasal angle (degrees) 28.80 ± 5.91, 22.28 ± 7.50 ($P < 0.001$); temporal angle (degrees) 29.95 ± 6.74, 22.82 ± 8.43 ($P < 0.001$); pupil diameter (mm) 4.08 ± 0.91, 4.68 ± 0.92 ($P < 0.001$); CCT (μm) 519 ± 33.88, 519 ± 33.88.

Conclusions: There was no significant difference in the ACD in photopic and scotopic conditions. While the nasal and temporal angles showed a significant decrease, the pupil diameter showed a significant increase in scotopic conditions. Mean central ACD decreased with age and was shallower in females than in males. It was highest in myopes and lowest in hypermetropes. CCT was not influenced by photopic and scotopic conditions.

Key words: Anterior segment optical coherence tomography, anterior segment parameters, Indian eyes

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Accurate assessment of ocular dimensions has gained increasing importance with the advent of newer surgical techniques. Biometry of the anterior segment of the eye is performed with biomicroscopic optical techniques or ultrasonic systems. Recently, low coherence interferometry has emerged as a new modality for biometry.

Anterior segment optical coherence tomography (AS OCT) is a new noncontact imaging technique that provides high-resolution cross-sectional images of the anterior segment of the eye using 1310-nm infrared light.[1–8] It employs low coherence interferometry to obtain high resolution images *in vivo.* It has a range of potential uses, including evaluation of accommodation, measuring the angle in glaucoma patients, measuring corneal flap depths and residual stromal thickness in patients who are candidates for re-treatment following refractive surgery.[9,10] It can also be used as a tool to measure intraocular dimensions prior to phakic intraocular lens (IOL) implantation.[11]

Currently, there are only a few studies of the anterior segment of the eye using AS OCT.[1–19] To the best of our knowledge, there are no reports on the comparison of anterior segment parameters in photopic and scotopic conditions in Indian eyes using AS OCT. The purpose of the present study was to compare the anterior segment parameters of normal eyes under photopic and scotopic conditions using AS OCT.

Materials and Methods

This observational comparative study included 100 eyes of 100 normal subjects who attended the outpatient department of our hospital for a routine eye examination from February 2007 to March 2007. The left eye was selected by the systematic random method. Subjects were 50 women (50%) and 50 men (50%), with a spherical equivalent refraction of −8.0 to +3.0 diopters (D). There were 47 emmetropic, 28 myopic (−0.5 to −8.0D) and 25 hypermetropic eyes (+0.25 to +3.0D). The mean age of the group was 36.78 ± 14.46 years (range, 19 to 76 years). Informed consent was obtained from all subjects before the procedure.

Exclusion criteria were history of glaucoma, trauma, active ocular disease, previous ocular surgery including laser trabeculoplasty, laser iridotomy, laser photocoagulation and systemic diseases with ophthalmic repercussions.

All participants underwent imaging with the Visante™ OCT (Carl Zeiss Meditec Inc., Dublin, CA, USA) with the room lights on and off. Examinations were done at a standard ambient luminance to mimic photopic and scotopic conditions. The intensity of the room light was measured with the Lutron LX 101 LUX METER. The intensity was 310 lux with the lights on,

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and it was not recordable with the lights off. Internal fixation was used in all subjects for its reproducibility and ease of use. In order to obtain maximum pupil dilation in the dark, the subjects were instructed to continue fixing on the internal target until the room lights went off, and imaging was repeated.

To perform AS OCT imaging in a non-accommodated state, the subject's refractive correction was used to adjust the internal fixation target for the patient's distance correction. Anterior segment single line scan was used to acquire the images. All scans were taken by a single examiner. Scans were centered on the pupil and taken along the horizontal meridian (nasal - temporal angles at 0 to 180 degrees).

Proper alignment of the eye was maintained in X, Y and Z planes. The corneal apex was aligned with the vertical yellow target line and placed between the two horizontal green target lines. The scan was optimally aligned when the optically produced corneal reflex was visible as a vertical white line along the center of the cornea. The default fixation angle (zero) position in the AS OCT corresponds to the image aligned along the visual axis. If the scans were noticeably off from the horizontal, the fixation angle was adjusted to align the image along the geometric axis.

The AS OCT images were processed later using internal specific software that readjusts for image distortion arising from variation in the corneal optical transmission properties. The images with the best quality were selected. The chamber tool provided by the software was used to measure the central corneal thickness (CCT), anterior chamber depth (ACD) and pupil diameter (PD). The 'true ACD,' the distance from the corneal endothelium to the anterior lens surface, was recorded [Fig. 1]. The nasal and temporal angles were measured using the anterior chamber (AC) angles tool.

Statistical analysis

Student's t test was done to determine whether differences due to gender were present. Descriptive analyses including mean values and standard deviation (SD) of the anterior segment measurements were performed. Paired t-test was done to compare measurements under photopic and scotopic conditions. One-way ANOVA was performed for the comparison of means among groups for age and refractive error. A 'P' value of less than 0.05 was considered to be statistically significant. Pearson correlation coefficient was performed to test the strength of the relationship between CCT and ACD and between the various anterior segment parameters and age. Statistical analyses were performed with the SPSS version 10.0. MedCalc statistical software was used to obtain the scatter plots.

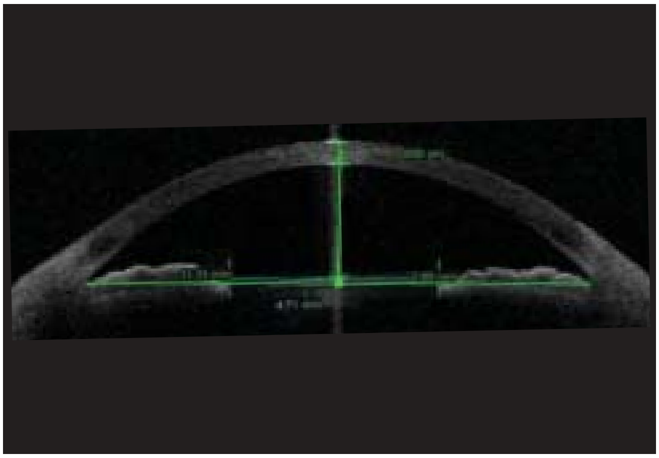

Figure 1: Analysis of the anterior segment by anterior segment optical coherence tomography

Results

The mean and SD of the anterior segment parameters in photopic and scotopic conditions respectively were – central ACD 2.88 ± 0.32 mm, 2.89 ± 0.32 mm; PD 4.08 ± 0.91 mm, 4.68 ± 0.92 mm; nasal angle 28.80 ± 5.91 degrees, 22.28 ± 7.50 degrees; and temporal angle 29.95 ± 6.74 degrees, 22.82 ± 8.43 degrees. Table 1 shows the mean difference of the parameters between photopic and scotopic conditions.

The mean CCT was 519 μm ± 33.88. It remained unchanged in photopic and scotopic conditions [Table 2]. It was independent of sex, age and refractive error. There was no correlation between CCT and ACD ($r = 0.053$; $P = 0.60$).

Table 2 shows the mean and SD of the anterior segment parameters for all eyes, males and females. Although males had higher mean values than females (except PD diameter), the differences in mean values between them were not significant.

One-way ANOVA was performed to compare the mean values of the various anterior segment parameters in photopic and scotopic conditions within the refractive error groups [Table 3] and age groups [Table 4]. Myopic eyes had the maximum mean values (except PD in photopic condition), while hypermetropic eyes had the minimum mean values.

We found a significant difference ($P<0.001$) in the ACD, PD and angles among the refractive error groups in both photopic and scotopic conditions.There was also a significant difference nasal angle in photopic condition P=0.003 and temporal angle in scotopic condition P=0.004 in the ACD, PD and angles among the different age groups in both photopic and scotopic conditions. There was a significant negative correlation of central ACD ($r = -0.45$, $P < 0.001$; $r = -0.45$, $P < 0.001$), PD ($r = -0.47$, $P < 0.001$; $r = -0.54$, $P < 0.001$), nasal angles ($r = -0.26$, $P = 0.01$; $r = -0.26$, $P = 0.01$) and temporal angles ($r = -0.46$, $P < 0.001$; $r = -0.34$, $P < 0.001$) with age in photopic and scotopic conditions respectively. Figs.2-4 are scatter plots showing the correlation of ACD and angles in photopic conditions relative to age. Fig. 5 is a scatter plot showing ACD relative to refractive error.

Table 5 shows the comparison of ACD in various studies with this study using AS OCT.

Table 1: Anterior segment parameters – difference between photopic and scotopic conditions (n = 100)

Parameter	Mean difference (P-S)	*P* value
Anterior chamber depth	-0.01	0.10
Pupil diameter	-0.59	<0.001
Nasal angle	6.52	<0.001
Temporal angle	7.13	<0.001

P - Photopic condition; S - Scotopic condition

Table 2: Comparison of anterior segment parameters in photopic and scotopic conditions – variation with sex (mean ± SD)

Group	Parameter	All eyes (n=100)	Males (n=50)	Females (n=50)	P^a (t-test)
Photopic	CCT in μm	519 ± 33.88	522 ± 33.64	516 ± 34.17	0.36
	ACD in mm	2.88 ± 0.32	2.90 ± 0.32	2.86 ± 0.32	0.52
	PD in mm	4.08 ± 0.91	4.08 ± 0.90	4.09 ± 0.93	0.98
	Nasal angle in degrees	28.80 ± 5.91	28.94 ± 6.26	28.66 ± 5.59	0.81
	Temporal angle in degrees	29.95 ± 6.74	30.46 ± 6.24	29.43 ± 7.24	0.45
Scotopic	CCT in μm	519 ± 33.88	522 ± 33.64	516 ± 34.17	0.36
	ACD in mm	2.89 ± 0.32	2.89 ± 0.32	2.87 ± 0.33	0.69
	PD in mm	4.68 ± 0.92	4.68 ± 0.94	4.68 ± 0.93	0.98
	Nasal angle in degrees	22.28 ± 7.50	22.93 ± 8.19	21.64 ± 6.77	0.39
	Temporal angle in degrees	22.82 ± 8.43	23.40 ± 8.51	22.23 ± 8.39	0.49

CCT - Central corneal thickness; ACD - Anterior chamber depth; PD - Pupil diameter. [a]No significant difference of anterior segment parameters between males and females; *P* - Level of significance

Table 3: Anterior segment parameters – variations with refractive error (range, –8.0 to +3.0D) mean ± SD

Group	Parameter	Emmetropes (no power) (n=47)	Myopes (-0.5 to - 8.0D) (n=28)	Hypermetropes (+0.25 to + 3.0D) (n=25)	P^a
Photopic	CCT in μm	512 ± 34.54	527 ± 34.30	522 ± 30.86	0.168
	ACD in mm	2.88 ± 0.29	3.08 ± 0.24	2.65 ± 0.29	<0.001
	PD in mm	4.36 ± 0.88	4.10 ± 0.84	3.54 ± 0.82	<0.001
	Nasal angle in degrees	28.66 ± 5.90	32.18 ± 4.86	25.29± 4.96	<0.001
	Temporal angle in degrees	29.51 ± 5.88	34.73 ± 5.85	25.41 ± 5.85	<0.001
Scotopic	CCT in μm	512 ± 34.54	527 ± 34.30	522 ± 30.86	0.168
	ACD in mm	2.89 ± 0.29	3.09 ± 0.25	2.65 ± 0.29	<0.001
	PD in mm	4.92 ± 0.91	4.77 ± 0.76	4.12 ± 0.89	<0.001
	Nasal angle in degrees	21.93 ± 7.17	26.96 ± 7.40	17.71 ± 4.96	<0.001
	Temporal angle in degrees	22.18 ± 7.64	28.51 ± 8.21	17.62 ± 6.21	<0.001

D - Diopter; CCT - central corneal thickness; ACD - anterior chamber depth; PD - pupil diameter. [a]One-way ANOVA for comparison of means within the groups was done; *P* - Level of significance

Table 4: Anterior segment parameters – changes with respect to age mean (SD)

Group	Parameter	<20 yrs (n=6)	20-29 yrs (n=29)	30-39 yrs (n=24)	40-49 yrs (n=21)	50-59 yrs (n=12)	≥60 yrs (n=8)	P^a
Photopic	CCT in μm	523 (45)	516 (34)	526 (33)	517 (26)	518 (47)	507 (17)	0.796
	ACD in mm	3.07 (22)	3.01 (23)	3.03 (24)	2.66 (25)	2.73 (46)	2.62 (24)	<0.001
	PD in mm	4.65 (78)	4.48 (88)	4.36 (83)	3.79 (72)	3.28 (53)	3.34 (90)	<0.001
	Nasal angle in degrees	30.08 (6.4)	30.02 (5.0)	31.71 (5.8)	25.42 (4.5)	26.49 (7.6)	27.04 (4.7)	0.003
	Temporal angle in degrees	30.80 (8.7)	32.67 (5.4)	33.30 (5.8)	26.93 (5.3)	25.98 (7.3)	23.23 (4.9)	<0.001
Scotopic	CCT in μm	523 (45)	516 (34)	526 (33)	517 (26)	518 (47)	507 (17)	0.796
	ACD in mm	3.10 (26)	3.03 (23)	3.02 (24)	2.66 (25)	2.74 (46)	2.62 (25)	<0.001
	PD in mm	5.31 (60)	5.11 (73)	5.01 (87)	4.36 (81)	3.76 (56)	3.85 (81)	<0.001
	Nasal angle in degrees	20.70 (8.1)	24.53 (6.9)	26.55 (7.5)	17.11 (5.2)	19.99 (7.7)	19.50 (4.2)	<0.001
	Temporal angle in degrees	23.62 (10.0)	25.66 (7.6)	25.95 (8.8)	19.25 (6.3)	19.28 (9.0)	17.15 (6.5)	0.004

CCT - Central corneal thickness; ACD - Anterior chamber depth; PD - Pupil diameter; r - Correlation coefficient; *P* - Level of significance

Discussion

Unlike conventional ultrasound biomicroscopy (UBM), AS OCT is an easy, noninvasive, less time-consuming imaging technique that does not require an immersion bath. AS OCT also has the added advantage of better spatial resolution and reproducibility compared to UBM.[4]

Anterior segment imaging using OCT was first demonstrated in 1994 using light with a wavelength of 830 nm.[1] Later

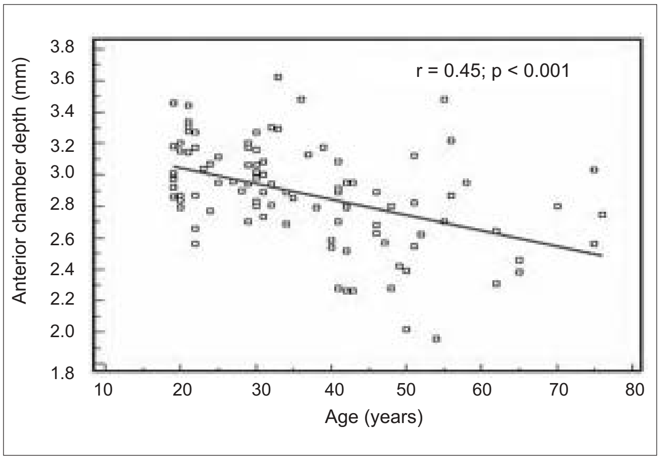

Figure 2: Scatter plot demonstrating the correlation between age and anterior chamber depth in photopic conditions

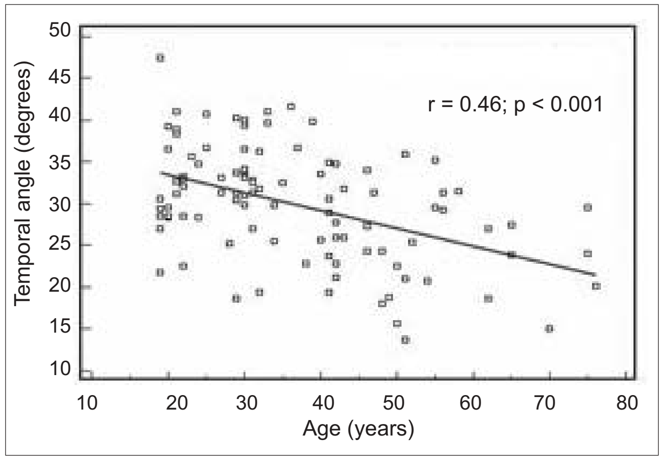

Figure 4: Scatter plot demonstrating the correlation between age and temporal angle in photopic conditions

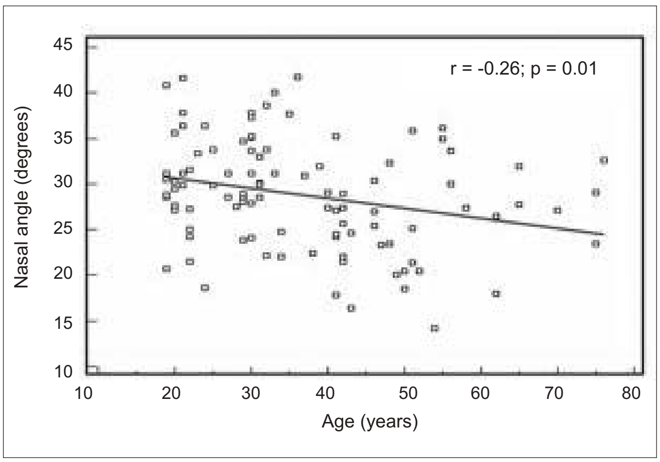

Figure 3: Scatter plot demonstrating the correlation between age and nasal angle in photopic conditions

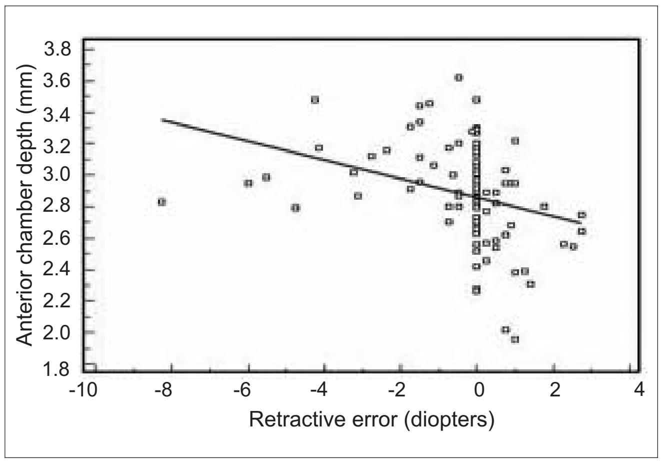

Figure 5: Scatter plot showing anterior chamber depth relative to refractive error in photopic conditions

Table 5: Comparison of anterior chamber depth in various studies using anterior segment optical coherence tomography

Various Studies	Sample size	ACD (Mean ± SD)	Significance (t-test)
Baikoff *et al.*[4]	104	3.61 ± 0.38 mm	Higher
Baikoff *et al.*[5]	107	3.64 ± 0.33 mm	Higher
This Study	100	2.88 ± 0.32 mm	

ACD - Anterior chamber depth; [a]Significant difference between others' and our study using t-test ($P < 0.01$).

generations of OCT employed light with a wavelength of 1310 nm, which reduced the amount of scattering in tissue. This increased tissue penetration through scattering tissues like sclera and iris, thereby enhancing better visualization of the AC angle structures.[4-6]

Here we report the comparison of the various anterior segment parameters in photopic and scotopic conditions using AS OCT, which is a valuable technique for quantitative assessment that provides reproducible measurement[17] and objective documentation by different examiners. In our study, all measurements were carried out by one examiner.

The use of infrared light source in the AS OCT keeps the pupil size unaltered, thereby presumably giving a more accurate ACD value. We have found that once the eye gets adapted to the scotopic environment, the PD decreases to a certain extent when compared to its initial size in the scotopic environment. All scans were therefore taken as soon as the lights were turned off, thereby obtaining standard maximum dilation in all subjects.

AS OCT measures along the geometric axis by adjusting the fixation angle in the device. We have ensured that all scans were aligned on the geometric axis by adjusting the fixation angle in case the scan was aligned on its visual axis. Baikoff *et al.*[17] reported that a centering error of 0.5 mm away from the eye's geometric center gave a 20µ underevaluation for ACD by AS OCT. Being in the geometric axis, the AS OCT measurement probably reflects a more accurate estimation of ACD. Studies have also shown that AS OCT gave deeper ACD results as compared to IOL Master and scanning peripheral ACD analyzer.[20]

In this study, although ACD was slightly deeper in scotopic conditions, it was not statistically significant when compared with photopic conditions (P = 0.10). The PD increased but angles, on the other hand, decreased significantly under scotopic conditions. There was significant inter-angle variation between the nasal and temporal angles in photopic conditions (P = 0.02); but in scotopic conditions, the inter-angle variation was not significant (P = 0.31). This implies that irrespective of the quadrant of the angle, the angles decreased significantly in scotopic conditions.

There were no significant differences in the various anterior segment parameters between males and females. Neither did Kumar *et al.*[21] obtain significant differences between males and females among the normals using UBM. Other studies have reported that men have higher ocular biometric values than females.[22] This might be due to the larger sample size compared with our sample. However, the tendency for shallower ACD and narrower angles was found more often among the females than the males in this study.

In our study, mean CCT in males was 6 µm greater than that in females. This is not in agreement with most studies,[23] which found a slightly increased CCT in females over that of males. However, the difference was small and not statistically significant.

We found significant differences in the ACD, PD and angles among the refractive groups. Myopes showed the maximum values for ACD and angles, proving the fact that they have deeper anterior chambers and wider angles than hypermetropes, who had the minimum values.

Though a correlation between CCT and refractive error was found, it was not significant in the multivariate analyisis.[23] It is usually thought that myopes have thinner corneas compared to hypermetropes. This was not true in our study. In fact, myopic eyes had slightly thicker corneas than normal or hypermetropic eyes, but this was not statistically significant. We probably failed to reproduce the results of other studies due to differences in the range of refractive errors (−8.0 to +3.0D) studied.

We found that the ACD, PD and angles decreased significantly with age. Previous studies have revealed that CCT tends to decrease with increasing age.[24] In our study, although there was a negative correlation between CCT and age, it was not statistically significant (r = −0.08; P = 0.40).

The ACD in the present study was tabulated along with the results from other studies in which AS OCT was used [Table 5]. Baikoff *et al.* reported a higher ACD compared with our study. The mean CCT in our study (519 ± 34 µm) was lower than that reported by Wirbelauer *et al.*[7] (541 ± 43 µm). The statistically significant difference in ACD and CCT measurements could be attributed to racial differences.

In conclusion, our study demonstrates that while ACD is not influenced by ambient lighting conditions, the PD increased and angles decreased significantly in scotopic conditions. We therefore suggest that goniometry with AS OCT should always be done with the room lights off.

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