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. 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. It can also be used as a tool to measure intraocular dimensions prior to phakic intraocular lens (IOL) implantation.

Currently, there are only a few studies of the anterior segment of the eye using AS OCT. 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 of both sexes, aged 19 to 76 years, who 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

The Eye Research Foundation, Vijaya Hospital, Chennai, India
Correspondence to Dr. Shaun Dacosta, The Eye Research Foundation, Vijaya Hospital, 180 N5K Salai, Chennai – 600 026, India. E-mail: shaundacosta@yahoo.com
Manuscript received: 30.03.07; Revision accepted: 6.6.07
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 central 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.

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.

![Figure 1: Analysis of the anterior segment by anterior segment optical coherence tomography](image-url)
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.

Anterior segment imaging using OCT was first demonstrated in 1994 using light with a wavelength of 830 nm. Later
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 measurement17 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

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; *Significant difference between others’ and our study using t-test (P < 0.01).
angle in case the scan was aligned on its visual axis. Baikoff et al. reported that a centering error of 0.5 mm away from the eye’s geometric center gave a 20 µm 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.

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. 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. 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, 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 analysis. 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 +3.0 D) 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. 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. (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.

References

1. Izatt JA, Hee MR, Swanson EA, Lin CP, Huang D, Schuman JS, et al. Micrometer-scale resolution imaging of the anterior eye in vivo with optical coherence tomography. Arch Ophthalmol 1994;112:1584-9.
2. Koop N, Brinkmann R, Lankenu E, Flache S, Engelhardt R, Birngruber R. Optical coherence tomography of the cornea and the anterior eye segment. Ophthalmologe 1997;94:481-6.
3. Hoerauf H, Wirbelauer C, Scholz C, Engelhardt R, Koch P, Laqua H, et al. Slit lamp adapted optical coherence tomography of the anterior segment. Graefes Arch Clin Exp Ophthalmol 2000;238:8-18.
4. Radhakrishnan S, Rollins AM, Roth JE, Yazdanfar S, Westphal V, Bardenstein DS, et al. Real - time optical coherence tomography of the anterior segment at 1310 nm. Arch Ophthalmol 2001;119:1179-85.
5. Hoerauf H, Scholz C, Koch P, Engelhardt R, Laqua H, Birngruber R. Transsceral optical coherence tomography: A new imaging method for the anterior segment of the eye. Arch Ophthalmol 2002;120:816-9.
6. Radhakrishnan S, Goldsmith J, Huang D, Westphal V, Dueker DK, Rollins AM, et al. Comparison of optical coherence tomography and ultrasound biomicroscopy for detection of narrow anterior chamber angles. Arch Ophthalmol 2005;123:1053-9.
7. Wirbelauer C, Scholz C, Hoerauf H, Pham DT, Laqua H, Birngruber R. Non contact corneal pachymetry with slitlamp-adapted optical coherence tomography. Am J Ophthalmol 2002;133:444-50.
8. Wirbelauer C, Gochmann R, Pham DT. Imaging of the anterior eye chamber with optical coherence tomography. Klin Monatsbl Augenheilkd 2005;222:856-62.
9. Wirbelauer C, Scholz C, Hoerauf H, Engelhardt R, Birngruber R, Laqua H. Corneal optical coherence tomography before and immediately after excimer laser photorefractive keratectomy. Am J Ophthalmol 2000;130:693-9.
10. Maldonado MJ, Ruiz-Oblitas L, Munuera JM, Aliseda D, Garcia-Layana A, Moreno-Montanes J. Optical coherence tomography evaluation of the corneal cap and stromal bed features after laser in situ keratomileusis for high myopia and astigmatism. Ophthalmology 2000;107:81-8.
11. Baikoff G. Anterior segment OCT and phakic intraocular lenses: A perspective. J Cataract Refract Surg 2006;32:1827-35.
12. Wirbelauer C, Karandish A, Häberle H, Pham DT. Optical coherence tomography in malignant glaucoma following filtration surgery. Br J Ophthalmol 2003;87:952-5.
13. Wirbelauer C, Karandish A, Häberle H, Pham DT. Non contact goniometry with optical coherence tomography. Arch Ophthalmol 2006;123:179-85.
14. Baikoff G, Lutun E, Wei J, Ferraz C. Contact between 3 different phakic intraocular lens models with the crystalline lens: An anterior chamber optical coherence tomography study. J Cataract Refract Surg 2004;30:2007-12.
15. Baikoff G, Lutun E, Wei J, Ferraz C. Anterior chamber optical coherence tomography study of human natural accommodation in a 19-year old albino. J Cataract Refract Surg 2004;30:696-701.
16. Baikoff G, Lutun E, Ferraz C, Wei J. Static and dynamic analysis of the anterior segment with optical coherence tomography. J Cataract Refract Surg 2004;30:1843-50.
Baikoff G, Jodai HJ, Bourgeon G. Measurement of the internal diameter and depth of the anterior chamber: IOL master versus anterior chamber optical coherence tomographer. J Cataract Refract Surg 2005;31:1722-8.

Nolan WP, See JL, Chew PT, Friedman DS, Smith SD, Radhakrishnan S, et al. Detection of primary angle closure using anterior segment OCT in Asian eyes. Ophthalmology 2007;114:33-9.

Leung CK, Chan WM, Ko CY, Chin SI, Woo J, Tsang MK, et al. Visualization of anterior chamber angle dynamics using optical coherence tomography. Ophthalmology 2005;112:980-4.

Lavanya R, Teo L, Friedman DS, Aung HT, Baskaran M, Gao H, et al. Comparison of anterior chamber depth measurements using the IOLMaster, scanning peripheral anterior chamber depth analyser, and anterior segment optical coherence tomography. Br J Ophthalmol 2007;91:1023-6.

Ramani KK, Mani B, Ronnie G, Joseph R, Lingam V. Gender variation in ocular biometry and ultrasound biomicroscopy of primary angle closure suspects and normal eyes. J Glaucoma 2007;16:122-8.

Foster PJ, Alsbirk PH, Baasanhu J, Munkhbayar D, Uranchimeg D, Johnson GJ. Anterior chamber depth in Mongolians: Variation with age, sex and method of assessment. Am J Ophthalmol 1997;124:53-60.

Brandt JD, Beiser JA, Kass MA, Gordon MO. Central corneal thickness in the Ocular Hypertension Treatment Study (OHTS). Ophthalmology 2001;108:1779-88.

Foster PJ, Baasanhu J, Alsbirk PH, Munkhbayar D, Uranchimeg D, Johnson GJ. Central corneal thickness and intraocular pressure in a Mongolian population. Ophthalmology 1998;105:969-73.

Source of Support: Nil, Conflict of Interest: None