Comparison of anterior segment optical coherence tomography and ultrasound biomicroscopy for assessment of the anterior segment

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PURPOSE: To compare anterior segment parameters using quantitative imaging by anterior segment optical coherence tomography (AS-OCT) and ultrasound biomicroscopy (UBM).

SETTING: Tertiary-care glaucoma research center.

METHODS: Sixty-three eyes of 63 subjects had anterior segment evaluation by AS-OCT (Visante-Zeiss) and UBM (Paradigm). Central corneal thickness (CCT), anterior chamber depth (ACD) (measured from the central corneal endothelium to the anterior lens capsule), and the peripheral iridocorneal angles (temporal and nasal) were assessed and compared.

RESULTS: There was an excellent correlation between AS-OCT and UBM measurements for the nasal angle ($r = 0.84$; $P<.0001$), temporal angle ($r = 0.86$; $P<.0001$), ACD ($r = 0.97$; $P<.0001$), and CCT ($r = 0.91$; $P<.0001$). There was no significant difference (paired *t* test) between the mean ACD, CCT, and angle parameters measured by AS-OCT or UBM. The mean values of the parameters measured by AS-OCT and UBM were, respectively, as follows: nasal angle, 26.25 degrees $\pm$ 11.0 (SD) and 28.27 $\pm$ 11.3 degrees ($P = .3$); temporal angle, 25.1 $\pm$ 11.4 degrees and 28.3 $\pm$ 13.5 degrees ($P = .15$); ACD, 2.85 $\pm$ 0.5 mm and 2.78 $\pm$ 0.5 mm ($P = .2$); and CCT, 512 $\pm$ 46 μm and 502 $\pm$ 46 μm ($P = .25$). The AS-OCT images showed sharper definition of the scleral spur than the UBM images.

CONCLUSION: Anterior segment optical coherence tomography and UBM can both be used for anterior segment measurements and yielded comparable results.

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Both anterior segment optical coherence tomography (AS-OCT) and ultrasound biomicroscopy (UBM) allow imaging of anterior ocular structures. Anterior segment optical coherence tomography produces images similar to B-mode ultrasound imaging except that it uses light instead of sound.[1] Anterior segment optical coherence tomography allows high-resolution analysis and measurement of the anterior segment without the need for ocular anesthesia or a water bath. The technique is gradually finding its place in the field of refractive surgery[2–4] and is also being used for imaging the ocular surface and iris neoplasia.[5] We have been using UBM for anterior segment evaluation; however, it is a contact method that requires topical anesthesia and a water bath with the patient in a supine position. We therefore performed a study to evaluate the utility of AS-OCT for imaging the anterior segment and compared the results with those of UBM.

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SUBJECTS AND METHODS

Sixty-three eyes of 63 normal subjects were evaluated at a tertiary-care glaucoma research center. After all subjects gave

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informed consent, AS-OCT and UBM were performed to evaluate central corneal thickness (CCT) and anterior chamber parameters.

The AS-OCT imaging was done before the UBM measurements. Optical coherence tomography was performed using Visante AS-OCT system (Carl Zeiss Meditec International). For AS-OCT, subjects were seated. The scanning speed of the system was 4000 axial scans per second, and each image frame had 500 axial scans per image. Thus, an image acquisition rate of 8 frames per second was obtained. The lateral resolution of AS-OCT is 60 μm, and the axial resolution is 18 μm. An anterior chamber biometry scan protocol was used with the anterior chamber single-scan mode. The scan was 16.0 mm in diameter and 6.0 mm deep (tissue). The fixation angle (angle between the instrument's optical axis and the eye's line of sight) was 0 degree. Three images of a 0- to 180-degree area in primary gaze were obtained. One of the 3 images was selected based on centration, quality, and visibility of the angle structures for analysis by the built-in software.

Ultrasound biomicroscopy was performed using the P40 machine (Paradigm Medical Industries). With the subject supine, topical anesthesia of proparacaine 0.5% was applied. The right eye of each subject was imaged using an appropriate-size eyecup filled with methylcellulose 2% as a coupling agent. Care was taken not to exert pressure on the globe. Variation in accommodation was minimized by fixation with the contralateral eye on a standard distance target on the ceiling. Each eye was examined in its axial section with the probe kept perpendicular to the corneoscleral surface. This system operated at 50 MHz and provided lateral resolution of approximately 50 μm and axial resolution of 25 μm. Tissue penetration was approximately 4.0 to 5.0 mm. The scanner produces a 5.0 mm × 5.0 mm field with 256 image lines at a scan rate of 8 frames per second. Both imagings were done in constant ambient lighting conditions in the same room. Three images each of the central cornea and the central anterior chamber were recorded in primary gaze, and 3 images each of the temporal and nasal anterior chamber angles were recorded in lateral gazes.

Separate observers masked to results of the other method manually performed quantitative analysis of the AS-OCT and UBM findings using drawing calipers and the anterior segment measurements obtained with each technique. The anterior segment parameters that were measured were anterior chamber angle at nasal and temporal areas (0 degree and 180 degrees), central anterior chamber depth (ACD), and CCT.[6] The anterior chamber angle (angle) was measured with the anterior chamber angle tool, whose apex was placed in the angle recess and the arms of the angle passing parallel to the iris surface and the corneal endothelium to give the iridocorneal angle recess. The ACD was measured from the central corneal endothelium to the anterior lens capsule using the chamber tool; the measurements are done once the calipers were placed at desired points. The CCT was measured from the inner surface of the corneal endothelium to the outer epithelial surface at the central part using the above-mentioned chamber tool.

Statistical Analysis

Data were managed on an Excel spreadsheet. All entries were checked for possible keyboard errors. For data analysis, Stata statistical software (version 7.0) was used. The correlation between the variables measured by the 2 methods was analyzed, and the degree of correlation by the Pearson correlation coefficient was calculated. The paired t test was used to compare the mean values. All tests were 2-tailed, and a P value less than 0.05 was considered statistically significant.

RESULTS

The mean age of the subjects was 43.5 years ± 9.8 (SD). Of the 63 subjects, 43 were men and 20 women.

There was a strong correlation between AS-OCT and UBM measurements for all parameters. The correlation coefficients between the observations made by AS-OCT and UBM were as follows: nasal angle, 0.839 ($P<.0001$); temporal angle, 0.866 ($P<.0001$); ACD, 0.97 ($P<.0001$); and CCT, 0.906 ($P<.0001$). Figures 1 and 2 show the correlations. Table 1 shows the mean values of the angle parameters measured by UBM and AS-OCT. Figure 3 shows UBM and AS-OCT images of the anterior segment of the same eye. The AS-OCT images showed sharper definition of the scleral spur than the UBM images but could not image the entire ciliary body because of attenuation of light by the overlying iris. The images of the superior and inferior angles were obstructed by the eyelids.

DISCUSSION

The original ultrasound biomicroscope developed by Pavlin et al.[7] is based on 50 to 100 MHz transducers incorporated into a B-mode clinical scanner. The P40 UBM machine provides high-resolution images (50 μm lateral resolution in the commercially available system) of the anterior chamber angle region, has a depth of penetration of 5.0 mm in tissue, and can image through opaque media. Studies show comparable quantitative and qualitative agreement of UBM images with histological sections.[7,8]

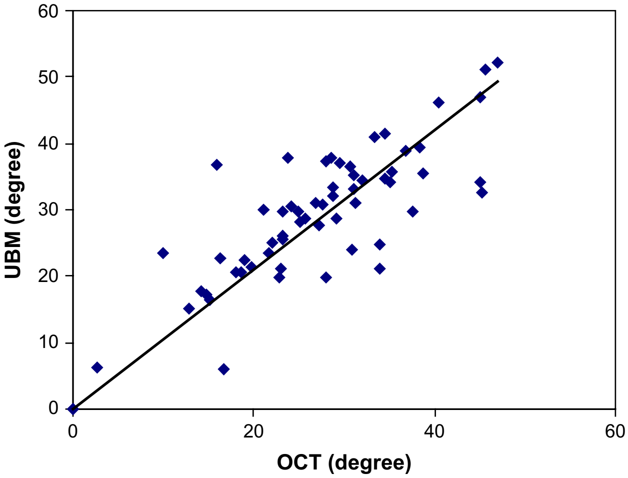

Figure 1. Correlation of anterior chamber angle (temporal) by AS-OCT and UBM.

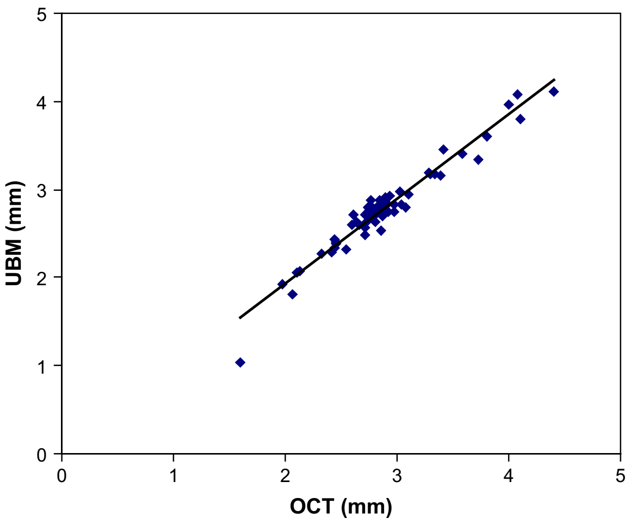

Figure 2. Correlation of ACD by AS-OCT and UBM.

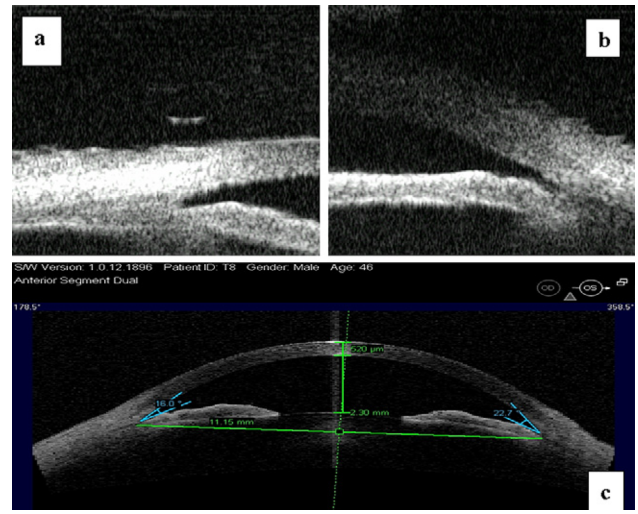

Figure 3. Nasal UBM (*a*), temporal UBM (*b*), and AS-OCT (*c*) images of the anterior segment of the same eye.

Ocular imaging with the 1.3 μm wavelength AS-OCT was first reported by Radhakrishnan et al.[9] using a system developed by Izatt's group.[10] Anterior segment optical coherence tomography is described as an attractive technique for optical biopsy because it can image tissue microstructure in situ, yielding micron-scale image resolution without the need to excise a specimen and process tissue processing.

The AS-OCT image represents the differential backscattering contrast between different tissue types on a micron scale. It is a gray scale or false color 2-dimensional representation of backscattered light intensity in a cross-sectional plane. Highly detailed images of the cornea and angle region, including the iris root, angle recess, anterior ciliary body, scleral spur, and, in some eyes, canal of Schlemm, is possible with 1.3 μm AS-OCT because of the lower scattering loss and the ability to penetrate the limbus and sclera to provide a view of the angle. The absorption of light by water is much higher for 1.3 μm wavelength.[11]

Optical coherence tomography has several advantages over the other techniques for objective assessment of the anterior chamber angle. Anterior segment optical coherence tomography can perform measurements without a coupling medium as it uses light energy; in UBM, sound energy is used. Anterior segment optical coherence tomography is a noncontact technique, which increases patient comfort and cooperation as well as safety, especially in pediatric patients. With standard software, the lateral resolution of AS-OCT is 60 μm and the axial resolution is 18 μm compared with 50 μm and 25 μm, respectively, with UBM. With high-resolution corneal software, axial resolution of AS-OCT can reach 8 μm. With the Visante AS-OCT, anterior segment scans up to 6.0 mm deep and 16.0 mm wide can be performed (data by Carl Zeiss Meditec). Important landmarks such as the scleral spur are more distinct in AS-OCT images. With AS-OCT, one can also examine the posterior capsule of the lens, which is not possible with UBM.

Imaging with UBM, on the other hand, has several limitations. A coupling medium is required so scanning must be performed through an immersion bath. Ultrasound biomicroscopy is performed with the patient supine, positioning that theoretically causes the iris diaphragm to fall back. This deepens the anterior chamber and opens the angle. Also, the inadvertent pressure on the eyecup used while scanning can influence angle configuration, as reported by Ishikawa et al.[12] using a small UBM eyecup. With UBM, it is not possible to pinpoint the exact location of the angle being imaged, unlike AS-OCT, which gives the exact

Table 1. Mean values of parameters measured by AS-OCT and UBM.

	Mean ± SD		
Parameter	AS-OCT Mean	UBM Mean	*P* Value
Nasal angle (degrees)	26.25 ± 11.00	28.27 ± 11.30	.3
Temporal angle (degrees)	25.10 ± 11.40	28.30 ± 13.50	.15
ACD (mm)	2.85 ± 0.5	2.78 ± 0.5	.2
CCT (μm)	512 ± 46	502 ± 46	.25

ACD = anterior chamber depth; AS-OCT = anterior segment optical coherence tomography; CCT = central corneal thickness; UBM = ultrasound biomicroscopy location in degrees. With AS-OCT, keeping the fixation angle (the angle between the instrument's optical axis and the eye's line of sight) at 0 degree, finding the exact location of the measured angle in degrees of an arc is possible. In UBM, there is no fixed reference point and the angle region measured is located subjectively as nasal, temporal, superior, inferior, and so forth, not in exact degrees of an arc. With UBM, only 1 quadrant can be imaged at a time. With AS-OCT, 4 quadrants can be scanned at once. The UBM procedure is more time consuming and requires a highly skilled operator to obtain high-quality precision images. There is a risk for infection or corneal abrasion because of the contact nature of the examination, and it is contraindicated in suspected open-globe injuries.

The limitations of AS-OCT are that it cannot obtain clear images through opaque media and is obstructed by the eyelids, making imaging of the superior and inferior angles difficult. It also provides limited visualization of the ciliary body.

In the present study, we found that AS-OCT provided a noncontact method for anterior segment imaging and correlated well with UBM results. There was no significant difference between the mean values of all the anterior chamber parameters; that is, the nasal and temporal angles, CCT, and ACD.

To our knowledge, only a single previous study[13] of anterior chamber angle parameters compares AS-OCT and UBM for detection of narrow anterior chamber angles. The study, comprising 31 eyes, found AS-OCT to be a promising method for screening primary angle closure and that both AS-OCT and UBM performed equally well in identifying eyes with narrow angles.

Wirbelauer et al.[14] compared goniometry and AS-OCT using current gonioscopic clinical parameters in the evaluation of the anterior chamber angle. They found a significant correlation with the clinical parameters of gonioscopic grading and AS-OCT findings ($P < .001$).

Slight differences may be seen in the measurements obtained with AS-OCT and UBM because of the differences in light conditions, accommodation, and supine versus sitting position, and there may be variations in the exact location being scanned. However, AS-OCT may not be suitable for diagnosing some situations in which clear ciliary body imaging is required, such as iris plateau.

Thus, AS-OCT using a 1.3 μm wavelength is a helpful tool for noncontact anterior segment evaluation. Its measurements correlate well with those of UBM, and it may be a promising tool for anterior segment imaging in clinical practice. Further long-term studies to elucidate the full potential of this new imaging modality are required.

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