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Characterizing Anterior Segment OCT Angle Landmarks of the Trabecular Meshwork Complex

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Purpose: To identify the presence or absence of 3 identifiable landmarks: trabecular meshwork (TM), Schlemm's canal (SC), and a novel landmark termed the band of extracanalicular limbal lamina (BELL), which is a landmark adjacent to SC visible on anterior segment (AS) OCT. These landmarks also were analyzed pathologically to identify all 3 landmarks.

Design: Retrospective review.

Participants: One eye per participant from prior institutional review board-approved studies in which AS OCT imaging was performed.

Methods: Horizontal images from 2-dimensional angle analysis scans using a CASIA SS-1000 (Tomey, Nagoya, Japan) AS OCT were evaluated by masked readers. Logistic regression was used to analyze the potential factors of age, gender, race, intraocular pressure, gonioscopy grade, angle location, and history or presence of surgery on the visibility of these structures. Pathologic correlation on 5 previously enucleated eyes also was performed.

Main Outcome Measures: Presence or absence of angle landmarks—TM, SC, and BELL—using Anterior Chamber Analysis and Interpretation software (ACAI, Houston, TX).

Results: Three hundred three angles of 153 horizontal images were included in this study. The mean age was 51.5±16.0 years, with 98 women (64%) and 100 white persons (66%). The outer border of the BELL was observed in 288 angles (95%), TM was found in 220 angles (73%), and SC was seen in 120 angles (40%). The outer border of the BELL was more visible in white persons ($P = 0.02$) than Asians and in eyes with a Spaeth gonioscopy grade of E than those with a grade of A ($P = 0.02$). Both TM ($P = 0.001$) and SC ($P = 0.001$) were more visible in temporal angles (81% for TM, 49% for SC) than in nasal angles (64% for TM, 30% for SC). Additionally, SC was more visible in open angles (43%) than in narrow angles (27%; $P = 0.02$). These 3 structures were verified in a pathologic study.

Conclusions: We identified a novel AS OCT landmark adjacent to SC. This structure also was identified on pathologic samples from enucleated eyes. Further study is needed to determine the pathophysiologic relevance of these findings. *Ophthalmology 2018;■:1–9 © 2018 by the American Academy of Ophthalmology*

Glaucoma is the second leading cause of blindness, with more than 60 million people worldwide with glaucoma-related optic nerve damage.[1,2] Intraocular pressure (IOP) homeostasis and trabecular meshwork (TM) drainage of aqueous humor are key in controlling this disease. Imaging angle structures not only helps our understanding of the pathophysiologic features of the disease, but also may play an important role in the diagnosis and management of glaucoma patients.

In the new era of ophthalmic imaging, OCT has revolutionized the way patients are diagnosed and treated. Although retinal imaging has become the standard of care for diseases like age-related macular degeneration and diabetic macular edema, anterior segment (AS) OCT is still being studied. The CASIA SS-1000 (Tomey, Nagoya, Japan) AS OCT device has the capability of imaging the peripheral angle with high resolution (7 × 10 μm per pixel) for evaluating the anterior chamber,[3] and previous studies demonstrated that using the CASIA SS-1000 resulted in high-quality images.[4] Additionally, with the CASIA SS-1000, it is possible to evaluate the AS OCT reflectivity of structures in the AS, including the TM and its relationship to the scleral spur and iris insertion. In previous studies, an angle landmark called the *TM shadow* was observed (Fig 1).[5] This TM shadow also was identified by Kagemann et al,[6] but was not characterized further. Other studies cite images where the TM shadow is present,[7] but do not comment on this AS OCT landmark. As far as we are aware, the structural or physiologic significance of this landmark is unclear; however, previous studies looking at the characteristics of the TM may have included the TM shadow erroneously in their measurements because of misidentification, poor resolution, or both.[8,9] Therefore,

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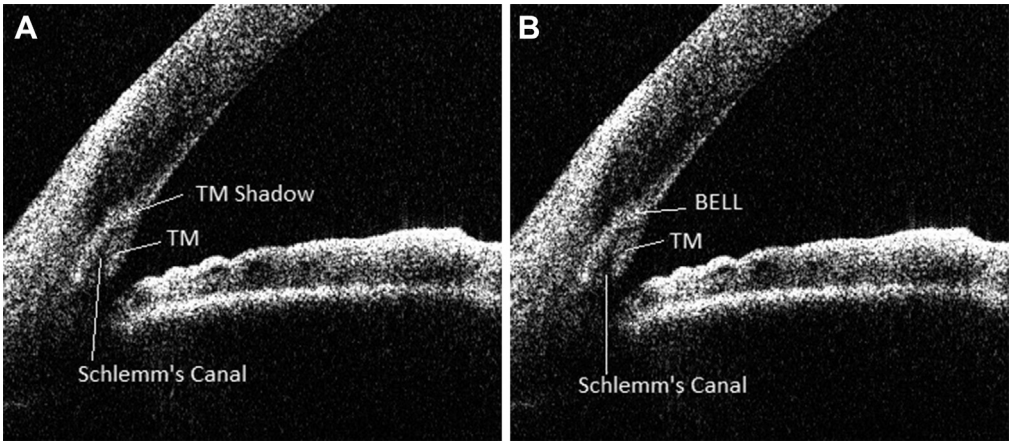

Figure 1. A, B, Two-dimensional anterior segment OCT angle image demonstrating landmarks: trabecular meshwork (TM), Schlemm's canal, band of extracanalicular limbal lamina (BELL), and TM shadow.

characterizing this landmark is a first step in identifying its clinical significance.

The purpose of this study was to identify the presence or absence of 3 identifiable angle landmarks on AS OCT: the TM, TM interface or Schlemm's canal (SC), and a novel anatomic landmark—a band of extracanalicular limbal lamina (BELL)—previously identified as the TM shadow. We also correlated this novel landmark with pathologic tissue samples of the angle structures in 5 eyes.

Methods

This retrospective review of AS OCT images was conducted at the Robert Cizik Eye Clinic of the Ruiz Department of Ophthalmology and Visual Science at the McGovern Medical School at The University of Texas Health Science Center at Houston. Institutional review board approval was obtained from The University of Texas Health Science Center Committee for the Protection of Human Subjects. All research adhered to the tenets of the Declaration of Helsinki and complied with the Health Insurance Portability and Accountability Act. Pathologic analysis was performed on enucleated globes and obtained from routinely acquired pathologic samples.

Participants

A chart review of participants 18 years of age or older from previously approved institutional review board studies[4,5,10–12] conducted at the Robert Cizik Eye Clinic was performed. Those participants who had undergone with 2-dimensional angle analysis scan imaging using the CASIA SS-1000 system were included. All eyes were phakic and underwent AS OCT imaging and gonioscopic examination on the same day or within 2 weeks before imaging. Eyes with a history of previous intraocular surgery, scleral buckle, or anterior segment abnormalities (e.g., significant corneal opacity, pterygium, etc.) that affected the identification of angle landmarks or measurements were excluded. If both eyes met the eligibility criteria, one eye was selected randomly. Participant demographics (age, gender, and race or ethnicity) were recorded in addition to the ocular characteristics of each study eye, including clinical diagnosis (normal or narrow angle suspect vs. open-angle suspect vs. angle-closure glaucoma vs. open-angle glaucoma), IOP, and number of IOP medications.

Gonioscopy Examination and Grading

Gonioscopy examination was performed using a Posner goniolens in the dark and graded as described previously[12] using the Spaeth grading system[13,14] (grading determined by the deepest visible anterior chamber angle structure without indentation: A = anterior to Schwalbe's line; B = between Schwalbe's line and scleral spur; C = scleral spur; D = ciliary body; and E = beyond 0.1 mm of the ciliary body). This grading system was determined for the entire eye and not for each individual angle quadrant. Presence of peripheral anterior synechiae was examined by indentation gonioscopy. A narrow angle was defined as when the scleral spur was not seen in at least 1 angle quadrant.

Anterior Segment OCT Imaging Instrument

The CASIA SS-1000, a swept-source Fourier-domain AS OCT system, uses a 1310-nm wavelength light with a scan speed of 30 000 A-scans per second to image the anterior chamber, including the peripheral angle structures. Images can be obtained in high-resolution 2-dimensional mode (2048 A-scans each, 1 pixel = 7.9 × 10.0 μm) with both horizontal and vertical meridian scans simultaneously in 0.2 seconds.

Acquisition of Anterior Segment OCT Images

All participants underwent angle imaging in a dark room (0 lux). Participants were instructed to focus on the internal fixation light. After adjusting the participant's position, eyes were scanned in 2-dimensional mode with the angle analysis scan and the autoalignment function.[10] The AS OCT operator viewed each scan to ensure that the quality was acceptable. As soon as an acceptable image was obtained, the image was saved. Only the first acceptable image was saved.

Anterior Segment OCT Reading Procedures

Several anatomic structures were defined as follows (Fig 1): the scleral spur, the point where there was a change in curvature in the corneoscleral—aqueous interface, often appearing as an inward protrusion of the sclera[10]; Schwalbe's line, the point where the anterior end of TM meets the peripheral end of the corneal endothelium; and Schlemm's canal (SC), a tubular canal located at the sclerocorneal junction. The TM was bordered by the scleral spur, the posterior end point of the SC, and Schwalbe's