Spectral domain optical coherence tomography to assess the insertion of extraocular rectus muscles

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PURPOSE To determine the distance of the horizontal rectus muscle insertion to the limbus using spectral domain optical coherence tomography (SD-OCT) and to evaluate whether results are correlated with sex, age, or axial length.

METHODS The right eyes of healthy, white subjects were imaged with SD-OCT. Subjects' sex and age were recorded, and axial length was measured using an optical biometer. The distance from the horizontal rectus insertion to the limbus was measured. The intraclass correlation coefficient (ICC) was used to assess the reproducibility of the measurements with a subset of images. A multivariate model was adjusted to analyze whether sex, age, and axial length was correlated with insertion distance.

RESULTS A total of 187 right eyes were included. Mean participant age was 43.7 ± 22.1 years (range, 6-85). Of the 187 patients, 129 were female; 25 were children. Mean axial length was 23.9 ± 1.6 mm (range, 20.4–29.3). Mean rectus insertion distance to the limbus was 6.47 ± 0.52 mm (range, 5.2–7.6 mm) for the lateral rectus muscle and 5.22 ± 0.51 mm (range, 4.1–6.1 mm) for the medial rectus muscle. ICC was >0.87 for intra- and interobserver reproducibility. The insertion–limbus distance was correlated with sex, being greater in males ($P = 0.040$ for the lateral rectus muscle; $P = 0.036$ for medial rectus muscle). There was no correlation between this distance and axial length or age ($P > 0.156$).

CONCLUSIONS In this study cohort, the insertion distance of the horizontal rectus muscles to the limbus on SD-OCT was greater in males than females; however, age and axial length were not correlated with insertion distance. (J AAPOS 2016;20:201-205)

Strabismus surgical planning relies on knowledge of standard insertion distances of the extraocular muscles to the limbus.[1] The exact insertion distances for each patient cannot be known prior to surgery. To date, some techniques have been used to image the extraocular muscle, such as magnetic resonance imaging and computed tomography (CT) scans.[2-4] Unfortunately, these methods do not yield accurate results and cannot be used to determine the point of insertion of the muscle or to measure the distance from the limbus. Furthermore, these technologies are not readily available for routine consultation and are expensive; CT imaging is also limited by the hazards associated with radiation. B-scan ultrasonography allows for anatomic visualization of extraocular muscles but produces only a low-resolution image of the insertion.[5-7] By contrast, ultrasound biomicroscopy (UBM)[8-11] produces better images than previous techniques but is an uncomfortable contact technique and difficult to perform in children without anesthesia. All of these techniques are time consuming.

Optical coherence tomography (OCT) is a noninvasive technique for high-resolution imaging. OCT has evolved from time domain to spectral domain (SD) systems, which permit enhanced image acquisition speed and resolution. Few studies have reported on the visualization of extraocular muscles insertions using OCT.[12-15] In the first reported use of OCT to detect horizontal rectus muscle insertion distance, by Liu and colleagues,[12] measurements on imaging showed good agreement with intraoperative ones. Park and colleagues[13] reported that changes in eye position did not significantly affect the insertion distance measured by OCT. Ngo and colleagues[14] also described good agreement between OCT and intraoperative measurements in their study of the horizontal and vertical rectus insertions, which included primary and previously operated muscles.

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All of these studies used the Visante (Carl Zeiss Meditec, Dublin, CA), a time domain OCT system. There are currently no studies on this topic that use an SD-OCT system to measure the insertion distance of the rectus muscle. Furthermore, few authors[16-20] have studied how factors such as age or axial length can influence the outcome of strabismus surgery, and any correlation between these factors and insertion distances remains has not been previously investigated. The purpose of the present study was to determine the horizontal rectus muscle insertion distance to the limbus using SD-OCT in a large, white population, to assess the reproducibility of these measurements, and to investigate possible correlations between measurements and sex, age, and axial length.

Subjects and Methods

We conducted a prospective cross-sectional observational study on the right eyes of healthy subjects at the Hospital Universitario Clínico San Carlos in Madrid, Spain. The research adhered to the tenets of the Declaration of Helsinki, and approval was obtained from the Hospital Clínico San Carlos Ethics Board. All study participants provided informed consent.

A complete clinical history and an ophthalmologic examination were performed on all subjects. Patients with a history of strabismus surgery, strabismus, vertical misalignment or A and V pattern, and patients with ocular diseases that could make it difficult to define a clear limbus were excluded. The sex and age of the participants were recorded, and axial length of the right eye was measured using a Lenstar LS 900 (Haag-Streit AG, Koeniz, Switzerland) optical biometer.

SD-OCT images were obtained from the right eye of all of participants using the Spectralis (Heidelberg Engineering Inc, Heidelberg, Germany). The scanning plane was oriented parallel to the long axis of the muscle. The system captures 40,000 axial scans per second and has an axial resolution of 7 μm. The images were obtained using the anterior segment module, with the line raster scanning protocol and the sclera mode selected. The exploration protocol established consisted of 21 parallel line scans of 16.7 mm in length and 5.7 mm in height, taken at 278 μm intervals (Figure 1). With this raster protocol, the entire quadrant was analyzed, and the entire extension of the insertion muscle was included in the image. After image capture, the centermost scan (11 of 21) was selected as the reference when taking the measurement at 3 and 9 o'clock to visualize the horizontal rectus muscles (Figure 1). If that the muscle could not be easily identified in this concrete scan, then the clearest scan closest to the 11th was selected: the measurements were always made within 11 $\pm$ 2 scans (range, 9-13 scans).

Exploration was guided with a fixation light; patients were asked to assume a maximal temporal gaze during medial rectus muscle scanning and a maximal nasal gaze for lateral rectus muscle scanning. The posterior limbus was readily identified and marked in the external view of the eye on the image in the left side. The software showed a vertical line on the right side of the OCT image that marked the limbus, which was the point of reference for measurement (see e-Supplement 1, available at jaapos.org). The distance from the muscle insertion (at the point where the tendon ends) to the posterior corneoscleral limbus was measured using the software's caliper function. All scans were taken by a well-trained examiner and were analyzed by a single well-trained reviewer (LDPGL).

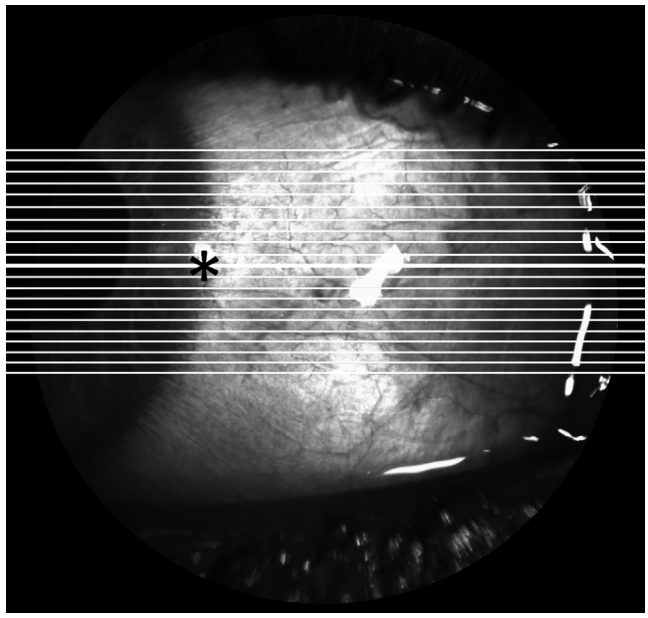

FIG. 1. Area covered by the 21 scans to explore the right medial rectus muscle. The centermost scan (wider line, 11 of 21) was selected as the reference when taking the measurement. If the central scan was not clear enough we selected the clearest scan closest to scan 11 ($\pm$2 scans: 9th-13th). The black asterisk at 3 o'clock marks the posterior limbus, which is the posterior region of the sclerocorneal junction. It was the reference point used to take the measurements from the muscle insertion to the limbus.

A subgroup of 30 eyes of 30 healthy subjects were selected at random to evaluate the intra- and interobserver reproducibility of the measurements obtained with SD-OCT. First, interobserver reproducibility was ensured by employing two independent reviewers, who measured the distance from the limbus to the muscle insertion on the same exploration images but on different days. Intraobserver reproducibility was ensured by comparing two OCT explorations performed for each patient 1 week apart by the same reviewer.

Statistical Analysis

The statistical analysis was performed using SPSS (Statistical Package for Social Sciences, v18.0; SPSS Inc, Chicago, IL). Quantitative data were described as the mean and standard deviation; qualitative data was described as the frequency of distribution. The intraclass correlation coefficient (ICC) was calculated for quantitative variables as a measure of interobserver and intraobserver reproducibility in order to assess the reliability of the SD-OCT measurements. A multivariate linear regression model was performed to adjust for possible inter-gender difference in the limbus–insertion distance measured by OCT and to study the influence of other parameters, such as axial length and age,