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Repeatability of tear meniscus evaluation using spectral-domain Cirrus® HD-OCT and time-domain Visante® OCT

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ABSTRACT

Purpose: To investigate the intra-rater, inter-rater and inter-device repeatability of a spectral-domain OCT (Cirrus) and a time-domain OCT (Visante) for tear meniscus height (TMH) and area (TMA) measurements.
Methods: 20 participants with no known eye disease were recruited. Both eyes of participants were imaged with both OCTs under the similar conditions. The inferior tear meniscus was imaged at 6 o'clock position whereas the superior meniscus was imaged at 12 o'clock position. Data from the right eyes was analyzed. Two raters independently measured TMH and TMA using the OCT images, and one rater repeated the measurements. Intra-rater, inter-rater and inter-device repeatability of measurements were assessed using Bland–Altman plots and pooled standard deviation.
Results: For intra-rater repeatability, TMH and TMA measurements were more repeatable in Cirrus than Visante (95% limits of agreement (LOA): TMH (μm), −22 to 66 (Cirrus), −125 to 45 (Visante); TMA (μm^2), −1632 to 5331 (Cirrus), −38,050 to 21,874 (Visante)). For inter-rater agreement, TMH and TMA were also more repeatable in Cirrus than Visante (95%LOA: TMH (μm), −29 to 107 (Cirrus), −215 to 252 (Visante); TMA (μm^2), −6650 to 9567 (Cirrus), −33,119 to 39,272 (Visante)). Inter-device agreement was poor (95%LOA: TMH (μm), −158 to 150; TMA (μm^2), −32,903 to 14,076). There was no significant difference in inferior TMH between Cirrus and Visante ($p > 0.05$). Inferior TMA was significantly lower in Cirrus by a mean difference of 10,223 μm^2 (95% confidence interval, 5479, 14,966) ($p = 0.0002$).
Conclusion: Spectral-domain OCT is superior to time-domain OCT for intra-rater and inter-rater repeatability of TMH and TMA measurements.

1. Introduction

The tear meniscus is the collection of tear between the globe and lid margin of the eye, and accounts for a significant amount of the steady-state total tear quantity [1,2]. Ophthalmologists have traditionally measured the tear meniscus height (TMH), which can be visualized using an eyepiece-attached graticule with or without additional fluorescein instillation, to assess tear volume [3]. The tear volume has been reported to be lower in patients with dry eye [4]. Therefore, some studies have proposed cut-off values [3,5] for inferior TMH for the diagnosis of dry eye.

The assessment of TMH with the traditional method lacks good repeatability due to variable reflex tearing from the bright light of the slit lamp and irritation induced by fluorescein staining. Patient movement and large intervals in the gracticule scale further contribute to measurement inaccuracy [6]. To overcome these problems, anterior segment optical coherence tomography (AS-OCT) has been used for tear meniscus evaluation [7]. As a non-invasive imaging tool, it does not cause any ocular stimulation in the form of visible light or irritation. Optical coherence tomography (OCT) measures back-scattered and back-reflected non-visible light to produce a cross-sectional image similar to ultrasonography [8,9]. It may also be used to assess additional information about the tear meniscus such as the tear meniscus area (TMA).

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Several studies have established the clinical usefulness of AS-OCT in assessing the tear meniscus for dry eye [4,10–17] and one study has proposed a specific cut-off TMH value of 0.30 mm for dry eye (based on the Japanese dry eye diagnostic criteria) with an acceptable sensitivity and specificity of 0.67 and 0.81 respectively [13]. For AS-OCT to be incorporated into routine clinical practice for dry eye assessment, good measurement repeatability is needed to ensure the usefulness of results between follow-ups. Good inter-device agreement may also permit different AS-OCT machines to be interchangeably used in tear meniscus assessment.

Thus far, repeatability studies have been mostly conducted for time-domain OCT models [6,10,13,18–20], such as the Visante® OCT. Spectral-domain OCT (SD-OCT) technology offers higher optical resolution and faster scan rate than time-domain OCT. One commercial model, the RTVue® SD-OCT (Optovue, Inc., Fremont, CA), was found to have better repeatability than time-domain OCTs [21–23]. The Cirrus® high definition optical coherence tomography (HD-OCT) is a SD-OCT that can also evaluate the tear meniscus but its repeatability for TMH and TMA has not been formally assessed yet.

It is not known if the higher optical resolution and scan rate of Cirrus® HD-OCT will translate into better measurement repeatability. Moreover, for patients who was previously followed-up on a TD-OCT but is now followed-up on a SD-OCT, it is not known if there is any systematic error between the measurements of these OCTs.

This study aimed to investigate the intra-rater and inter-rater repeatability of TMH and TMA measurement by the Visante® OCT and Cirrus® HD-OCT, as well as to compare the inter-device agreement of TMH and TMA between these OCTs.

2. Methods

2.1. Study design and participants

This was a cross-sectional study of 20 participants with no known eye disease at the Singapore National Eye Center, a tertiary eye hospital. This study was approved by the SingHealth Centralized Institutional Review Board and conducted in accordance with the Tenets of the Declaration of Helsinki. All participants gave written informed consent. The participants were screened for any history of ocular surface disease and active contact lens wear. The exclusion criteria were any history of eye surgery in the past 3 months; or any active ocular infection or pterygium that may affect tear film stability.

2.2. Image acquisition and measurement of tear meniscus

The participants were randomized equally (using a random number generator) to be either first imaged by the Cirrus® HD-OCT (Carl Zeiss Meditech, Dublin, CA) or the Visante® OCT (Carl Zeiss Meditech, Dublin, CA), followed by the other machine. A single operator (CHH) took a single image of the superior and inferior tear menisci of both eyes of all participants using both machines. The anterior segment 5 lines raster protocol was used for Cirrus® HD-OCT imaging whereas the high-resolution cornea scan type was used for Visante® OCT imaging.

During image acquisition, each participant was instructed to place his head and chin on the head and chin rest respectively, and to look at the fixation target. He was permitted to blink freely, except during the process of image capture, which took no more than 5 s. For both machines, superior tear meniscus images were taken at the 12 o'clock position, followed by the inferior tear meniscus at the 6 o'clock position. Images of both machines were acquired in the same visit and under similar conditions (centralized air-conditioning) with documentation of the room temperature and humidity.

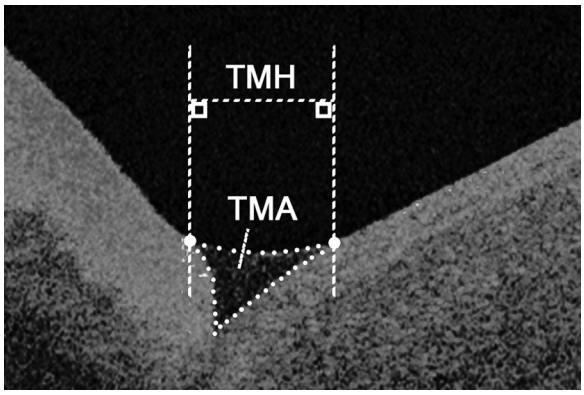

Fig. 1. Illustration of the measurement technique for TMH and TMA.

For each AS-OCT image obtained, tear meniscus height (TMH) and tear meniscus area (TMA) were measured using the line, polygonal lasso and histogram tools of Adobe Photoshop CS3® (Adobe System, Inc., San Jose, CA). Each investigator drew the line and polygon manually using software on the same computer screen at the same screen resolution and magnification. The two investigators also standardized their methods of measurement with practice images prior to this.

Measurements in pixels were converted to metric measurements using conversion factors of 4 μm/pixel (16 μm^2/pixel) for Cirrus® HD-OCT and 12.295 μm/pixel (151.167 μm^2/pixel) for Visante® OCT respectively. TMH was defined as the perpendicular distance between the two tails of the tear meniscus [13] (Fig. 1). TMA was defined as the triangular area bounded superiorly by the tear meniscus surface, anteroinferiorly by the lid margin, and posteroinferiorly by the anterior surface of cornea (Fig. 1).

2.3. Repeatability

For the assessment of inter-rater agreement, two graders (CHH and SLSY) graded the same images from the 20 subjects independently. For the assessment of intra-rater repeatability, the first grader (CHH) re-measured the same variables of the same scans 1 week later. For the assessment of inter-device agreement, CHH's repeat measurements were used.

2.4. Sample size

In our study, where there were two observations (two for intra-rater; two for inter-rater; two for inter-device) per case (20 cases), the width of the 95%CI is +/−31% of the pooled standard deviation.

2.5. Statistical analysis

The pooled standard deviation (S_p) was used to assess intra-rater repeatability of the TMH and TMA measurements. Bland–Altman plots were produced to assess intra-rater repeatability, and inter-rater and inter-device agreement. S_p was calculated by taking the square root of the pooled variance, where the pooled variance refers to the variability of TMH or TMA between readings. Normality of data was checked using the skewness and Kurtosis test, histogram and q–q plot. Paired t tests were performed to check for any significant difference in TMH and TMA between Cirrus® HD-OCT and Visante® OCT. A p-value of less than 0.05 was considered as significant. All analyses were performed with SPSS®, version 21 (IBM Corp, Armonk, NY).