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Interobserver variability of an open-source software for tear meniscus height measurement

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ABSTRACT

Purpose: Different values of the lower tear meniscus height (TMH) can be obtained depending on the method and technique of measurement employed. The aim of this study was to analyse the interobserver variability of a method for measuring TMH by using an open source software.

Material and methods: On a group of 176 subjects, two videos of the central lower tear meniscus, first under slit-lamp illumination and ten minutes later under Tearscope illumination, were generated by a digital camera attached to a slit-lamp. Images were extracted from each video by a masked observer. Two further observers measured in a masked and randomized order the TMH in each illumination method by using an open source software based on Java (NIH ImageJ). TMH was measured from the lower lid to the upper limit of the tear meniscus for both slit-lamp (TMH-SL) and Tearscope (TMH-Tc) illumination methods. Subsequently, in different order, observers assigned a four-grading and a healthy/abnormal subjective classification to each central meniscus.

Results: No significant differences were found between the TMH measurements obtained by both investigators in slit-lamp or Tearscope image datasets (*t*-test; both $p \geq 0.136$). When comparing TMH measurements stratified by grade, only interobserver significant differences were observed for grades 3 and 4 with silt-lamp (*t*-test; both $p \leq 0.009$). Significant differences on TMH results between subjective subgroups were observed for both illumination techniques (ANOVA, all $p \leq 0.045$).

Conclusion: This study showed a useful tool to objectively measure TMH by photography.

1. Introduction

Dry eye disease (DED) is a common condition that causes discomfort and visual distortions, with changes in tear film composition and inflammation of the ocular surface that lead to inflammatory events which negatively affect ocular surface cells [1–3], triggering symptoms such as eye irritation and blurred vision with impacts on quality of life [3–6]. A good balance in tear film production is necessary to fulfil its numerous functions on the ocular surface health [7]. Tears are secreted by the lacrimal gland, and they are subsequently distributed over the ocular surface during the process of blinking, departing from the ocular surface via evaporation and drainage. Tear film volume is one of the key components of tear dynamics [7–9]. Tear meniscus evaluation offers a non-invasive indication of the total volume of the tear film, since it is directly related with the total tear film volume [8–11]. It has been estimated that the tear meniscus holds 75–90% of the total tear film volume [10], although a lower estimate of 27%, has been made [12]. Therefore, parameters as the tear lower meniscus height (TMH) [13–18], radius of curvature (TMR) [19,20], area (TMA) [21–23] or depth (TMD) [22,23] may be important in DED diagnosis [8,13,22,24–27].

Assessment of the TMH by slit-lamp biomicroscope is performed universally by eye care practitioners as part of routine ocular assessments [28,29]; however, it is difficult to measure in real time due to the problem to identify the meniscus limits [30]. Moreover, the subjective evaluation of the meniscus appearance is the most common way to address TMH in clinical settings, being advocated as part of routine ocular assessments [31]. Clinical grading scales have significantly improved the monitoring of

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changes in ocular physiology, proving more stable and sensitive than verbal descriptions [17,32]. However, there is still wide interobserver variability despite their use and a bias towards round numbers. Therefore, objective image analysis techniques have been developed over the past decade to improve the repeatability and reproducibility [33,34].

The software assistance is a resource that is being used for captured image processing [33–35]. Free domain written on java software ImageJ (National Institutes of Health, Bethesda, MD; http://imagej.nih.gov/ij/) [36,37] is a common tool used for diverse applications fully free to everyone. Previous authors had applied this software in tear meniscus parameters analysis on TMR measurements [19,20], TMH measurement on Tearscope images (NI-TMH) [25], or the analysis of the eyelid geometry, position and upper lid tear meniscus depth [38].

The aims of the presented study were: (1) to analyse the interobserver variability of ImageJ on TMH measurement; and (2) to compare the method to an existing grading system. Both studies were carried on a set of images acquired by two different illumination techniques (slit-lamp illumination and Tearscope-Plus), in order to check the possible variability of the procedure protocol.

2. Material and methods

2.1. Subjects and procedure

This study was conducted on 176 subjects with a mean age of 30.07 ± 14.96 years (age range from 18 to 65 years) recruited among patients of the Optometry Clinic of the Optometry Faculty (Universidad de Santiago de Compostela, Spain). Subjects were excluded if they had a history of conjunctival, scleral or corneal disease, prior eye surgery (including refractive surgery or eyelid tattooing), glaucoma, diabetes mellitus, thyroid disorder, were pregnant or breast-feeding, wore contact lenses or had systemic inflammatory/autoimmune disease [20,34,37,39]. No participant was under any type of medication or used artificial tears at the time of the testing session [20,34,37,39]. Table 1 shows age, sex, symptom and common sign profile of subjects who participated in this study [37,40–44]. To avoid the effects of overstating the precision of statistical estimates, only the right eye was examined [45]. To minimize diurnal variation, measurements were taken in the afternoon between 5.00 and 6.00 PM [8,19]. All recordings were made under similar conditions of light, temperature (20–23 °C) and humidity (50–60%).

The procedures followed the Declaration of Helsinki and the protocol was reviewed and approved by the Ethics committee of the Universidad de Santiago de Compostela.

Table 1
Subject demographics and entering habitual symptoms and signs of DED. SD: Standard Deviation; IQR: Interquartile range.

Factor		Value
Sex. n (%)	Male	79 (44.9%)
	Female	97 (55.1%)
Age (Mean ± SD) [years]		31.7 ± 15.3
OSDI score (Median (IQR))		12.5 (6.25–27.08)
McMonnies score (Median (IQR))		7.5 (4–14)
Phenol red (Mean ± SD) [mm]		17.66 ± 6.32
Osmolarity (Mean ± SD) [mOsm/l]		308.7 ± 14.73
Corneal fluorescein Staining (Oxford scale). n (%)	0	134 (76.1%)
	1	23 (13.1%)
	2 or more	19 (10.8%)

2.2. Image acquisition method

Two different acquisition techniques were used for TMH visualization: slit-lamp illumination and Tearscope^{TM} Plus (Keeler, Windsor, UK) [25,46,47]. In all subjects, measurements were always made in the same order: first using the slit-lamp and then the Tearscope instrument ten minutes later. This order was set because of the scarce invasiveness of the slit-lamp technique, where a short light beam with moderate illumination was used to avoid reflex tearing by glaring or heating [17,18,37].

In both protocols, subjects were positioned at the chin rest and instructed to look at a target located to maintain primary eye gaze and lower tear meniscus was observed by a Topcon SL-D4 biomicroscope set at 40×. Subjects were instructed to blink naturally, without squeezing, in order to avoid other factors that could affect the visualization (for example, an excessive lipid component generated by a meibomian gland expression). Meniscus videos were recorded by a Topcon DV-3 digital camera attached to the biomicroscope and stored by a connected computer via Topcon IMAGEnet i-base at a spatial resolution of 1024 × 768 pixels in the RGB colour space.

2.2.1. Meniscus observed with slit-lamp illumination

Tear meniscus was evaluated with the slit-lamp as illumination system (Fig. 1A). To avoid reflex tearing, a short light beam (3 mm wide and 5 mm height) with moderate illumination was used to prevent the light shining directly into the pupil during measurements [17,37]. The settings for video capture were specific, following the procedure previously done [17]. Since the height of the tear meniscus varies along the length of the lower eyelid [17,39], the video was recorded at the centre of the lower lid margin [17,18,37]. Central meniscus was captured at the 6 o'clock position perpendicularly below the pupil centre, with the observation and illumination systems set at 0° and without tilt of the illumination column [17,37,39].

2.2.2. Meniscus observed with Tearscope Plus

Ten minutes later, lower tear meniscus was videotaped with Tearscope [25,46,47] (Fig. 1B), which was fixed to the slit-lamp to keep the distance between the chinrest and the device constant during the imaging capture. During all the recording, the illumination was provided by the Tearscope (the slit-lamp was switched off). This device offers two sets of illumination; in all the cases the brightest one was used because of the better limits definition and therefore visualization (Fig. 1B).

2.3. Tear meniscus image selection

A total of 352 tear meniscus images (from 176 patients) extracted from recorded videos were evaluated, being 2 per subject, one for each acquisition technique used (slit-lamp illumination and Tearscope). In order to avoid interblink variations, in all cases frames were extracted 2–3 s after blinking, when the meniscus was stable with minimal changes and completely expanded [9,19,39].

2.4. Evaluation of tear meniscus parameters

2.4.1. Computer-assisted image analysis: ImageJ

Two masked investigators measured the TMH in the image databases. The computer-assisted image analyses were conducted using a Java-based open source image processing software, ImageJ software v1.49b (National Institutes of Health, Bethesda, MD; http://imagej.nih.gov/ij/) [36,37]. The TMH was marked with the *straight* tool, which allows the user to set a line with a free size and position (Fig. 1). The line was picked in the middle of the