

Influence of Conjunctival Folds on Calculated Tear Meniscus Volume Along the Lower Eyelid



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ABSTRACT Purpose: In calculating tear meniscus volume (TMV), tear meniscus height (TMH), radius (TMR) and cross-sectional area (TMA) are usually measured at the center of the lower lid margin, but lid-parallel conjunctival folds (LIPCOFs) are known to influence the tear meniscus regularity. The aim of this study was to analyze the influence of LIPCOFs on TMA measured by optical coherence tomography (OCT) and consequently, the calculated tear meniscus volume (TMV). **Methods:** Using OCT (Cirrus-HD; Carl Zeiss Meditec, Jena, Germany), the TMH, TMR and TMA in 42 subjects (13M, 29F; mean age 27.3 SD±8.4 years) were measured directly below the pupil center, plus at temporal and nasal locations perpendicularly below the limbus, where LIPCOFs were also evaluated and graded. TMV for the different locations was calculated. Correlations between LIPCOFs and the tear meniscus parameters were analyzed using the Spearman Rank-Order coefficients. Differences between tear meniscus parameters at the different locations were evaluated by the paired t-test. **Results:** Central TMV ($5.30 \pm 1.42 \times 10^{-2} \mu\text{l}/\text{mm}$) was significantly positively correlated to LIPCOF sum (grade 2.4 ± 1.2) ($r=0.422$; $P<.05$). The

calculated temporal TMV was greater by $0.53 \times 10^{-2} \mu\text{l}/\text{mm}$ compared to the central TMV ($P=.037$), while there was no significant difference in tear volume between the other locations. **Conclusions:** Using OCT it was possible to investigate the influence of LIPCOFs on TMH, TMR, and for the first time on TMA, at central and paracentral positions along the lower lid margin. The presence of LIPCOF results in an irregularity of tear meniscus with a difference in the amount of predicted tear volume while measuring TMH or TMR at the different locations.

KEY WORDS conjunctival folds, LIPCOFs, optical coherence tomography, tear meniscus, tear volume

I. INTRODUCTION

The tear fluid on the ocular surface is present in three sections: at the exposed area between the lids covering the cornea and sclera, in the tear menisci at the lid margins, and in the conjunctival sacs of the upper and lower lid.¹ The tear menisci along the superior and inferior lid margins represent 75% to 90% of the tear film volume at the ocular surface,² although a lower estimate of 27% has been made.¹ The shape of the lower central meniscus is described to be roughly wedge-shaped in sagittal section, with a concave anterior surface, and posterior and peripheral surfaces that bathe and moisten the hydrophilic mucosae of the cornea and bulbar conjunctiva or palpebral conjunctiva.³ However, the cross-sectional profile of the meniscus is likely to have a more complex shape,³ with a parabolic anterior profile⁴ and a posterior surface that is influenced by the shape of the underlying conjunctiva at the paracentral lid locations.⁵

At the central lid location, the evaluation of tear meniscus parameters is regarded as an indicator of tear film volume.^{6,7} The tear meniscus can be characterized by tear meniscus height (TMH), tear meniscus radius (TMR) or cross-sectional tear meniscus area (TMA), and these have been shown to be significantly correlated to one another at the central point of the tear meniscus.⁸⁻¹¹ For paracentral positions along the lower eyelid, however, the

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OUTLINE

- I. Introduction
- II. Materials and Methods
 - A. Subjects
 - B. Instrumentation and Procedures
 - C. Lower Tear Meniscus Volume Calculation
 - D. Statistical Methods
- III. Results
 - A. Differences between Tear Meniscus Parameters with Location
 - B. Correlations between LIPCOFs and Tear Meniscus Parameters
 - C. Calculated Tear Meniscus Volume at the Different Locations
- IV. Discussion
- V. Conclusion

relationship between meniscus height, radius, and cross-sectional area has not yet been published.

The volume of the tear meniscus (TMV) has traditionally been calculated from TMH, TMR or TMA of the central lower tear meniscus multiplied by the length of the lid margin.^{12,13} Since the meniscus is spread along the eyelid margins, variations in the measured meniscus parameters along the lid are likely to influence the calculation of the lower lid tear meniscus volume. Lid parallel conjunctival folds (LIPCOFs) are folds in the inferotemporal and inferonasal quadrants of the bulbar conjunctiva, parallel to the lower lid margin. LIPCOFs can be observed with the slit lamp or by optical coherence tomography (OCT), and they have been found to correlate with dry eye symptoms.^{5,14-19} Like conjunctivochalasis, LIPCOFs are assumed to alter the measurement of the tear meniscus area.^{16,18,20,21}

Using a portable digital meniscometer (PDM), it was shown that an increase in LIPCOF grade is associated with a higher TMH and a larger TMR at the nasal and temporal locations of the tear meniscus.²² Furthermore, it was suggested that LIPCOFs also impact the central TMH evaluation, and that the presence of LIPCOFs may cause the central TMH measurement to overestimate the actual central tear meniscus volume.²³ However, TMH and TMR measurements are limited to one dimension and describe only the anterior

surface of the tear meniscus; they do not account for the posterior section of the meniscus, so the extent of the LIPCOFs is likely to influence the cross-sectional TMA.

Consequently, the aims of this study were: 1) to investigate the influence of LIPCOFs on TMH, TMR and on TMA, measured by OCT at the central and paracentral position of the lower lid, and 2) to analyze the influence of LIPCOFs on the calculated tear meniscus volume at the different locations.

II. MATERIALS AND METHODS**A. Subjects**

Forty-two subjects (13 male, 29 female) were randomly selected from the staff and students of the Höhere Fachschule für Augenoptik Köln (Cologne School of Optometry), Cologne, Germany. The mean age of the subjects was 27.3 ± 8.4 (SD) years (range, 20-67 years). Subjects were excluded if they were pregnant or breast-feeding; had a current or previous condition known to affect the ocular surface or tear film; had a history of previous ocular surgery, including refractive surgery, eyelid tattooing, eyelid surgery, or corneal surgery; had any previous ocular trauma; were diabetic; were taking medication known to affect the ocular surface and/or tear film; and/or had worn contact lenses during the preceding two weeks prior to the study.

All subjects gave written, informed consent before participating in the study. All procedures obtained the approval of the Cardiff School of Optometry and Vision Sciences Human Ethics Committee and were conducted in accordance with the requirements of the Declaration of Helsinki.

B. Instrumentation and Procedures

OCT images of the lower tear meniscus were obtained during a single session using the Cirrus HD-OCT (Carl Zeiss Meditec, Jena, Germany). This instrument uses spectral domain OCT (SD-OCT), with a wavelength of 840 nm to achieve an axial resolution of 5 μm . The cross-sectional images of the tear meniscus in this study were taken using five vertically oriented raster lines directly below the pupil centre, plus temporally and nasally tangential below the limbus at the same locations where LIPCOFs are present (Figure 1). In this mode, five parallel vertical lines of 3 mm-length and a line distance of 0.25 mm were scanned; each line was composed of 4096 A-scans.

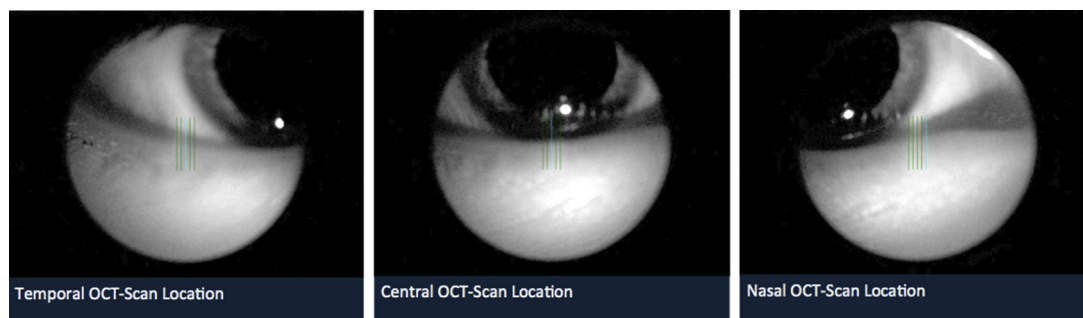


Figure 1. Anterior segment 5 lines raster of the Cirrus HD-OCT, showing the observer's view and the alignment targets at the three locations along the lower lid.

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