Measurement of Tear Meniscus Height with the Kowa DR-1α Tear Interferometer

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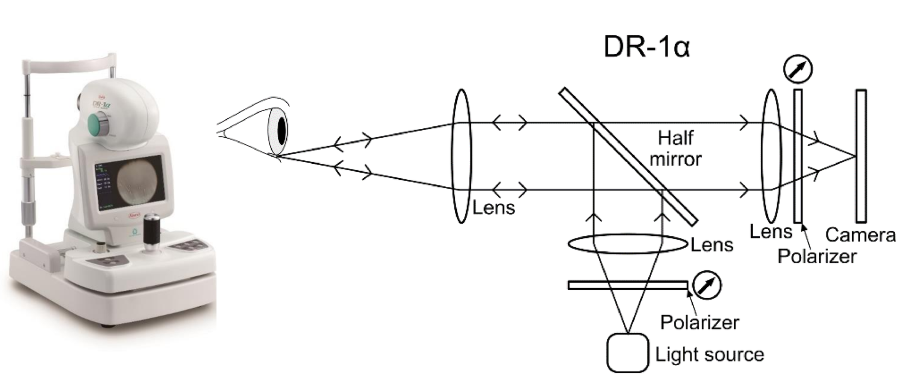
Introduction

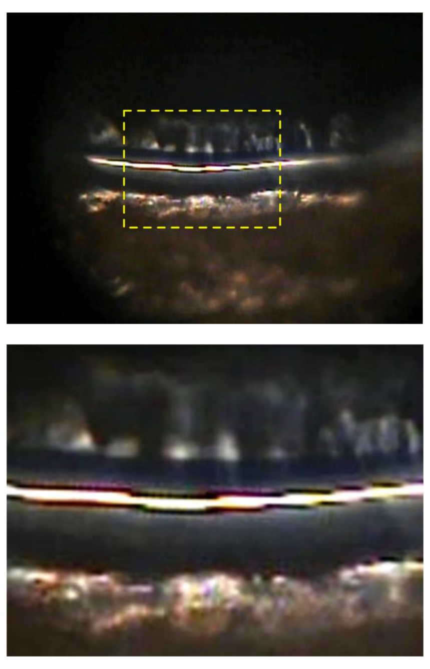
- Dry eye disease (DED) is a global clinical problem, with a reported prevalence of 5% to 50% among adults and afflicting >30 million people in the United States alone.
- Dry eye is a multifactorial disease of the ocular surface characterized by a loss of homeostasis of the tear.[1] We previously showed that aqueous and lipid layers of the tear film each compensate for deficiencies in the other in an attempt to maintain homeostasis of the tear film.[2, 3]
- Evaluation of DED thus requires examination of both lipid and aqueous layers of the tear film.
- Measurement of tear meniscus height (TMH) has proved informative for DED diagnosis,[4] showing a relatively high sensitivity and specificity in this regard. Several methods have been applied to measurement of TMH[5] including those based on the use of a graticule,fluorescein staining, reflective meniscometry,[6] the TearScope Plus instrument,[7] optical coherence tomography (OCT),[8-12] or the Keratograph 5M instrument (OculusOptikgerate GmbH, Wetzlar, Germany). TMH measurement by OCT has been described as reliable for diagnosis of DED with high sensitivity and specificity.[11, 13]
- The DR-1α tear interferometer (Kowa, Aichi, Japan) allows evaluation of the lipid layer of the tear film .
- The previous report [14] developed the original software to evaluate tear meniscus volume using DR-1 tear interferometry.
- The purpose of the present study was to develop a method for quantitation of TMH with the DR-1α instrument automatically based on the histogram of brightness, to compare intraoperator repeatability as well as interoperator and intesession reproducibility of TMH measurement with newly developed software for DR-1α and by anterior-segment swept-source OCT (CASIA 2 instrument; Tomey, Aichi, Japan), and to assess the agreement between the two devices.

Methods

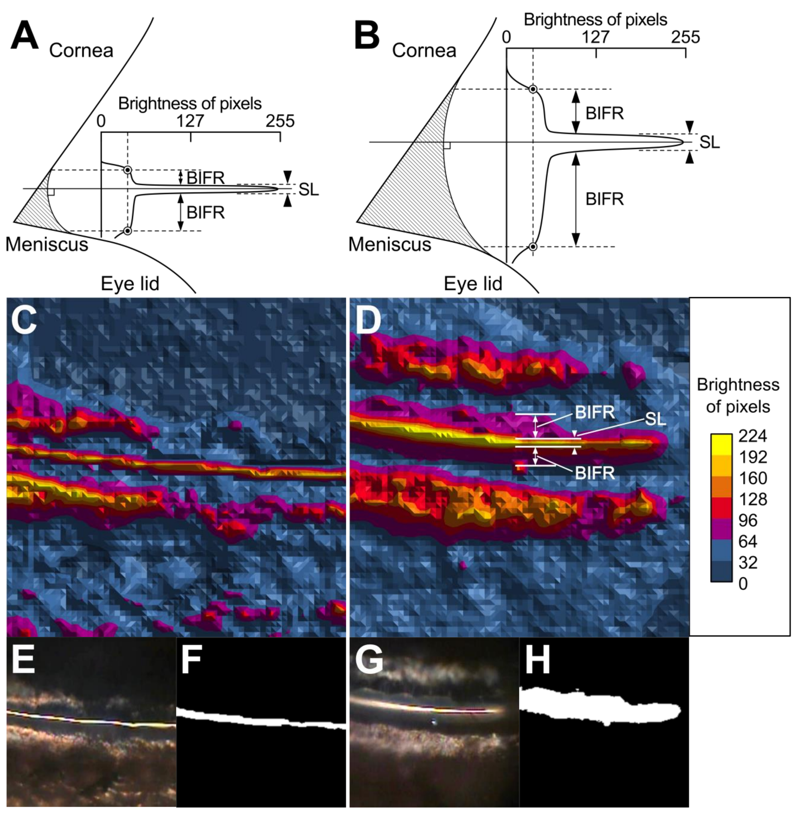
- New grading system
  We developed software to measure interferometric TMH based on the brightness histogram of the tear meniscus obtained with DR-1α.
- Validation test
  TMH of 27 eyes of 27 healthy subjects was measured with DR-1α and by anterior segment swept-source optical coherence tomography (SS-OCT, CASIA2). Measurements were made four times by each of two observers. Intraoperator repeatability and interoperator and intersession reproducibility were assessed based on the within-subject standard deviation (Sw), coefficient of variation (CoV), and intraclass correlation coefficient (ICC), respectively. Agreement between both devices was also determined in Bland- Altman plots. Correlations between tearfilm parameters were analyzed.



Interferometric fringe images of the lower tear meniscus are captured by DR-1α for measurement of meniscus height. Two parallel polarizers are installed to enhance the sharpness of the interferometric fringe colors and to reduce contamination by unintended reflected light from the lens system.



An interferometric fringe image of the lower tear meniscus obtained with DR-1α is shown in the upper panel, the dashed box of which is shown at higher magnification in the lower panel.



(**A**, **B**) Intensity brightness patterns for pixels derived from interferometric images of the tear meniscus. BIFR, brighter interferometric fringe region; SL, specular line. (**C**, **D**) Color maps of interferometric fringe images. (**E**, **G**) Original interferometric fringe images of the tear meniscus. (**F**, **H**) Binarized interferometric fringe images. Panels (A), (C), (E), and (F) and panels (B), (D), (G), and (H) correspond to eyes with a smaller and larger tear volume, respectively.

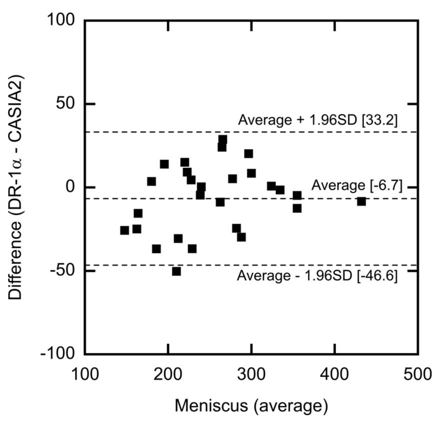
Mean lower tear meniscus height measurements

	DR-1α, Mean +/- SD, um	CASIA2, mean+/-SD, um
Observer 1		
First image	247.9+/-67.2	252.2+/-68.2
Second image	251.3+/-69.5	258.6+/-67.7
Observer 2		
First image	256.5+/-68.3	262.3+/-64.3
Second image	257.4+/-75.3	258.9+/-65.6
First image second session	241.7+/-77.7	249.3+/-73.9
Second image, second session	252.8+/-79.7	266.3+/-68.3
	251.3+/-73.0	256.0+/-68.1

Interoperator and intersession reproducibility of lower tear meniscus height measurements

	Mean ± SD (μm)	Sw (μm)	2.77Sw (μm)	CV (%)	ICC (95% CI)
Interoperator reproducibility					
DR-1α					
First image	248.7 ± 71.2	2.9	8.0	0.5	0.94 (0.92–0.96)
Second image	253.8 ± 74.8	3.5	9.8	0.6	0.92 (0.88–0.94)
CASIA 2					
First image	247.2 ± 70.3	4.1	11.5	0.7	0.99 (0.99–1.00)
Second image	246.9 ± 70.6	3.8	10.6	0.6	0.99 (0.99–1.00)
Intersession reproducibility					
DR-1α					
First session	254.3 ± 70.6	3.5	9.7	0.5	0.89 (0.85–0.93)
Second session	248.0 ± 75.7	3.1	8.6	0.5	0.87 (0.82–0.91)
CASIA 2					
First session	248.7 ± 69.4	6.1	17.0	1.0	0.99 (0.99–1.00)
Second session	248.7 ± 69.4	5.4	14.9	0.8	0.99 (0.99–1.00)

Bland-Altman Plot



A Bland-Altman plot also revealed excellent agreement between the two devices, with the mean difference between the measurements obtained with the two instruments being 6.7 μm.

Spearman's rank correlation coefficient (ρ) and *P* values for the relation between characteristics

		Age	DEQS	BUT	Schirmer's test value	Lid margin abnormalities	Meibum expression
DEQS	ρ	0.168					
	p	0.40					
BUT	ρ	-0.268	-0.214				
	p	0.18	0.28				
Schirmer's test value	ρ	-0.098	0.267	0.419			
	p	0.63	0.18	0.030*			
Lid margin abnormalities	ρ	0.464	0.130	-0.100	-0.014		
	p	0.015*	0.52	0.62	0.94		
Meibum expression	ρ	0.559	0.029	-0.092	-0.048	0.320	
	p	0.003*	0.89	0.65	0.81	0.10	
TMH with DR1α	ρ	-0.128	0.260	0.338	0.852	-0.211	-0.146
	p	0.53	0.19	0.085	<0.001*	0.29	0.47

Discussion

- We applied tear interferometry to the evaluation of TMH.Our new approach to measurement of THM by tear interferometry is based on the interferometric reflection pattern and intensity histogram and is automated. The measurement of interferometric TMH is thus highly repeatable and can be performed by trained nonphysician medical staff.
- We previously showed that tear interferometry with DR-1α allows evaluation of the balance between the aqueous and lipid layers of the tear film. We found that the amounts of these two layers change in a reciprocal manner in response to disturbances, suggesting that tear film components compensate for each other in order to maintain an appropriate balance
- Limitations of the present study include the small number of subjects. Establishment of a reliable procedure for interferometry-based measurement of TMH will require the performance of multicenter studies with larger numbers of subjects

Conclusion

Tear interferometry with DR-1α allows measurement of TMH as reliably as SS-OCT. DR-1α may therefore inform not only the diagnosis of dry eye disease but also identification of disease subtype.

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