Ocular surface analysis: A comparison between the LipiView® II and IDRA®

Article *in* European Journal of Ophthalmology · December 2020

DOI: 10.1177/1120672120969035

1 author:

Kyung Min Koh
Kim's Eye Hospital
20 PUBLICATIONS **73** CITATIONS

SEE PROFILE

Original research article

EJO European Journal of Ophthalmology

European Journal of Ophthalmology
1–7

DOI: 10.1177/1120672120969035
journals.sagepub.com/home/ejo
SAGE

Ocular surface analysis: A comparison between the LipiView® II and IDRA®

Jeong Min Lee, Young Joon Jeon, Kook Young Kim, Kyu-Yeon Hwang, Young-A Kwon and Kyungmin Koh

Abstract

Purpose: To compare the lipid layer thickness (LLT), meibomian gland (MG) dropouts, and blinking pattern determined by the analysis of images acquired from the LipiView® II (LVII) and the IDRA® Ocular surface analyzer.

Methods: A cross-sectional single-visit observational study was conducted. The LLT (minimum, maximum, and average), percentages of MG dropouts, and partial blink rates (PBR) were taken from both eyes of 47 participants using LVII and IDRA. Both devices were used to image the inferior eyelid of each participant in a random order.

Results: Forty-seven participants (mean age 56.77 ± 14.47 (21–79) years, 66% female) completed the study. There was no significant difference in LLT between the two devices. A significant difference in percentages of MG dropouts was obtained between the LVII (36.51 ± 17.53) and the IDRA (45.36 ± 21.87), $p = 0.003$). There was also a significant difference in PBR between the LVII (0.51 ± 0.37) and the IDRA (0.23 ± 0.27), $p < 0.001$).

Conclusion: No significant difference in LLT was obtained between LVII and IDRA. IDRA had a significantly lesser percentage of MG dropout and a higher PBR compared to LVII. These results indicate that these devices should not be used interchangeably for the evaluation of MG dropouts and PBR.

Keywords

Diseases of the ocular surface, eyelid disease, lid inflammation affecting the ocular surface, Tear deficiency states

Date received: 8 July 2020; accepted: 5 October 2020

Introduction

A tear film is composed of three layers of lipid, aqueous, and mucin. The lipid layer, the external layer of the tear film, is an oily secretion formed in the meibomian glands (MG).[1] MG dysfunction (MGD) is categorized by insufficient MG secretions, dry eye symptoms, and fluorescein staining of the cornea attributable to a chronic, diffuse abnormality of the MG.[2] Tear lipids secreted from the MGs are an essential part in keeping the stability of the tear film.[3] MGD is a major cause of evaporative dry eye, which is more frequent than aqueous-deficient dry eye.[4] The evaluation of both the function and morphology of MG is also essential to the diagnosis of MGD.[5] Non-invasive meibography with infrared illumination can detect the morphological alterations of MG, whereas tear interferometry permits assessments of the lipid layer of the tear film. Such assessments of MG morphology provide clinical evidence that contribute to the diagnosis of evaporative dry eye, whereas that of the lipid layer of the tear film allow the monitoring of MG function.[6] One study showed that patients with dry eye diseases (DED) have thinner lipid layer thickness (LLT), and that 74% of patients with serious DED had LLT ⩽ 60 nm, while 72% of patients without DED had an LLT ⩾ 75 nm.[7] Therefore, preserving the stability of the tear film lipid layer is critical for decreasing evaporation and improving the symptoms of DED.[8]

Various instruments are now being applied at dry eye clinics to better evaluate DED.[9] LipiView® II ocular surface interferometer (TearScience Inc, Morrisville, NC, USA) (LVII), launched in 2011, provides a LLT using

Department of Ophthalmology, Kim's Eye Hospital, Konyang University College of Medicine, Seoul, South Korea

Corresponding author:
Kyungmin Koh, Department of Ophthalmology, Kim's Eye Hospital, Konyang University College of Medicine, 136 Youngshinro, Youngdeungpo-gu, Seoul 07301, Republic of Korea.
Email: kmkoh@kimeye.com

color interference patterns and a partial blink rate (PBR), and also uses an infrared light source for imaging the MG. Similar to the LVII, Oculus® Keratograph 5M (Oculus®, Arlington, WA, USA) has recently introduced. It is also a non-invasive device that provides datas about tear film and MG dropout through an infrared light source.[10] Studies on the comparison of the MG dropout and correlations between ocular parameters from these two latest devices were reported in 2018 and 2019.[10,11] However, no studies have been reported so far comparing LVII and IDRA® Ocular surface analyzer (SBM SISTEMI, Inc., Torino, Italy) (IDRA), which was released in 2018. This study therefore aims to compare the LLT, MG dropouts, and blinking pattern in the lower eyelid established by analysis of images acquired from the LVII and the IDRA, to judge whether the devices can be used interchangeably in the same clinical setting.

Materials and method

A cross-sectional single-visit observational study was conducted at the dry eye clinic of Kim's Eye Hospital, Seoul, South Korea from April 2020 to June 2020. This study was approved by The Institutional Review Board (IRB) of Kim's Eye Hospital in Seoul, South Korea (IRB number: 2020-06-001). All procedures adhered to the Declaration of Helsinki. Informed consent was taken from all participants before enrollment in the study. A single cornea specialist had diagnosed all subjects included with DED on the basis of the DEWS II criteria, with standard patient evaluation of eye dryness (SPEED) $\geqslant$ 6 points and Tear break-up time (TBUT) $<$ 10 sec.[12] Patients were excluded from study if they were under 18 years of age, were diagnosed with supra-nuclear motor weakness having an effect on movements of eyelid, had ptosis, had a rheumatologic disease including Sjögren syndrome, previous eye infection, and contact lens usage.

Dry eye questionnaire

A single cornea specialist had diagnosed all patients included with DED on the basis of the DEWS II criteria, with standard patient evaluation of eye dryness (SPEED) $\geqslant$ 6 points and Tear break-up time (TBUT) $<$ 10 seconds.[12] DED symptoms were evaluated according to the SPEED validated questionnaire (0–28).[13,14] A previous study showed that the SPEED questionnaire was compatible to the Ocular Surface Disease Index (OSDI).[15]

Interferometric assessment of lipid layer thickness

The order of the LVII and the IDRA® was randomized for each participant. Measurements were acquired from both eyes and the order of eyes were equally random. To reduce bias from patient exhaustion, measurements of these two devices were obtained with a 10-min interval.

The LVII is a non-invasive instrument that takes live digital images of the tear film, measures its lipid component, and calculates blink dynamics.[16] The LVII assesses lipid layer thickness using an Interference Color Unit (ICU) score (usual average $\geqslant$ 75). The absolute thickness of the LLT was determined by the LVII by analyzing more than 1 billion data points of the interferometric image. Patients were requested to look into a camera with blinking freely for a 20-sec video record. The participants were also requested not to contact their eyes throughout the imaging. For each measurement, participants were instructed to rest their heads on the chinrest. The interferometer was operated for its maximum filming time and the video was instantly analyzed for LLT in nanometers based on ICUs. The interferometer offers a non-invasive technique for the estimation of LLT. The area measured over the cornea, approximately 1 mm above the inferior tear meniscus and slightly under the inferior pupillary margin, was automatically established and also manually focused with interface controls. The extent of the measurement area was restricted to about 2.5 mm vertically and 5.0 mm horizontally.[17] Illumination over the lower third of the cornea, projected from LVII made a color interference pattern as a result of the specular reflection at the lipid-aqueous border.[18] The detected color is related to the LLT and is shown as ICU, which are equivalent to nanometers, by the instrument. The average, maximum and minimum LLT were documented for each participant.[17] An index C-factor verify the stability of LLT measurements. Results with C-factor $<$ 80% were excluded.[18]

IDRA is the novel device for the specific evaluation of tear film that permits a rapid detailed structural analysis of the tear components. The device can analyze all the layers of the tear film (lipid, aqueous, and mucin) and MG, which allows clinicians to determine which components should be treated according to the type of insufficiency. IDRA performs a non-invasive test for about 5 min. IDRA must be incorporated between a slit lamp and biomicroscope. Its pins have been built to fit completely into the hole that can be found when the plate used for the tonometer is eliminated. The participants sat comfortably using the chin holder and then were asked to look at the camera with natural blinking of their eyes. Videos can be recorded for a few seconds and the recording time can be adjusted according to the convenience of the clinician. In this study, it was recorded for 20-sec to proceed with the same time as the LVII. The device projects white light over the cornea and the light reflected from the tear film can be observed as a white fan-shaped area that covers the lower third of cornea. The automatic interferometry test of IDRA detects the interference of colors from the lipid layer on the tear film. It determines the average, maximum, and minimum LLT using the international grade scale of Dr. Guillon

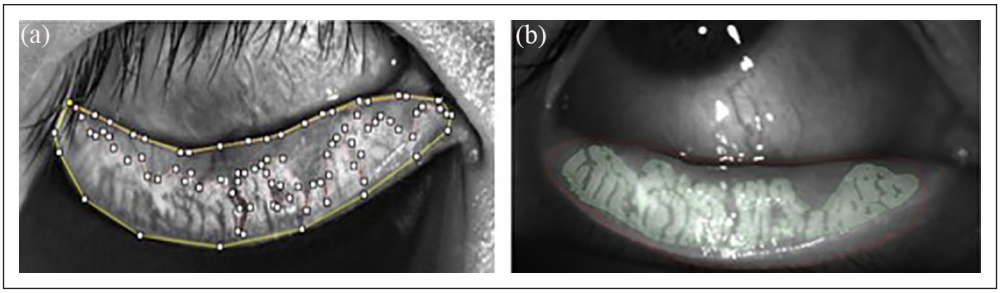

Figure 1. LipiView® II and IDRA® images about meibomian gland (MG) loss of 40 years old male patient. The lower eyelids were turned over and MGs were observed using an infrared transmitting filter, meibomian glands are apparent as areas of high reflectivity: (a) an image taken with the LipiView® II shows MG dropout. The free-hand tool in ImageJ was used to measure the amount (35%) of gland dropout with an image taken with the LipiView® II and (b) an image of the same subject taken with the IDRA® shows MG dropout. IDRA® automatically calculates the dropout rate of MGs, and this patient came out at 45%. As IDRA® calculates the remaining part of meibomian glands, so to subtract the dropout ratio, it was written as the value subtracted from 100.

with the thicknesses related to each grade of lipid layer pattern.[19,20] Depending on the patterns, the grades were converted to nanometers and could be classified between 15 nm and 100 nm. Both the LVII and IDRA have an upper cut-off of 100 nm.[12]

MG dropout measurement

IDRA calculates MG dropout rate in the resulting item. In contrast, the LVII only produces results on the image, so we used the ImageJ software (http://imagej.nih.gov/ij/; offered in the public domain by the National Institutes of Health, Bethesda, MD, USA) to quantify the amount of MG dropout with LVII (Figure 1(a)). A single-masked observer used ImageJ to analyze the images and graded the rate of dropout in the MGs on different day.[21] The dropout rate is calculated in the percentage by dividing the non-glandular zone by the total visible area of the lower lid.[22]

Blinking pattern measurement

LVII and the IDRA automatically detect and analyze blink rate and blinking quality through the videos recorded. They display the number of full and partial blinks and blink frequency numerically. This analysis also noted the data on the complete blinking rate and the incomplete blinking rate. The single investigator handled the LVII and IDRA throughout the study.[23]

NIBUT and TMH

IDRA can determine non-invasive break-up time (NIBUT) by using the projected ring patterns from a Placido's disc onto the cornea. The NIBUT evaluates the stability of the tear film, by measuring the time from the full blink to the presence of the first disruption of the reflected image on the cornea in seconds. So, participants were required to blink twice by the investigator and then stay their eyes open for as long as they could, without feeling uncomfortable, to reduce reflex tearing. The IDRA allows the clinician to select between manual and auto-NIBUT.

IDRA can also measure tear meniscus height (TMH). TMH can be taken in a non-invasive way in a flash by taking a photo for measurement. The device can detect the upper and lower tear meniscus and evaluate the tear meniscus height along the lower lid margin in the photo.

Statistical analysis

Data was analyzed with IBM Statistical Package for the Social Sciences (SPSS) version 22 (Chicago, USA) and statistical significance was established at $p < 0.05$. Continuous data was presented as means ± Standard deviation (SD). The t-test was used for the comparison of each parameter. A Bland-Altman plot was used for evaluating agreement and confidence interval. Agreement of the various parameters by the two devices was assessed using the method described by Bland and Altman.[24] An estimate of the mean bias, as measured by the mean of the paired differences between the two devices, was taken. The t test was performed to test if the mean bias significantly differed from zero. The 95% limits of agreement (LOA) (mean difference ± 1.96 standard deviation), which define the range within which most differences between measurements by the two devices will lie, also were computed.

Results

Sixty subjects were recruited. Among them, three participants were left out because of low LLT signal (C-factor < 80%). Ten participants with LLT ⩾ 100 nm were also left out because this could not be precisely calculated. Forty-seven subjects (94 eyes, mean age = 56.77 ± 14.47 (21–79) years, and 66% were women) completed the study (Table 1). Looking at the clinical DE parameter of the participants, the average SPEED score was 12.26 ± 5.29 points, the average NIBUT measured by IDRA was 10.22 ± 4.23 sec, and the TMH was 0.16 ± 0.06 nm (Table 1).

The results of comparison between LVII and IDRA are summarized in Table 2. No statistically significant difference in average, maximum, and minimum LLT was obtained between LVII and IDRA. A significant difference in MG dropout rate (mean ± SD) was calculated between the LVII (36.51 ± 17.53) and the IDRA (45.36 ± 21.87), $p = 0.003$). A significant difference in PBR (mean ± SD) was equally calculated between the LVII (0.51 ± 0.37) and the IDRA (0.23 ± 0.27), $p < 0.001$). Although good agreement was found for LLT by Bland–Altman plots. But MG dropout rate measurement by IDRA and PBR measurement by LVII were consistently larger by Bland–Altman plots (Figure 2).

Discussion

The IDRA is possible to measure LLT through the auto-interferometry and also measure tear meniscus height, auto-NIBUT, blinking quality and meibography, as well as the bulbar redness classification. Especially, since we have been waiting for the appearance of an automated objective measurement of TBUT,[25] the launch of IDRA will helps clinicians to diagnose the DED.

Table 1. Clinical characteristics of non-Sjögren dry eye patients.

Variable	Value
Age, years	56.77 ± 14.47 (21~79)
Sex	
Male	16 (34%)
Female	31 (66%)
Clinical dry eye parameters	
SPEED score	12.26 ± 5.29
NIBUT, seconds	10.22 ± 4.23
TMH, mm	0.16 ± 0.06

Data are presented as the mean ± standard deviation. SPEED, standard patient evaluation of eye dryness validated questionnaire (0–28). NIBUT and TMH were measured by IDRA® Ocular surface analyzer. NIBUT: non-invasive break-up time; TMH: tear meniscus height.

Previous studies have shown that the volume of lipid layer is correlated to the number and function of MGs.[26] The LLT and the incomplete blinking ratio are significantly related to DED symptoms.[18] When comparing the LVII with the IDRA for LLT, the field of the white light projected to cause interference of colors is directed at the lower third of the cornea, approximately 1 mm above the inferior tear meniscus in LVII[12], while it is directed a little higher, approximately 2 mm above the inferior tear meniscus in IDRA (Figure 3). Therefore, considering that the lipid layer of the tear film accumulates downwards under the influence of gravity, we had expected LLT in LVII to be a little thicker than IDRA. However, in this study, it was found that there was no statistically significant difference between the average, maximum, and minimum LLT determined by both devices. Because the two devices analyze the thickness of lipid layer in a similar way by using the principles of interferometry, which analyzes the color interference pattern generated by projecting white lights on tear film, they could not show any significant differences. In a study by Markouli and colleagues comparing the techniques of LVII and the Keeler Tearscope-Plus™ (Keeler, Windsor, UK), the measurements of average and minimum LLT from the LVII were remarkably thinner than the corresponding grades assigned in the Keeler Tearscope-Plus™. They supposed that one of the reasons for this difference between the two devices was the upper cut-off built in LVII measurements.[10] The upper cut-off for measurements of LLT from the LVII is 100 nm and the IDRA has this same upper limit. This may artificially decrease the average of LLT and make them similar. The lipid layer has proved to be especially changeable, depending on elements such as the blink rate and palpebral aperture,[27] and this is indicated by the large SDs for each variable between devices.

Significant differences existed between the two devices in detecting MG dropout. The percentage of MG dropout (%) was measured at 36.51 ± 17.53 in the LVII and 45.36 ± 21.87 in the IDRA respectively ($p = 0.003$), hence MG dropout in the LVII was found to be significantly lower

Table 2. Comparision of parameters by LipiView® II and IDRA®.

	LipiView® II	IDRA®	*p*-value
Average LLT, nm	77.89 ± 24.29	75.39 ± 13.01	0.383
Maximum LLT, nm	87.88 ± 18.06	84.48 ± 13.14	0.143
Minimum LLT, nm	61.87 ± 26.31	66.68 ± 15.01	0.128
Meibomian gland dropout, %	36.51 ± 17.53	45.36 ± 21.87	0.003*
Number of incomplete blinks	2.66 ± 2.63	1.63 ± 2.29	0.005*
Number of complete blinks	2.47 ± 2.49	4.27 ± 2.16	<0.001*
Number of total blinks	5.13 ± 2.93	5.89 ± 2.88	0.074
Partial blink rate, %	0.51 ± 0.37	0.23 ± 0.27	<0.001*

Student *t*-test was used for data analysis.
*Asterisks indicate statistically significant association ($p < 0.05$).
Data are presented as the mean ± standard deviation.
LLT: lipid layer thickness. Number of incomplete blinks, number of incomplete blinks per 20 s. Number of complete blinks, number of total blinks minus incomplete blinks. Number of total blinks, number of total blinks per 20 s.

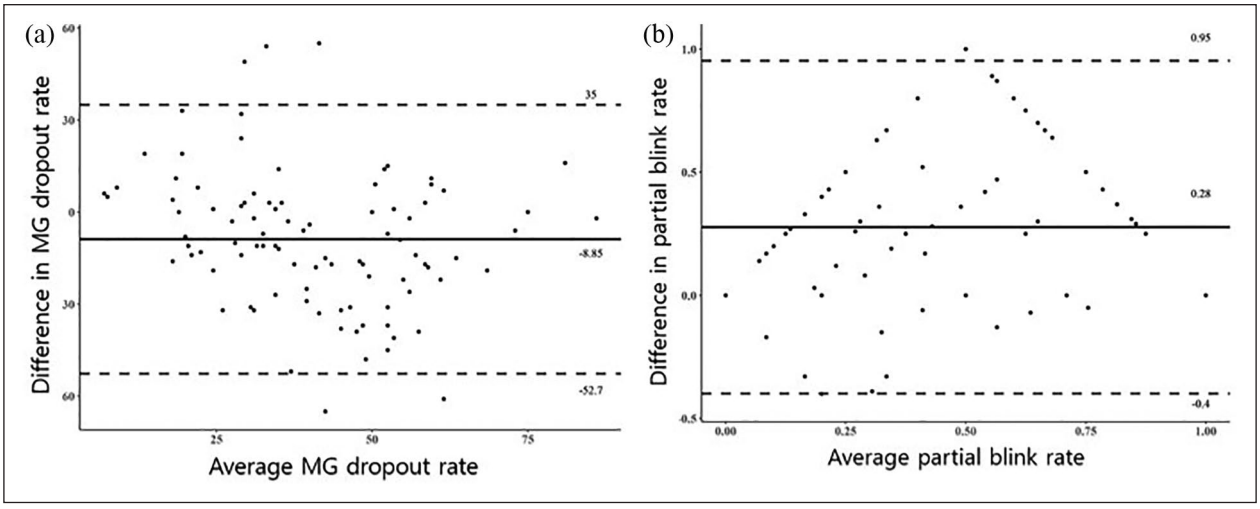

Figure 2. Bland–Altman agreement plots showing the agreement of demarcation line depth measurements between raters in pairs: (a) Bland–Altman plot of the mean difference of the meibomian glands (MG) dropout rate measured by LipiView® II and IDRA®. The mean difference of the MG) dropout rate obtained was –8.85 ± 22.37% (standard deviation) (95% confidence interval, –13.43 to –4.26; $p < 0.001$). The graph shows the 95% limits of agreement to be between –52.72 and 35.03, indicating that there was a greater proportion of larger measurements by IDRA® and (b) Bland–Altman plot of the mean difference of the partial blink rate measured by LipiView® II and IDRA®. The mean difference of the partial blink rate obtained was 0.28 ± 0.34 (standard deviation) (95% confidence interval, 0.21–0.35; $p < 0.001$). The graph shows the 95% limits of agreement to be between –0.4 and 0.95, indicating that there was a greater proportion of larger measurements by LipiView® II.

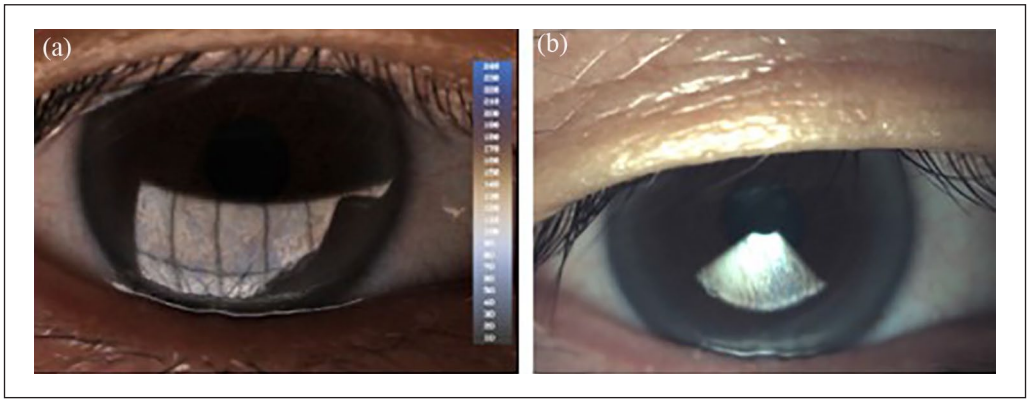

Figure 3. LipiView® II and IDRA® images about lipid layer thickness (LLT) of 58 years old male patient: (a) an image taken with the LipiView® II shows a better view of the full extent of the lid and improved contrast of the glands against the darker background of the eyelid. In this patient, the LLT values were measured by LipiView® II as follows: average 91 nm, maximum 100 nm, and minimum 46 nm and (b) an image of the same subject taken with the IDRA® shows a small visible area of the central lid. In this patient, the LLT values were measured by IDRA® as follows: average 68 nm, maximum 85 nm, and minimum 58 nm.

than in the IDRA. Figure 1 shows that the LVII has a more vivid image through black-and-white contrast and exposes a slightly wider field of eyelids turned over. Therefore, even if the same range of MGs are detected, it can be proven that the percentage of MG dropout is estimated lower in the LVII. Such differences in the same participants may be due to differences between the instruments everting the eyelids. The IDRA uses a simple plastic everter, while the LVII uses a light-emitting lid everter and adheres more to the lower lid. Moreover, in Figure 1, the surface lighting of the lid in LVII is less than that in IDRA, thus the shape of MGs becomes clearer. This is due to Dual-mode dynamic meibomian imaging (DMI) built in the LVII. The LVII recognizes alterations of the light intensity across the surface and compensates for the variations of lid thickness between participants through the illumination attached to the lid everter. This is called adaptive transillumination. This transillumination also forms shadows on areas where MGs are located and thus any glands below the visible exterior or at suboptimal positions may be seen with the illumination. In addition, surface lighting, which is called dynamic illumination originates from two sources, taking various images and merging them into a particularly glare-reduced image. Dual-mode DMI can maximize the image of MG structure

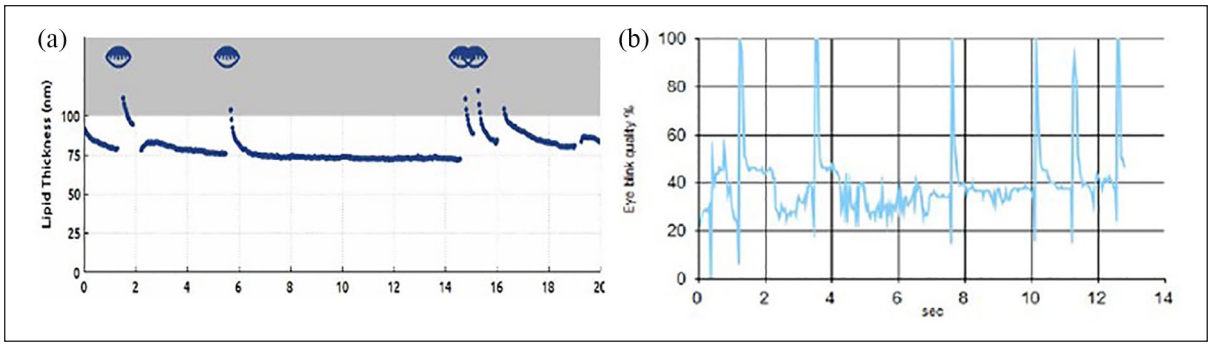

Figure 4. LipiView® II and IDRA® images about blinking pattern of 72 years old female patient: (a) an image taken with the LipiView® II shows a partial blink four times per 20 s, total blink seven times per 20 s, and partial/total blink ratio 0.57 and (b) an image of the same subject taken with the IDRA® shows a partial blink two times per 20 s, total blink seven times per 20 s, and partial/total blink ratio 0.29.

through the combination of adaptive transillumination and dynamic illumination. Therefore, compared to the IDRA which provides a traditional meibography, LVII expresses a clearer image of MG, and it is believed that the missing glands could be reduced. Finally, image processing methodology (imageJ analysis of LVII and automated system of IDRA) could be the cause of MG dropout difference in LVII and IDRA.

Many aspects such as ocular surface disorders, environmental conditions, psychological status, and systemic diseases may affect the blinking rate.[28] Blinking serves a vital function in preserving moisture and unity of ocular surface, production of the lipid layer, and extending of tear lipids.[29] An inadequate lipid distribution, which may increase evaporation can occur with a rise in incomplete blinking.[18] Comparing the detection of blinks, there was no significant difference in the count of total blinks in a 20-seconds inspection between the two devices. However, when comparing the number of incomplete blinks, the LVII showed 2.66 ± 2.63 and the IDRA showed 1.63 ± 2.29 incomplete blinks per 20-seconds ($p = 0.005$). In addition, the number of complete blinks also showed significant differences in LVII with 2.47 ± 2.49 and IDRA with 4.27 ± 2.16 complete blinks per 20-sec ($p < 0.001$). Therefore, the PBR (%) was also significantly higher in the LVII of 0.51 ± 0.37 than the IDRA of 0.23 ± 0.27 ($p < 0.001$). Such blinking differences between the two devices were not expected because participants were asked to blink freely, the same investigator controlled them throughout the study and the order of the examinations was randomized for each participant. Each stage in the blinking cycle was measured and recorded during the examination on both devices (Figure 4), and the partial blinks were defined as blinks without touching the upper and lower eyelids.[30] Nevertheless, considering the etiology of this difference; the difference in the intensity of the white light being projected during recording the video may lead to a difference in blink pattern, and even if there is little change in illumination between the two devices, glare and reflex tearing may occur in a wider range of light investigations, resulting in higher partial blinking rates. It may also be caused by a difference in the programs between the two devices detecting the partial blink. Therefore, regarding blink detection, the two devices are not compatible.

There were several limitations to this study. First of all, the number of subjects was small. We did not analyze the subjects based on dry eye severity. Assessments such as the cornea and the conjunctival staining score, blepharitis severity, or meibum quality were not considered as parameters.

Studies on the comparison of the MG dropout and correlations between ocular parameters from LVII have been reported.[10,11] But there is no publication about IDRA yet. Therefore, this study has the strength of comparing currently widely used LVII and IDRA to determine whether parameters between two devices are compatible.

In conclusion, no significant difference in LLT was obtained between LVII and IDRA. IDRA had a significantly lesser percentage of MG dropout and a higher PBR compared to LVII. These results indicate that these devices should not be used interchangeably for the evaluation of MG dropouts and PBR.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship and/or publication of this article.

ORCID iD

Kyungmin Koh https://orcid.org/0000-0003-0450-6423

References

1. Bai Y and Nichols JJ. Advances in thickness measurements and dynamic visualization of the tear film using noninvasive optical approaches. *Prog Retin Eye Res* 2017; 58: 28–44.
2. Nelson JD, Shimazaki J, Benitez-del-Castillo JM, et al. The international workshop on meibomian gland dysfunction: report of the definition and classification subcommittee. *Invest Ophthalmol Vis Sci* 2011; 52: 1930–1937.
3. Lee SM, Chung SJ and Lew H. Evaluation of tear film lipid layer thickness measurements obtained using an ocular surface interferometer in nasolacrimal duct obstruction patients. *Korean J Ophthalmol* 2018; 32: 445–450.
4. Nichols KK, Foulks GN, Bron AJ, et al. The international workshop on meibomian gland dysfunction: executive summary. *Invest Ophthalmol Vis Sci* 2011; 52: 1922–1929.
5. Arita R, Fukuoka S and Morishige N. New insights into the morphology and function of meibomian glands. *Exp Eye Res* 2017; 163: 64–71.
6. Arita R, Fukuoka S and Morishige N. Functional morphology of the lipid layer of the tear film. *Cornea* 2017; 36 Suppl 1: S60–S66.
7. Blackie CA, Solomon JD, Scaffidi RC, et al. The relationship between dry eye symptoms and lipid layer thickness. *Cornea* 2009; 28: 789–794.
8. Li Y, Sang X, Yang L, et al. Low concentration of sodium hyaluronate temporarily elevates the tear film lipid layer thickness in dry eye patients with lipid deficiency. *Int J Ophthalmol* 2018; 11: 389–394.
9. Abdelfattah NS, Dastiridou A, Sadda SR, et al. Noninvasive imaging of tear film dynamics in eyes with ocular surface disease. *Cornea* 2015; 34 Suppl 10: S48–S52.
10. Markoulli M, Duong TB, Lin M, et al. Imaging the tear film: a comparison between the subjective keeler tearscope-plus and the Objective Oculus(R) Keratograph 5M and LipiView(R) Interferometer. *Curr Eye Res* 2018; 43: 155–162.
11. Wong S, Srinivasan S, Murphy PJ, et al. Comparison of meibomian gland dropout using two infrared imaging devices. *Cont Lens Anterior Eye: J Br Cont Lens Assoc* 2019; 42: 311–317.
12. Zhao Y, Tan CL and Tong L. Intra-observer and inter-observer repeatability of ocular surface interferometer in measuring lipid layer thickness. *BMC Ophthalmol* 2015; 15: 53.
13. Amparo F, Schaumberg DA and Dana R. Comparison of two questionnaires for dry eye symptom assessment: the ocular surface disease index and the symptom assessment in dry eye. *Ophthalmology* 2015; 122: 1498–1503.
14. Finis D, Pischel N, König C, et al. Comparison of the OSDI and SPEED questionnaires for the evaluation of dry eye disease in clinical routine. *Ophthalmologe* 2014; 111: 1050–1056.
15. Asiedu K, Kyei S, Mensah SN, et al. Ocular Surface Disease Index (OSDI) Versus the Standard Patient Evaluation of Eye Dryness (SPEED): a study of a nonclinical sample. *Cornea* 2016; 35: 175–180.
16. Kawashima M and Tsubota K. Tear lipid layer deficiency associated with incomplete blinking: a case report. *BMC Ophthalmol* 2013; 13: 34.
17. Eom Y, Lee JS, Kang SY, et al. Correlation between quantitative measurements of tear film lipid layer thickness and meibomian gland loss in patients with obstructive meibomian gland dysfunction and normal controls. *Am J Ophthalmol* 2013; 155: 1104–1110.e1102.
18. Chou YB, Fan NW and Lin PY. Value of lipid layer thickness and blinking pattern in approaching patients with dry eye symptoms. *Can J Ophthalmol* 2019; 54: 735–740.
19. Guillon JP. Abnormal lipid layers. Observation, differential diagnosis, and classification. *Adv Exp Med Biol* 1998; 438: 309–313.
20. Guillon JP. Non-invasive Tearscope Plus routine for contact lens fitting. *Cont Lens Anterior Eye: J Br Cont Lens Assoc* 1998; 21 Suppl 1: S31–S40.
21. Pult H and Riede-Pult BH. Non-contact meibography: keep it simple but effective. *Cont Lens Anterior Eye: J Br Cont Lens Assoc* 2012; 35: 77–80.
22. Srinivasan S, Menzies K, Sorbara L, et al. Infrared imaging of meibomian gland structure using a novel keratograph. *Optom Vis Sci* 2012; 89: 788–794.
23. Eom Y, Na KS, Cho KJ, et al. Distribution and characteristics of meibomian gland dysfunction subtypes: a multicenter study in South Korea. *Korean J Ophthalmol* 2019; 33: 205–213.
24. Bland JM and Altman DG. Measuring agreement in method comparison studies. *Stat Methods Med Res* 1999; 8: 135–160.
25. Schargus M, Ivanova S, Stute G, et al. Comparable effects on tear film parameters after femtosecond laser-assisted and conventional cataract surgery. *Int Ophthalmol* 2020; 40(11): 3097–3104.
26. Lin X, Xu B, Zheng Y, et al. Meibomian gland dysfunction in type 2 diabetic patients. *J Ophthalmol* 2017; 2017: 3047867.
27. Pansell T, Porsblad M and Abdi S. The effect of vertical gaze position on ocular tear film stability. *Clin Exp Optom* 2007; 90: 176–181.
28. Himebaugh NL, Begley CG, Bradley A, et al. Blinking and tear break-up during four visual tasks. *Optom Vis Sci* 2009; 86: E106–E114.
29. Finis D, Pischel N, Schrader S, et al. Evaluation of lipid layer thickness measurement of the tear film as a diagnostic tool for Meibomian gland dysfunction. *Cornea* 2013; 32: 1549–1553.
30. Su Y, Liang Q, Su G, et al. Spontaneous eye blink patterns in dry eye: clinical correlations. *Invest Ophthalmol Vis Sci* 2018; 59: 5149–5156.