



Comparison of meibomian gland dropout using two infrared imaging devices



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ABSTRACT

Purpose: To measure the degree of meibomian gland (MG) dropout in the lower eyelid determined by analysis of images obtained from the LipiView II (LVII) and the Keratograph 5M (K5M).

Methods: The inferior eyelid of each participant was imaged in a random order using both devices. All images were subjectively assessed by a single-masked investigator to determine the extent of MG loss using the Arita 4-point meiboscoring scale. The images were also semi-objectively analyzed with ImageJ to calculate the percentage of MG dropout, by tracing around the non-glandular area and the total exposed area of the lower lid.

Results: Twenty participants (mean age 37 years, range 23–60, 60% female) completed the study. A significant difference in meiboscoring (mean \pm SD) was obtained between the LVII and the K5M (1.43 ± 0.78 vs. 1.90 ± 0.81 , $Z = 3.25$, $p = 0.001$). The meiboscoring 95% limit of agreement (LOA) ranged from -1.88 to $+0.93$. A significant difference was found with mean ImageJ percentage dropout between the LVII and the K5M (31.5% vs 43.4%, $t = -4.8$, $p = 0.00003$). The percentage dropout 95% LOA ranged from -42.79% to $+19.06\%$.

Conclusions: LVII images had significantly lower meiboscoring and less percentage MG dropout. Varying amounts of dropout were observed between the devices due to the amount of eyelid that was typically everted and because of differences in image quality. These results indicate that these devices should not be used interchangeably to evaluate MG dropout.

1. Introduction

Meibomian glands (MGs) are modified sebaceous glands located within the upper and lower eyelids [1]. MGs run in parallel along the eyelids and have a long central duct surrounded by grape-like clusters of acini [2], which secrete lipids [3] into the tear film and prevent its evaporation from the ocular surface [4]. Disruption to the structure and function of the MGs can result in visible clinical signs or subjective symptoms of dryness or discomfort [5,6].

The leading cause of evaporative dry eye is meibomian gland dysfunction (MGD) [7]. MGD is estimated to affect between 3.5% [8] and 74.5% [9] of the population, with increasing prevalence reported in Asian populations [10]. In 2011, the International Workshop on MGD recommended that MGD be defined as “a chronic, diffuse abnormality of the meibomian glands, characterized by terminal duct obstruction

and/or qualitative/quantitative changes in the glandular secretion. This may result in alteration of the tear film, symptoms of eye irritation, clinically apparent inflammation, and ocular surface disease” [11].

In 1977, Tapie used transillumination of an everted eyelid in conjunction with a slit lamp to visualize the morphology of the MGs [12]. Molinari and Tapie also subsequently combined transillumination with infrared (IR) photography to record images of the MGs [13]. Jester et al. [14] improved on Tapie’s technique with the use of slit-lamp biomicroscopy to take IR photographs of a transilluminated rabbit eyelid. A non-invasive technique of viewing the MGs using IR photography was first introduced in 2008 [15], which overcame several problems associated with the transilluminator, namely a limited field of view and discomfort due to the sharp tip and heat generated by the device [15]. Multiple commercial manufacturers have developed instruments since that time, which allow the MGs to be photographed. These

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include the Meibom Pen (Japan Focus Co, Ltd., Tokyo, Japan) [16,17], the LipiView II [18–21] and LipiScan [22] (Johnson & Johnson Vision, Jacksonville, FL, USA), the Keratograph 5M (K5M) (OCULUS, Wetzlar, Germany) [23–25], the DC-4 or DC-7 slit-lamp and camera in conjunction with a BG-4M illuminator (Topcon, Tokyo, Japan) [17,26] and the ANTARES topographer, EyeTop-S topographer, SIRIUS Scheimpflug camera topographer [27] and the Cobra fundus camera using Phoenix Meibography Software [28] (bon Optic Vertriebsges, mbH, Lübeck, Germany), the EASYTEAR view + dacriroscope (EASYTEAR, Trento, Italy) [29], and the me-check (Espansione Group, Bologna, Italy) [30].

Different grading scales, ranging from a 2-grade scale [31] to a 7-grade [23] scale, have been created to assess the amount of gland dropout within an eyelid. The most commonly used scales are either 4- [2,15,32,33] or 5-grade [2] scales, with a 4-grade scale [15] being the most widely used in clinical research [21,23,25,34–36]. Semi-objective computerized digital analysis using ImageJ has also been used to determine the percentage of MG dropout. This is defined by a ratio of the area of gland loss to the total area of the eyelid [2,23,34,36]. Computerized grading with ImageJ has been shown to have better inter- and intra-observer agreement than the subjective 4- or 5-grade scales [2].

As noted earlier, two currently available methods for imaging the MGs are the OCULUS Keratograph K5M (OCULUS, Wetzlar, Germany) and the LipiView II Ocular Surface Interferometer (LVII) (Johnson & Johnson Vision, Jacksonville, FL, USA). Based on the Keratograph 4, which has been used to determine MG dropout [36,37], the K5M has been optimized to perform meibography. The newer K5M version has a larger field of view than the Keratograph 4 and the placement of the IR diodes has been adjusted to minimize reflections from the lid [23]. Manipulation of the eyelid for imaging is made either using the operator's fingers or a cotton-tipped applicator.

The LVII also uses a series of IR diodes to illuminate the eyelid, and features a patented Lid Everter. The Lid Everter assists in everting the lower eyelid, in addition to providing additional illumination to the lid. The LVII can provide images of the MGs under three different imaging modes: Dynamic Illumination, Adaptive Transillumination, and Dual-Mode Dynamic Meibomian Imaging [38]. Images taken with the Dynamic Illumination mode are able to reduce the amount of glare and backscatter from the MGs in comparison to images taken with other meibographers. The LVII does so by taking a minimum of two images of the MGs with the illumination source positioned at different angles. The separate images are then combined to produce a single image with reduced glare [39]. Dual-Mode Dynamic Imaging combines the Dynamic Illumination and Adaptive Transillumination images to provide a multidimensional view of the MGs [18,20].

These two methods might be expected to produce different findings of the morphology of the MGs, as a result of their differing imaging and lid manipulation methods. It is therefore important that a comparison is made of the expected outcomes from each instrument so that any variation in results can be identified. Furthermore, there is a relative lack of peer-reviewed literature regarding the use of the LVII to perform meibography [19–21].

The purpose of this study was to compare the amount of MG dropout in the lower eyelid obtained with images from the LVII and the K5M, to assess whether the devices can be used inter-changeably within a clinical setting.

2. Materials and methods

Ethics clearance was obtained through the Office of Research Ethics at the University of Waterloo prior to commencing the study. All procedures adhered to the Declaration of Helsinki. Informed consent was obtained from all participants prior to enrollment in the study.

Twenty participants were enrolled in this prospective, single-visit pilot study, which was conducted at the Centre for Ocular Research & Education, at the University of Waterloo. Subjects with prior refractive or eyelid surgery over the past year and ocular disease or infection

Table 1
Summary of clinical tests and grading scales.

Clinical Tests	Grading scale
Quality of secretion	Individually graded for 5 glands in the central, nasal, and temporal area of the lower lid 3: Clear liquid oil 2: Colored/cloudy liquid 1: Inspissated (semi-solid, toothpaste-like) 0: No secretion (including capped orifices) Total quality of secretion = sum of the secretion for the 15 glands
Corneal staining	Type, extent and depth of staining were individually graded for the central, nasal, temporal, inferior, and superior zones Type: 0 – 4 (0.5 steps) 0: No staining 1: Trace, minimal superficial diffuse staining or stippling, or trace abrasion or foreign body tracks 2: Mild, regional or diffuse punctate staining, or mild abrasion or foreign body tracks 3: Moderate, significant dense coalesced staining, corneal abrasion or foreign body tracks 4: Severe abrasions greater than 2 mm diameter, ulcerations, epithelial loss, or full thickness abrasion Extent: 0-4 (1 step) 0: No staining 1: 1-15% of area 2: 16-30% of area 3: 31-45% of area 4: > 45% of area Depth: 0-4 (1 step) 0: No staining 1: Superficial epithelium 2: Deep epithelium, delayed stromal glow 3: Immediate localized stromal glow 4: Immediate diffuse stromal glow, or full thickness Zone score = Type*Extent*Depth Total corneal staining score = Sum of the zone scores for each zone
Erythema	0: None 1 = Minimal 2 = Mild 3 = Moderate 4 = Severe
Lid margin telangiectasia	0: None 1: Single telangiectasia 2: 2 to 5 telangiectasia 3: > 5 telangiectasia 4: Severe (entire lid involvement)

where lid eversion could lead to unacceptable discomfort were excluded from the study. Eleven of the participants were current contact lens wearers and were not allowed to wear contact lenses on the day of the visit.

The visit consisted of a screening visit to assess eligibility by assessing the ocular and medical history, high contrast visual acuity, and biomicroscopy of the anterior eye and eyelids. Participants were examined for clinical signs, which included the quality of secretion in 15 MGs located along the lower lid, corneal staining using a strip of sodium fluorescein (BioGlo; HUB Pharmaceuticals, Rancho Cucamonga, CA, USA), lid erythema, and telangiectasia. Additional information regarding the clinical signs and grading scales used to evaluate these clinical signs are provided in Table 1.

2.1. MG secretion

MG secretion was assessed with the MG Evaluator™ (Johnson & Johnson Vision, Jacksonville, FL, USA) [40] at 5 glands in each of the temporal, central, and nasal regions of the lower eyelid. Each secretion was individually graded on a 4-point scale (0 = no secretion [including capped orifices], 1 = inspissated [semi-solid, toothpaste-like], 2 = colored/cloudy liquid, 3 = clear liquid oil) [41], and the secretions for

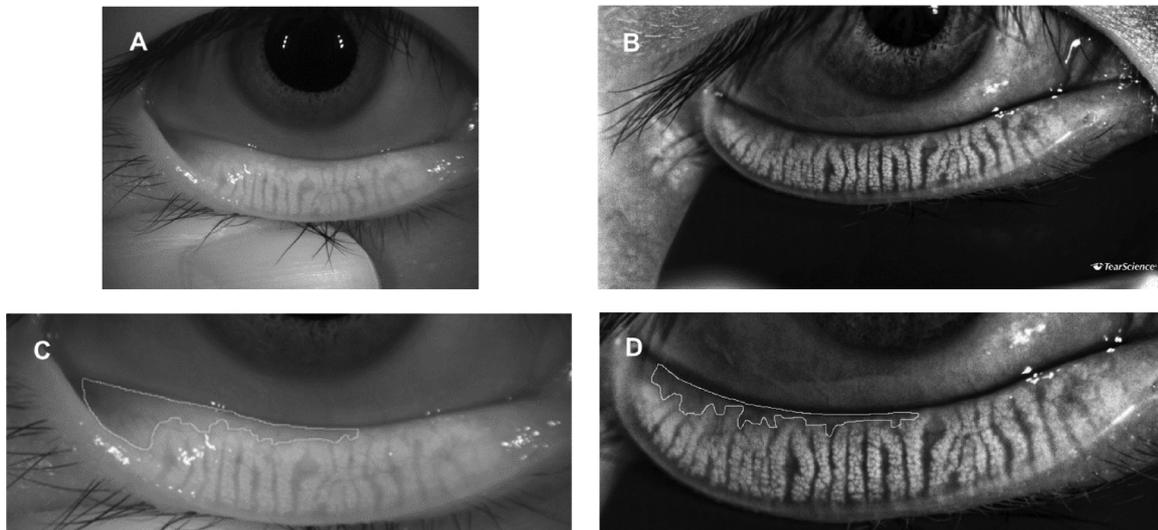


Fig. 1. Keratograph and LipiView images. (A) An image taken with the K5M shows a large visible area of the central lid, but a poor view of the temporal lid. Reflections are also present on the surface of the eyelid. (B) An image of the same subject taken with the LVII shows a better view of the full extent of the lid and improved contrast of the glands against the darker background of the eyelid. The free-hand tool (white outline) in ImageJ was used to measure the amount of gland dropout with the K5M (C) and the LVII (D). 8.21% and 19.19% percentage dropout was found for this participant with the K5M and the LVII, respectively.

each of the 15 glands per eyelid were summed to calculate the total score for each eye.

2.2. Imaging the MGs

Participants who were eligible to continue with the study underwent meibography of the lower eyelids with both the LVII and the K5M. Participants were randomly assigned to the first instrument that he or she would be imaged with. The first eye to be photographed at each instrument was also performed in a random order. The same investigator everted each participants' eyelids with both instruments.

Following the standard operating procedure for the K5M, the lower eyelid of each participant was everted with the investigator's thumb to expose the palpebral conjunctiva to obtain images of the MGs (Fig. 1A). A thumb was used to manipulate the lid, rather than a Q-tip or cotton-tipped applicator, to give the investigator more flexibility. Participants were given a 10-minute break prior to having photographs taken with the other instrument.

Following the standard operating procedure for the LVII, the investigator positioned the Lid Everter on the lower eyelid to expose as much of the palpebral conjunctiva as possible for each participant (Fig. 1B). A significant amount of training was provided to the investigator who conducted the meibography. Live images were projected onto a 32-inch television screen (Model UN32J5205AF; Samsung, Seoul, South Korea) while an assistant focused the device to obtain the best possible image. The images were saved and the best Dynamic Illumination photograph for each eye was exported for further analysis.

2.3. Image analysis

A single-masked observer subjectively graded the meiboscore for each image on a 22-inch computer monitor (Model V223 W EJbd; Acer, Taipei, Taiwan) in a darkened room. The meiboscore was graded with a 4-point scale [15] (Grade 0 = no loss of MG, Grade 1 = area of loss less than 1/3 of the total MG area, Grade 2 = area of loss between 1/3 and 2/3 of the total MG area, Grade 3 = area of loss > 2/3 of the total MG area). Images analyzed with ImageJ (<https://imagej.nih.gov/ij/>, National Institutes of Health, Bethesda, MD, USA) were conducted on a separate day using the same set up as the meiboscore grading. The same masked observer used ImageJ to semi-objectively grade the percentage of dropout in the MGs using a technique initially described by Pult [42]

and Pult and Riede-Pult [43,44]. Srinivasan et al. [36] modified this technique by using the free-hand tool to trace around non-glandular areas (Fig. 1C and D). The percentage of dropout was calculated by dividing the non-glandular area by the total exposed area of the lower lid.

2.4. Statistical analysis

Data was analyzed using Statistica 13 (Dell, Austin, TX, USA) and GraphPad Prism 7.02 (GraphPad Software, Inc., La Jolla, CA, USA). Data from both of the participants' eyes was analyzed. Descriptive statistics were used to describe the clinical signs. Data was assessed for normal distribution using the Shapiro-Wilk W test. Paired *t*-tests and Wilcoxon matched-pairs tests were used to compare data with a normal distribution and non-normal distribution, respectively. Correlations of normally distributed values and ordinal/non-normally distributed values were analyzed with the Pearson correlation coefficient (*r*) and the Spearman rank correlation, respectively. The mean difference and limits of agreement for the meiboscore and percentage dropout were graphed with Bland-Altman plots. A *p*-value of < 0.05 was considered statistically significant.

3. Results

Twenty participants (12 women, 8 men) completed the study. The mean \pm SD age was 36.6 ± 13.1 years (range 23–60 years). A total of 80 images (40 LVII and 40 K5M images) were analyzed. No adverse events were reported during the study.

3.1. Clinical signs

A summary of the clinical signs (MG secretion, corneal staining, erythema, and telangiectasia) is provided (Table 2). No significant correlation was found between the clinical signs and the meiboscore with either the LVII (Spearman's $r < 0.16$, $p > 0.10$) or the K5M (Spearman's $r < 0.11$, $p > 0.28$) (Table 3). Significant correlations were also not observed between the clinical signs and the percentage dropout with the LVII (Spearman's $r < 0.10$, $p > 0.07$) or the K5M (Spearman's $r < 0.13$, $p > 0.41$) (Table 4).

Table 2
Summary of clinical signs.

Technique	Lower Quartile	Median	Upper Quartile	Mean \pm SD	Range
Quality of secretion	7	12.5	24	15.5 \pm 12.5	0-45
Corneal staining	1	3.5	6.25	3.8 \pm 2.9	0-10
Erythema	0	0	0	0.18 \pm 0.38	0-1
Telangiectasia	0	0	0	0.30 \pm 0.72	0-2

3.2. Meiboscore

LVII: mean \pm SD meiboscore was 1.43 ± 0.78 (median = 1, mode = 1, lower quartile = 1, upper quartile = 2); K5M: mean \pm SD meiboscore was 1.90 ± 0.81 (median = 2, mode = 2, lower quartile = 1, upper quartile = 2.5). The frequency distribution of the meiboscore obtained with the two instruments is provided in Fig. 2A. A statistically significant difference in the meiboscore was observed between the two instruments ($Z = 3.25$, $p = 0.001$) (Fig. 2B).

A statistically significant correlation was found between the meiboscore obtained with the LVII and the K5M (Spearman's $r = 0.60$, $p < 0.0001$) (Fig. 3A).

The mean difference \pm SD in meiboscore was -0.48 ± 0.72 . A statistically significant difference in the mean meiboscore was obtained with the two instruments ($Z = 3.25$, $p = 0.001$). The 95% limit of agreement (LOA) ranged from -1.88 to $+0.93$ (Fig. 4A).

3.3. Total visible area of the eyelid

LVII: mean \pm SD visible area of the eyelid was 108147 ± 19014 pixels (median = 106430, lower quartile = 96580, upper quartile = 121547); K5M: mean \pm SD visible area of the eyelid was 177830 ± 46828 pixels (median = 169317, lower quartile = 143443, upper quartile = 204104). A statistically significantly smaller total area of the lower eyelid was visible with the LVII than with the K5M ($Z = 5.51$, $p < 0.00001$).

3.4. ImageJ percentage dropout

Semi-objective analysis revealed a statistically significant difference in the (mean \pm SD) percentage of MG dropout with the LVII ($31.5\% \pm 18.9\%$) versus the K5M ($43.4\% \pm 18.9\%$) ($t = -4.8$, $p < 0.0001$) (Fig. 2C).

A statistically significant correlation was found between the mean percentage of dropout with the LVII and the K5M (Pearson $r = 0.65$, $p < 0.0001$) (Fig. 3B).

There was a statistically significant difference in the mean percentage difference of MG dropout \pm SD between the LVII and the K5M ($-11.87 \pm 15.78\%$, $p < 0.0001$). The 95% LOA ranged from -42.79% to $+19.06\%$ (Fig. 4B). This is clinically unacceptable because percentage dropout with the K5M may be 19.1% above or 42.8% below the amount found with the LVII.

4. Discussion

This study compared the amount of MG dropout obtained with two

commercially available meibographers. A significant difference was found with both the meiboscore and percentage dropout between the LVII and the K5M. The meiboscore obtained with the two instruments was found to vary by up to two grades. In some cases, the LVII showed no gland dropout, but the amount of loss visible with the K5M was graded as missing up to 2/3 of the glands on the lower lid. Clinically, this implies that these two instruments cannot be used interchangeably to perform meibography of the lower eyelid.

The limit of agreement for the percentage of dropout between the two instruments covered a wide range from -42.8% to $+19.1\%$. There was a greater amount of disagreement between the instruments when approximately 25% or less of the MGs were missing. This is most likely due to the difference in the amount of eyelid that was everted. The agreement between the devices improved as the amount of dropout increased, with the K5M showing a trend towards having a higher amount of dropout compared to the LVII. This may be due to an over-estimation in assessing gland loss due to the poorer contrast of the photos and increased amount of reflections.

The calculation of dropout measured with ImageJ assumes that any area on the lid which does not currently have MGs is an atrophic area. This is not always an accurate representation of dropout, especially when a large area of the lower lid has been everted. Some of the exposed areas of the lid which are analysed as missing glandular tissue are likely to have never contained any MGs. Perhaps using a different method to grade MG loss, such as counting the number of partial or whole MGs within an image [33] or only examining 8 [45] or 10 [46] glands in the central lid would have produced more similar results between two instruments.

A difference in image quality may have also affected the results. The contrast of the MGs against the lid are easier to see with the LVII as they appear white against a dark gray background, as seen in Fig. 1B. The borders of the MGs are more well-defined with the LVII. The Lid Everter of the LVII also minimizes reflections on the photographs, which makes it easier to assess the extent of glandular tissue on the lid. The K5M images had more reflections, as seen in Fig. 1A, which made it more difficult to judge whether an area had any glandular loss. The appearance of white MGs on a light gray background on the K5M also made it more difficult to assess which areas of the lid were covered by a gland. The edges of the MGs were also not as well-defined as when observed with the LVII, which may have also caused a discrepancy in judging the amount of dropout with the meiboscore and ImageJ analysis between the two devices.

This study did not assess the upper eyelid because the novel Lid Everter designed for the LVII can only be used with the lower lid. Apart from the benefits of the lower lid being easier to evert and more comfortable for the patient, Finis et al. [25] have suggested that solely examining the lower lid may be sufficient to assess the amount of MG atrophy in most cases. Pult et al. [44] have also found that the predictive ability for dry eye is similar between the amount of dropout in the lower lid versus the upper lid. One reason for the difference in values obtained between the two instruments is due to the different methods of everting the eyelid and the varying amounts of the lower lid that were visible in the images. Although it would be interesting to compare the images obtained from the two instruments using the same lid eversion technique, this was not done in order to replicate the procedure that would be followed in a routine clinical practice.

Table 3
Correlation of clinical signs to meiboscore.

	Instrument	MG quality of secretion	Corneal staining	Erythema	Telangiectasia
Spearman's r correlation to meiboscore	LVII	$r = -0.27$ $p = 0.10$	$r = 0.11$ $p = 0.51$	$r = 0.16$ $p = 0.32$	$r = 0.05$ $p = 0.76$
Spearman's r correlation to meiboscore	K5M	$r = -0.17$ $p = 0.28$	$r = 0.11$ $p = 0.50$	$r = 0.05$ $p = 0.78$	$r = -0.05$ $p = 0.77$

Table 4
Correlation of clinical signs to percentage MG dropout.

	Instrument	MG quality of secretion	Corneal staining	Erythema	Telangiectasia
Spearman's <i>r</i> correlation to percentage dropout	LVII	$r = -0.29$ $p = 0.07$	$r = 0.06$ $p = 0.71$	$r = 0.10$ $p = 0.54$	$r = -0.01$ $p = 0.94$
Spearman's <i>r</i> correlation to percentage dropout	K5M	$r = -0.06$ $p = 0.73$	$r = -0.06$ $p = 0.72$	$r = 0.13$ $p = 0.41$	$r = 0.02$ $p = 0.88$

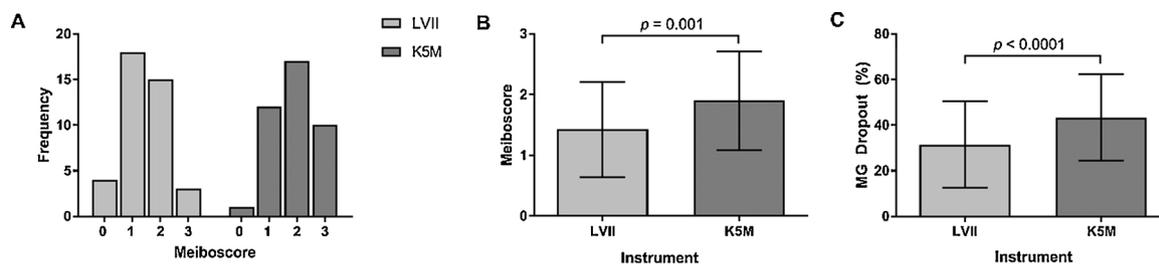


Fig. 2. Keratograph and LipiView meiboscoring. (A) Histogram of the meiboscoring grading with the LVII and the K5M, (B) the mean \pm standard deviation meiboscore values and (C) percentage of MG dropout for the LVII and the K5M.

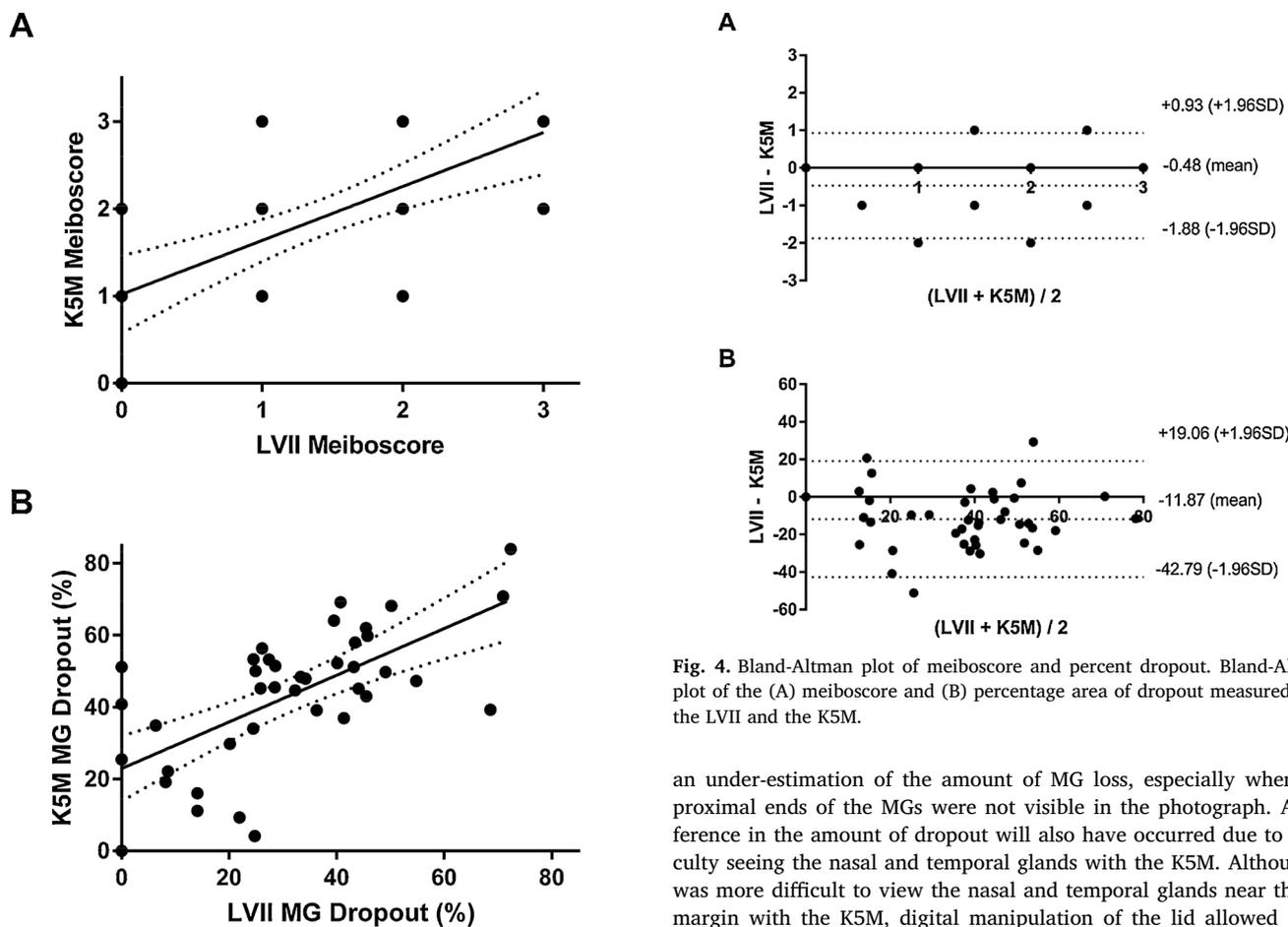


Fig. 3. Scatterplot of meiboscore and percent dropout. (A) Scatterplot of the 4-grade meiboscore and (B) the percentage area (ImageJ) dropout measured with the K5M versus the LVII showing the regression line (solid black line) and the 95% confidence intervals (dotted lines).

The size and shape of the Lid Everter made it more difficult to fully evert the lower lid; therefore, it was harder to view the proximal ends of the MGs in lids that had smaller amounts of dropout. This resulted in a smaller total visible area of the lid with the LVII when the images were analyzed semi-objectively with ImageJ analysis. This may have led to

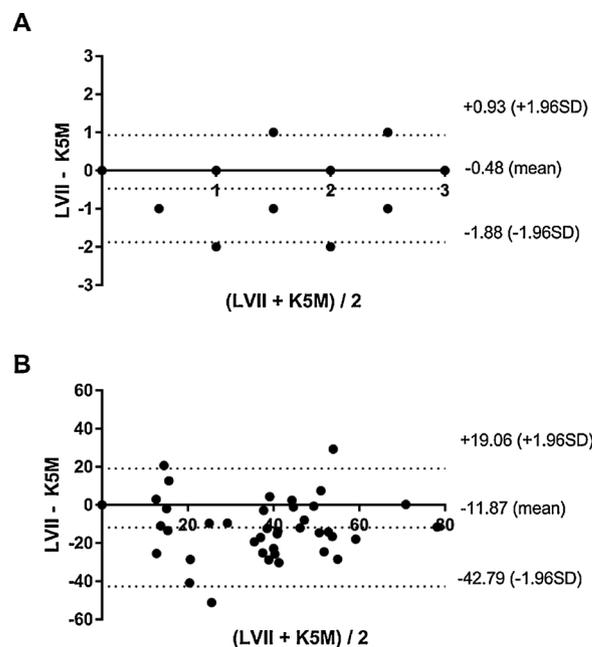


Fig. 4. Bland-Altman plot of meiboscore and percent dropout. Bland-Altman plot of the (A) meiboscore and (B) percentage area of dropout measured with the LVII and the K5M.

an under-estimation of the amount of MG loss, especially when the proximal ends of the MGs were not visible in the photograph. A difference in the amount of dropout will also have occurred due to difficulty seeing the nasal and temporal glands with the K5M. Although it was more difficult to view the nasal and temporal glands near the lid margin with the K5M, digital manipulation of the lid allowed for a better view of the proximal MGs within the central lid. However, this may have led to the K5M over-estimating the amount of dropout. In order to be able to assess the true extent of MG dropout, one would need to know the position within the lid of the MGs prior to atrophy occurring [23].

The Lid Everter is designed to fit along the length of the lower lid and has a larger surface area with which to hold the lid in place than a Q-tip or tip of a finger can provide. This allows for a better overall view of the distal MGs adjacent to the lid margin with the LVII, especially in the nasal and temporal areas of the eyelid in comparison to the K5M.

Recently a new grading scale for MGD has recommended only assessing dropout in the central two-thirds of the lid due to problems photographing the MGs at the edges of the eyelid [47]. However, an advantage of the Lid Everter is that almost the full extent of the lid can be imaged in one photograph. It may be of significant clinical importance to assess the nasal third of the lid because a larger amount of atrophy has been observed in this area [25]. Hence, if clinicians using the K5M only intend to take a single image, then care should be taken to fully evert the lower lid to try to capture the central and peripheral edges of the lid. Otherwise it may be necessary to take additional photographs in separate areas of the lid in order to get a clear image of the nasal, central, and temporal zones to assess the amount of MG dropout along the entire lid. However, this would make grading of the images more difficult, unless the different areas of the lid are assessed separately.

No statistically significant correlation was found between lid margin signs (corneal staining, quality of meibum secretion, erythema, and telangiectasia) with either the meiboscore or percentage of MG dropout. Ngo et al. [23] was also unable to find a significant correlation between clinical signs and the meiboscore or percentage dropout using the K5M. However, Srinivasan et al. [36] found a significant correlation between both the quality of meibum and the number of blocked MGs, with the meiboscore, using the Keratograph 4. This could be due to a younger population being examined in this current study (mean age = 36.6 years) and by Ngo et al. [23] (mean age = 32.2 years), in comparison to an older population (mean age = 57.8 years) investigated by Srinivasan et al. [36]. The older population may have presented with an increased amount of lid margin changes, because some signs, such as telangiectasia, increase in prevalence with age [48].

This study may have been limited by the use of a single-masked observer to subjectively and semi-objectively assess the amount of MG loss. Although this will have helped maintain overall consistency in grading dropout, it may have also introduced bias. Objective methods of determining MG loss have been created for different imaging systems [17], including the K5M, with reported sensitivities of 99.3% [49] to 98% [50] and specificities of 97.5% [49] to 100% [50]. The benefit of an objective analysis is that any variations due to inter-observer and intra-observer grading will be removed. If an objective method is to be developed to assess the LVII images, care should be taken to manipulate the Lid Everter so that the nasal and temporal areas of the lid are located within the same plane as the central lid, in order to avoid blurry images of the MGs in the periphery of the lid.

Both the LVII and the K5M are useful in clinical practice because they are multi-functional and can perform other tests besides meibography. Based on our experience in this study, the K5M was more clinician friendly, as it was easier for a single operator to use and the image acquisition process was faster than with the LVII. Two people were used in this study to perform meibography with the LVII because it was difficult for a single operator to hold the Lid Everter steady, while simultaneously trying to focus the device. The patient set-up, prior to imaging, also took longer with the LVII due to the time spent optimizing eversion of the lid with the Lid Everter. Temporary discomfort was reported by some participants, due to a destabilized tear film while the eyelids were held open. Although the LVII provides a better view of the distal MGs across the entirety of the lid, image acquisition takes longer than with the K5M because multiple scans of the lid are taken to produce photographs under the 3 different modes of illumination. Future research is needed to investigate if a recently introduced dedicated meibographer, the LipiScan (which also uses the Lid Everter), might be easier for a single operator to use due to its more compact size [22].

5. Conclusions

Statistically significant differences in meiboscore and percentage of MG dropout were obtained from images taken with the K5M when compared to the images from the LVII. Images obtained with the LVII, on average, resulted in lower meiboscores and had lower percentages of

gland dropout when compared to the K5M. Due to the large range in limit of agreement of percentage dropout between the devices, it is recommended that the instruments cannot be used interchangeably within a clinical setting to assess MG loss. Different values of MG dropout may have been found between the devices due to different techniques used to evert the eyelid, which resulted in differing amounts of lid eversion, and because of differences in the quality of the images obtained with the K5M and the LVII.

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