The Use of Infrared Autorefractometer for Meibomian Gland Imaging

Mohammed Alsaab 1, Abdulrhman S. Alsadun 2, Eyad Alrsheed 1, Khaled Almutairi 1, Abdullah Alkhudhayr 1, Meshari A. Alharbi 3, Waleed Alghamdi 3, Omar Solyman 5

1. Department of Optometry, Qassim University Medical City, Buraidah, SAU 2. Department of Optometry, Qassim University, Buraydah, SAU 3. Department of Ophthalmology, Qassim University, Buraydah, SAU 4. Department of Optometry, Qassim University Medical City, Buraidah, SAU 5. Department of ophthalmology, Qassim University Medical City, Buraidah, SAU

Corresponding author: Omar Solyman, dr.omar.solyman@gmail.com

Abstract

Introduction: This study proposes the utility of infrared autorefractometers for meibography and compares meibographs obtained by autorefractometer to meibographs obtained by a designated meibography machine.

Methods: A prospective observational comparative study of meibographs of patients with clinical signs of meibomian gland dysfunction (MGD) using a designated meibography machine and an infrared autorefractor. The images of the two machines were graded by five masked experienced interpreters. The Kappa test was used for calculation of Inter-rater and inter-rater agreements between meibography machine and automated refractor grading of meibomian gland dysfunction.

Results: High quality photos of all 30 eyes delineating the meibomian glands (MG) were successfully obtained with both the meibography machine and the autorefractor. There was a good intra-rater agreement between both methods (κ = 0.667 to 0.784, average 0.738). Poor to fair interrater agreement was noticed in grading of autorefractor images (κ = -0.030 to 0.343, average 0.092) and poor to moderate agreements between investigators for meibography machine images (κ = -0.016 to 0.420, average 0.175).

Conclusion: High quality non-contact IR digital meibography could be captured using commercially available autorefractor.

Categories: Ophthalmology
Keywords: imaging, mgd, meibomian gland, autorefractor, meibography

Introduction

Meibomian glands, also known as tarsal glands, are tubulo-acinar sebaceous gland with holocrine function which are responsible for secretion of the lipid superficial layer of the tear film known as meibum [1]. Meibum consists of a variety of lipids including wax esters, cholesteryl esters, free cholesterol, triacylglycerols, free fatty acids, phospholipids, and sphingomyelins [2]. This lipid layer plays a fundamental role in vitality of the ocular surface by maintaining the vertical stability of the precorneal tear film, lubricates eyelid movements and minimizes evaporation of the aqueous layer of the tear film [3]. Meibomian gland dysfunction is defined as a chronic, diffuse abnormality of the meibomian glands, commonly characterized by terminal duct obstruction with or without qualitative or quantitative changes in the glandular secretion [4]. MGD has a global prevalence of about 21.2% to 40% [3, 5-8]. In Saudi Arabia the prevalence of MGD is thought to be twice as the world average affecting about 70-80% of the population [9]. Morphological changes of meibomian glands associated with MGD include atrophy or loss, tortuosity, thickening, and shortening of the gland. These changes are thought to precede functional changes and result in alteration of the tear film, symptoms of eye irritation, clinically apparent inflammation, and ocular surface disease [10], [11].

MGD can be studied using a variety of methods including a slit-lamp examination for lid morphology and gland expressibility, tear film lipid layer thickness, tear osmolarity, interferometry and evaporimetry, and meibography [12]. Meibography provides photographic delineation of the MG morphology by means of infrared photography. Study of the infrared meibographs helps with the diagnosis and grading of MGD [13], [14]. Meibography is traditionally performed by stationary designated expensive machines which makes...
it limited to tertiary and research centers. Autorefractors although are also bulky and stationary machines, they are widely available in ophthalmology clinics and optometry offices. Herein, we study the utility of infrared autorefractometers for infrared meibography and compare infrared meibographs obtained by infrared autorefractometers to meibographs obtained by a designated meibography machine for the same patients.

**Materials And Methods**

**FIGURE 1:** A- a photograph showing the process of capturing meibography images using the A- Nidek autorefractor B- Oculus Meibography machines.

This prospective observational comparative study was approved by the institutional review board of Qassim University, Almulida, Al-Qassim, Saudi Arabia and was performed in accordance with all local laws and in compliance with the principles of the Declaration of Helsinki. Patients with clinical signs of MGD including eyelid margin irregularity or telangiectasia, pouting or plugging of meibomian gland orifices were included. Patients with excessive eyelid scarring which may affect the resolution of infrared images including patients with history of prior eyelid surgery or eyelid lacration repair, severe trachomatous scarring, chemical injury or burns of the eyelids were excluded. A written informed consent was obtained from all study participants. Infrared meibography of one upper lid was performed for patients with clinical diagnosis of MGD using OCULUS Keratograph ® 5M meibography machine, (Oculus, Menlo Park, California) and Nidek AR-1 infrared autorefractometer, (Nidek, Gamagori, Aichi, Japan).

Each participant was properly seated on the autorefractor machine as per regular autorefraction examination and the upper eyelid of the patient’s choice was everted by a Q-tip to take the first image (Figure 1A). The chin rest height was adjusted until the upper eyelid of concern was centered in the view. The autorefractometer was manually focused until the morphology of the meibomian glands was in sharp delineation at which time 3 digital photographs of the autorefractor’s screen were captured using an outside smartphone camera. The patient was then moved and seated on the Oculus Keratograph machine, where a meibography of the same eyelid was obtained (Figure 1B). The meibography images obtained from both machines were daintified and coded before they were graded by five masked investigators (an ophthalmologist and four optometrists). Pult grading system was used for grading of the meibographs in which grade zero when there is no change observed, Grade 1 was considered when there is less than 25% meibomian gland loss. Grade 2, 3 and 4 were considered when there is 26-50% MG loss, 51-75% MG loss and >75% MG loss respectively. Interpretation data was fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). The Kappa test was used for calculation of Inter-rater and inter-rater agreements between meibography machine and automated refractor grading of meibomian gland dysfunction [15]. The significance of the obtained results was judged at the 5% level.

**Results**

Thirty upper eyelid meibographs of 30 patients with MGD were successfully obtained using the OCULUS Keratograph ® 5M meibography machine and the Nidek AR-1 infrared autorefractometer.

All 30 autorefractor Miebographs were found to be of high quality and delineated the MG morphology comparable to the designated meibography machine. Masked interpretation of the autorefractor and meibography machine-based images showed a good intra-rater agreement in terms of MGD grading with a kappa value ranging between 0.667 to 0.784 with an average of 0.738 (table 1). A poor to fair agreement was noticed between the investigators in grading of autorefractor-based meibographs \( (\kappa = -0.030 \text{ to } 0.343, \text{ average}= 0.092) \) while poor to moderate interrater agreement was noticed for meibography machine-based images \( (\kappa = -0.016 \text{ to } 0.420, \text{ average}= 0.173) \), (table 2).
**TABLE 1: Intra-rater agreement between MGD grading for Nidek autorefractor and Oculus Meibography machine based meibographs.**

<table>
<thead>
<tr>
<th>Autorefractor vs. Meibography</th>
<th>κ value</th>
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<tbody>
<tr>
<td>Investigator 1</td>
<td>0.784</td>
</tr>
<tr>
<td>Investigator 2</td>
<td>0.683</td>
</tr>
<tr>
<td>Investigator 3</td>
<td>0.777</td>
</tr>
<tr>
<td>Investigator 4</td>
<td>0.667</td>
</tr>
<tr>
<td>Investigator 5</td>
<td>0.779</td>
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</tbody>
</table>

Poor agreement < 0.20, Fair agreement 0.21 – 0.40, 0.41 – 0.60 moderate agreement, 0.61 – 0.80 good agreement, 0.81 – 1.00 very good agreement.

Then paired images were presented to the investigators without masking and each of the 5 investigators concluded that the autorefractor based meibographs were comparable in quality to their meibography machine-based counterparts and reflected the same meibomian gland morphologies in the 30 images (figure 2).

**FIGURE 2: Upper eyelid meibographs using Nidek autorefractor (upper line A, B, C & D) & Oculus Meibography machine (lower line E, D, E & F)**
Table 2: Inter-rater agreement between MGD grading for Nidek autorefractor and Oculus Meibography machine based meibographs.

<table>
<thead>
<tr>
<th></th>
<th>Autorefractor</th>
<th>Meibography</th>
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<tbody>
<tr>
<td></td>
<td>( \kappa ) value</td>
<td>( \kappa ) value</td>
</tr>
<tr>
<td>Investigator 1 vs. Investigator 2</td>
<td>0.291</td>
<td>0.420</td>
</tr>
<tr>
<td>Investigator 1 vs. Investigator 3</td>
<td>0.073</td>
<td>0.164</td>
</tr>
<tr>
<td>Investigator 1 vs. Investigator 4</td>
<td>0.066</td>
<td>0.080</td>
</tr>
<tr>
<td>Investigator 1 vs. Investigator 5</td>
<td>-0.014</td>
<td>0.039</td>
</tr>
<tr>
<td>Investigator 2 vs. Investigator 3</td>
<td>0.099</td>
<td>0.239</td>
</tr>
<tr>
<td>Investigator 2 vs. Investigator 4</td>
<td>0.009</td>
<td>-0.016</td>
</tr>
<tr>
<td>Investigator 2 vs. Investigator 5</td>
<td>-0.022</td>
<td>0.024</td>
</tr>
<tr>
<td>Investigator 3 vs. Investigator 4</td>
<td>0.108</td>
<td>0.270</td>
</tr>
<tr>
<td>Investigator 3 vs. Investigator 5</td>
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<td>0.163</td>
</tr>
<tr>
<td>Investigator 4 vs. Investigator 5</td>
<td>0.343</td>
<td>0.345</td>
</tr>
</tbody>
</table>

Discussion

Meibography is a relatively new imaging technique which describes various methods of visualizing and imaging the meibomian glands. The first description of Meibography by Tapie [16] in 1977 employed endovitrectoreal light probe to visualize the silhouette of the meibomian glands by transillumination through an everted eyelid. The resolution of the meibomian glands was poor. Resolution and delineation of the meibomian glands was improved by the introduction of infrared imaging in 1982 by Jester et al [17], which was first described in in a rabbit model before it was applied clinically [18]. At that time infrared film photography technique was technically challenging and time consuming. Digital meibography was introduced in 1994, Mathers et al, [19] who captured digital real-time video meibography videos of transilluminated lid using an infrared camera connected to a computer.

Current non-contact IR meibography was introduced in 2008 by Arita et al [20], who describe capturing digital images of the meibomian glands of an everted eyelid using a slit lamp equipped with an IR charge-coupled device video camera which is combined with an IR-transmitting filter. This non-contact method increased patient comfort during the acquisition of the images, making meibography more feasible to perform in clinical practice.

Currently there are several commercially available meibography machines including the Keratograph 5M (OCULUS, Wetzlar, Germany) which was used in the current study and the LipiScan Dynamic Meibomian Imager (TearScience, Johnson and Johnson Vision, Morrisville, North Carolina, USA) [21]. Unfortunately, these devices come at a relatively expensive cost which limits their availability to large practices and academic centers. In addition, they are bulky and stationary which limits their use to limits their use to one place. A cost effective method of non-contact IR meibography by Pult et al. [22], described using a modified IR security for near observation which was connected to a computer which enabled image captured using generic software.

Another method of addressing the cost limitations of the dedicated infrared webography machine is by repurposing already available devices. Napoli et al. [23], obtained non-contact IR meibography images by means of imaging of the everted eyelid by a commercially available spectral-domain optical coherence tomography (OCT) machine (Cirrus™ HD-OCT 4000, Carl Zeiss Meditec Inc., Dublin, California, USA). Because the detection of meibomian glands is difficult or nearly uninterpretable in the raw infrared image on the OCT machine, post capture modifications of the contrast and brightness were required to increase the visibility of the meibomian glands using the built-in software of the OCT machine [23].

In the current study, we investigated the utility of commercially available autorefractors for infrared meibography. High quality infrared meibography images could be obtained from all study participants using the Nidek AR-1 autorefractometer. The quality of the images was comparable in clarity of meibomian gland...
visualization to the results obtained from the designated meibography machine (OCULUS Keratograph ® SM). There was a good intra-rater agreement between MGD grading using the meibography machine and the autorefractor (table 7). However, a poor to fair agreement was noticed between different investigators. This reflects the subjectivity of the grading system and the big step size (25% step size). However, when investigators were unmasked to the paired images from both machines, all investigators concluded that the images obtained with the two imaging techniques were comparable in resolution and quality.

Autorefractometers are widely available in ophthalmology clinics and optometry offices which makes meibography readily accessible to a wide range of eye care professionals, compared to OCT machines and commercially designated meibography machines. Moreover, unlike the OCT dependent techniques, our method did not require any post-processing thus sparing the time of the operator.

Limitations of this technique include the inability to save the images directly on the autorefractor machine or exporting it to the medical record system. This requires one extra-step of external photography of the monitor of the autorefractor by an external camera, like a smartphone camera, for which an assistant may be required. Limitations of this study include the small number of participants. This study aimed at proving the concept of this new technique. We believe that these limitations can be addressed in future studies.

Conclusions

Repurposing Auto-refractometers to perform meibography is a viable cost-effective method for morphologic evaluation of the meibomian glands. It provided excellent visualization and delineation of the meibomian glands and reflected all the details comparable to the designated meibography machine. Adopting this technique may make meibography accessible to a wide range of eye care professionals worldwide.

Additional Information

Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. Committee of Research Ethics, Deanship of Scientific Research, Qassim University issued approval 23-60-04. Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue. Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work. Financial relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References


