Optimization of the non-contact meibography by means of an experimental Corneal Topographer

Ernst-Abbe-Fachhochschule Jena
University of Applied Sciences Jena

M.Sc., Dipl. Ing. (FH) M. Sinnig (formerly Michel)[1,2]; Prof., Dipl.-Ing. (FH) W. Sickenberger, MS. Optom. (USA)[1,2]
[1]University of Applied Sciences Jena, Germany; [2] JENVIS Research Institute, Germany

Introduction:

The term Meibomian Gland Dysfunction (MGD) describes abnormalities of the meibomian glands, which are commonly characterized by obstructions of the glands and changes of the gland secretion, respectively [1]. It is considered to be one of the most important causes of the evaporative Dry Eye [2]. It is believed, that the prevalence of MGD is at 70% [3]. Nevertheless there was no generally applicable definition and classification, especially in German speaking countries until recently. Not least this was accounted for by a lack of diagnostic opportunities. The so called meibography, an assessment to make the morphology of the glands visible takes a key role in the diagnosis of MGD and becomes more and more important. New devices are supposed to make the assessment more accessible in daily practice and more comfortable for the investigator and the patient as well. Consequently the causes of Dry Eye can be investigated more precisely and specific therapy options can be applied to alleviate the patients symptoms.

Purpose:

To optimize the non-contact meibography to improve the image quality and to make an assessment of the meibomian gland morphology more accessible in daily practice, easier for the practitioner and more comfortable for the patient. For this purpose different devices were tested regarding their capability for non-contact meibography. The focus was on a corneal topographer (*Keratograph, OCULUS*). Modifications of the *Keratograph* were determined and were implemented in terms of a prototype.

Methods:

Capability testing of different devices

General requirements for non-contact meibography:

- Infrared light source for the illumination of the eyelids or
- Light source with visible spectrum that includes rates of IR radiation in combination with an infrared filter
- Camera system without band-elimination filter for infrared light

The following devices were tested regarding their capability for non-contact meibography:

Biomicroscope (*NIDEK SL-1800*) with a modified Camerasystem (*OCULUS ImageCam 2*)

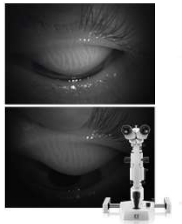

Figure 1: Meibography images with the sliptamp with two different filters

- Assessment of the meibomian glands with only one filter in front of the observation unit
- Variable magnifications
- sufficient working distance
- glands can be observed with filters of different wavelengths
- images of high quality with high resolution

- Cost-intensive due to the required facilities
- Two different cameras are necessary (one for normal images, one for meibography images)
- special retainer for IR-filter necessary
- Light falloff in the periphery

Pachymeter/ Autorefraktometer/ Keratometer (*OCULUS PARK 1*)

Figure 2: Meibography images with *OCULUS PARK 1*

- Device is equipped with IR-diodes and an IR sensitive camera system
- No further facilities are necessary
- Eversion of the eyelids easy to handle due to the slim design of the device

- Low resolution
- Reflex interference makes the assessment very difficult
- Light falloff in the periphery, not all glands can be assessed
- Small display
- No intensity adjustment

Topographer (*OCULUS Keratograph 4*)

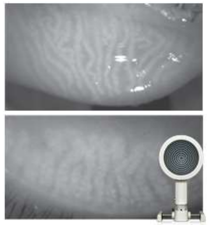

Figure 3: Meibography images with *OCULUS Keratograph 4*

- Device is equipped with IR-diodes and an IR sensitive camera system
- No further facilities necessary
- Intensity adjustable

- Limited quality of the images due to low resolution
- Reflex interference
- Light falloff in the periphery
- Insufficient working distance due to the large diameter of the calotte
- Small region of interest

With all tested devices the non-contact meibography is possible. However they are limited regarding their technical requirements or cost-intensive facilities are necessary. During the further procedure the *Keratograph* was used to test different modifications and to optimize the non-contact meibography with this device.

Development process with an experimental topographer

A commercial corneal topographer (*OCULUS Keratograph 4)* was used to assess meibography images regarding illumination, magnification and field of view. With different lenses which were adjusted in the calotte of the device the region of interest, the optimal magnification and in this regard an appropriate working distance were determined to simplify the gland assessment for the investigator in terms of the eversion of the eyelid. With a - 4.00 D lens the region of interest was optimized from 14.5mm to 25mm and a working distance of 12cm was realized, which was only at 4cm before.

Figure 4: *Keratograph 4* with test lens for the determination of magnification and region of interest

Region of interest approx. 25 mm
➡ entire range of the everted eyelid is visible
Working distance approx. 12cm
➡ enough space to evert the eyelids and fix them during the measurement

Based on the *OCULUS Keratograph 4* an experimental topographer was developed. The previous determinations were realized and sophisticated by equipping the prototype with a manually adjustable, provisory magnification changer. Additionally the prototype was equipped with a high resolution color camera, which is equivalent to the *ImageCam 2* (*OCULUS*) and ensures high quality images of the meibomian glands.

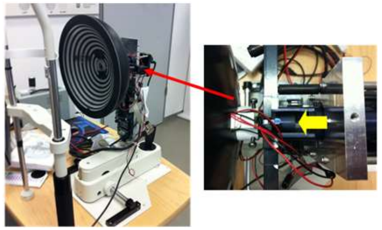

Figure 2: Prototype with provisory magnification changer

The illumination was modified, to achieve a good and uniform illumination over the entire area of the everted eyelid without reflex interferences. Therefore, different IR-diodes with seven different wavelengths (720 nm, 770 nm, 810 nm, 840 nm, 880 nm, 950 nm und 1020 nm) were tested as well as the number and the arrangement of the diodes. The number of the IR diodes was determined to three vertically arranged diodes each in the mid-periphery of the calotte. Each diode radiates light in another orientation to ensure a diffuse and uniform illumination over the entire region of interest. The brightness of the diodes was modified by means of a separate power supply device.

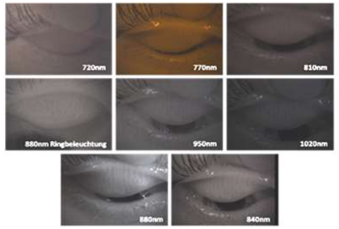

Figure 6: Images of the meibomian glands assessed with different wavelength

Wavelength 840nm
➡ best visibility of the glands
Number of diodes = six
➡ uniform illumination over the entire area of the everted eyelid without light falloff in the periphery
Arrangement of the diodes in different orientation angles
➡ Minimization of interfering reflexes

In addition, some software settings regarding white balance, exposure time and gain were optimized.

Figure 7: Determination of number and arrangement of the diodes

Figure 7: Final number and arrangement of the diodes

Finally it was tested, if the quality of the images is influenced by the ambient light conditions. For this purpose non-contact meibography images were examined in different lighting situations (darkened room, moderate darkened room, artificial room illumination, daylight). It turned out that the ambient light conditions have bare influence on the image quality. Also in bright light conditions it is not necessary to change the presetting concerning exposure time and gain.

Results:

The modifications tested were implemented in a new device (Meibo-Scan, Keratograph 5M, Oculus). With this device, the assessment of the meibomian glands is possible with an adequate field of view of 25mm. The greater working distance facilitates the eversion of the eyelid. Due to the high resolution camera, high-quality photos and videos can be taken. Six vertically arranged IR-diodes with a wavelength of 840nm ensure a uniform illumination.

Figure 7: *Meibo-Scan* Software of the *Keratograph 5M*

Conclusion:

The morphology of the meibomian glands can be examined with the new device in an investigator and patient-friendly way. Using the modified topographer for the assessment of the meibomian glands is a novel approach with considerable advantages compared to other devices, e.g. the illumination. The excellent quality of the meibography images simplifies the evaluation of morphologic gland changes. The constant measuring situation regarding illumination and region of interest provides best basic requirements for long-term studies, follow-up investigations and for the monitoring of the progress of MGD.

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contact: Corresponding Author: Martina Sinnig E-Mail: m.sinnig@jenvis-research.com; Ernst-Abbe-University of Applied Sciences, Carl-Zeiss-Promenade 2, 07745 Jena, Germany