Tear film stability assessment by corneal reflex image degradation

Mikel Aldaba[1*], Alejandro Mira-Agudelo[2], John Fredy Barrera Ramírez[2], Carlos Enrique García-Guerra[1] and Jaume Pujol[1]

[1]Centre for Sensors, Instruments, and Systems Development (CD6), Universitat Politècnica de Catalunya (UPC), Terrassa, Spain

[2]Grupo de Óptica y Fotónica, Instituto de Física, Facultad de Ciencias Exactas y Naturales, Universidad de Antioquia (UdeA), Medellín, Colombia

*Corresponding author: mikel.aldaba@upc.edu

A method for tear film break up measurements based on the degradation of corneal reflex images caused by dry spots is presented. The experimental setup, which is based on recording the corneal reflex image or the first Purkinje image, is described, as well as the method used to determine tear film stability by means of the associated break up time using the corneal reflex image degradation. Images obtained through simulations of the experimental setup are also shown.

Keywords: clinical applications, ophthalmic optics and devices, dry eye, tear film

1. Introduction

There are several tests in clinical practice for dry eye diagnosis, such as questionnaires, measurements of tear film stability or break up time (BUT), staining, and reflex tear flow. In recent years, big efforts have been made to develop objective and non-invasive methods based on new technologies. However, up to date, no gold standard exists for the diagnosis of dry eye, and some of the methods based on new technologies are unfeasible in clinical environments because they cannot be adapted for daily clinical practice, where inexpensive and easy-to-use tools are needed [1].

After blinking, the tear film is regenerated in a process that takes a few seconds, and, afterwards, it degrades [2] and finally breaks up. The dry spots in the tear film cause abrupt height differences in its surface and, moreover, its smoothness can be lost if the corneal epithelium is exposed. When illuminated with coherent light, dry spots in the tear film could produce diffraction patterns and speckle on the corneal reflex image, caused mostly by phase differences. Thus, after blinking, the corneal reflex image would remain without significant changes until the break up, in which time the corneal reflex image would be altered or degraded due to the previously cited effects owing to phase differences induced by the dry spots.

In this work, we present a method for the assessment of tear film stability by means of break up measurements based on corneal reflex image degradation caused by dry spots.

2. Methods

<u>Setup and Image Processing</u>

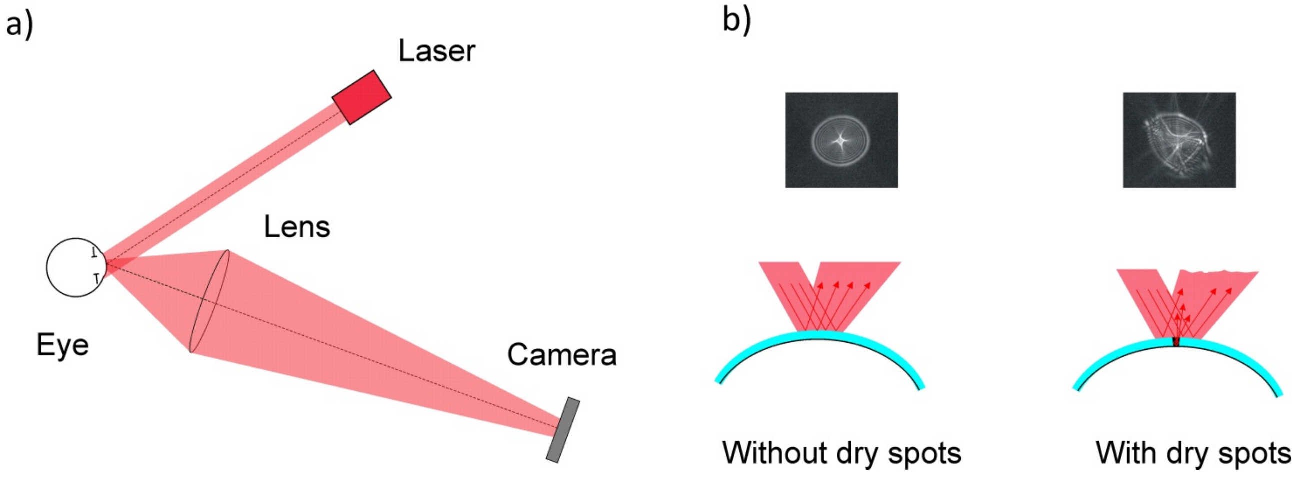

Figure 1. a) Schematic diagram of the proposed setup. b) Representation of light reflections on tear films and images recorded from (left) a smooth and regular tear film and (right) a broken up tear film with a dry spot.

The proposed setup consists of a system to record the corneal reflex image or first Purkinje image, as shown in Figure 1a. An infrared laser diode illuminates the eye. The light reflected on the tear film is recorded using a CCD camera after passing through a lens.

After blinking, the corneal reflex remains without changes (left image on Figure 1b), but when the dry spots appear, the corneal reflex image is degraded and the image breaks into several structures (right image on Figure 1b). Tear film stability is assessed by means of its break up time, the time interval between the last blink and the appearance of dry spots when blinking is prevented. In the proposed method, the appearance of dry spots is identified by the degradation of the corneal reflex. For this purpose the number of structures in which the image is broken as a result of the dry spots is counted. The number of counted structures is plotted against time and an exponential curve is fitted, the break up time corresponds to the moment when the number of structures abruptly increases, which is the end of the horizontal asymptote.

<u>Simulation</u>

The images obtained with the experimental setup were reproduced in simulations using Matlab. The cornea and the illumination conditions were approximated as a flat surface impinged by a collimated beam with a diameter of 4 mm with normal incidence. The length and the number of pixels of the surface were 8 mm and 256×256 pixels, respectively. In the presence of break up, the light reflected by the surface was simulated as a beam with constant amplitude and local phase variations at the location of the dry spots. The dry spots were circular structures 0.2 mm in diameter and 2.50±0.15λ (λ = 780 nm) deep, distributed randomly along the pupil.

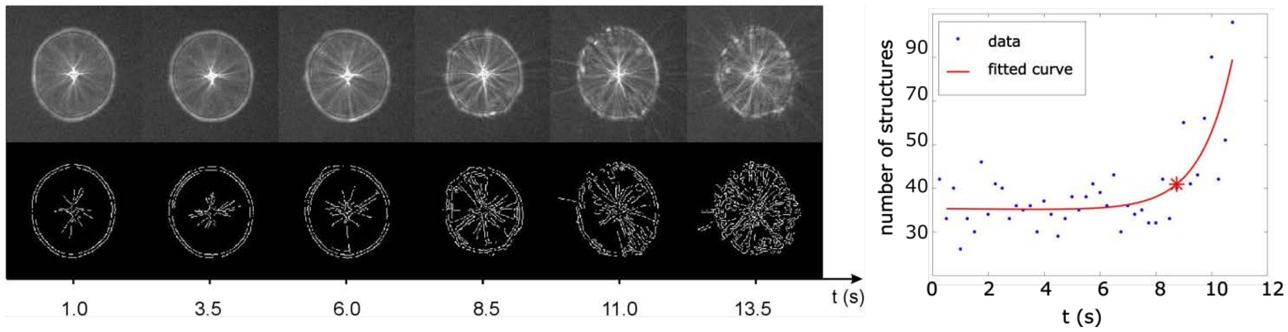

Figure 2. On the left, corneal reflex image sequence after blinking. Raw (upper) and binarized (lower) images are shown. On the right, number of structures counted plotted against time after blinking.

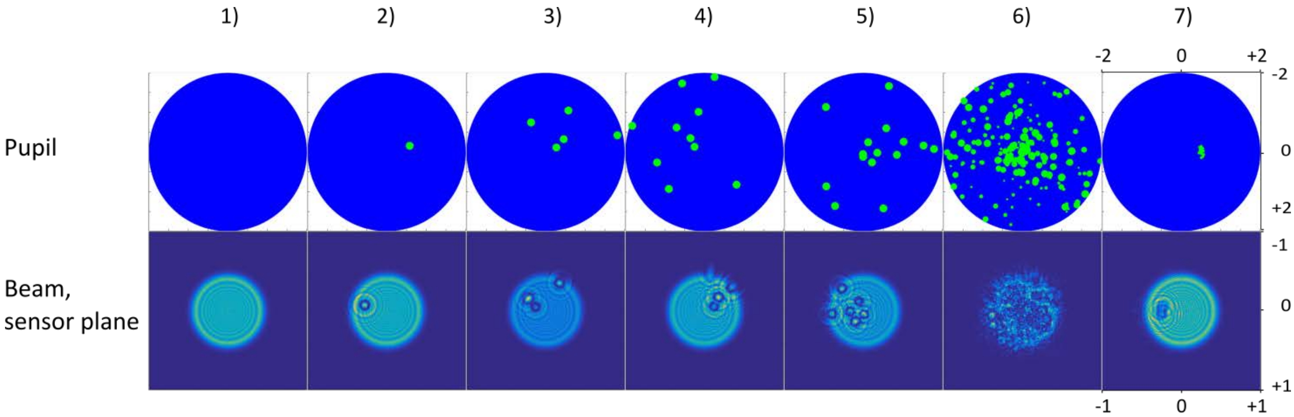

Fig. 3. Simulation of dry spots on the pupil plane (top) and the image in a defocused plane (bottom).

3. Results

In Figure 2 (left), the sequence of corneal reflex images after blinking for a particular case is shown from left to right, with a time interval of 2.5 seconds between each image. The first image on the left corresponds to a post-blink image. The upper images correspond to the raw images recorded, while the lower ones correspond to the binarized images used to count the number of structures. It can be seen in the figure that the raw images remained stable for some time (images 1 to 3) and degraded afterwards, mainly after the fourth image (8.5 seconds). In Figure 2 (right), the number of structures counted in the images after blinking are plotted versus time. As shown in the images themselves, it can be seen that, at first, the number of structures is stable, but when the image degrades, this number increases rapidly.

In Figure 3, for each simulated case, the images with the dry spots located in the pupil plane (top) and the image propagated to the sensor plane (down) are shown. The simulations showed structures similar to the patterns present in the real recorded images.

4. Conclusions

In summary, in this study, we investigated the suitability of a new method for measuring tear film break up time, based on the degradation of the corneal reflex images due to the appearance of dry spots. We have shown that the corneal reflex image degrades when the tear film breaks up, and our results are in accordance with our simulations. However, the proposed method has some limitations, such as reduced measured area, which could be overcome with a new design of the optical setup. In conclusion, this simple, objective, and non-invasive method is affordable for implementation as a system to measure tear film break up time, and may be used in clinical applications.

References

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