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# Computational approach for tear film assessment based on break-up dynamics

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Dry eye syndrome is a common disorder of the tear film which affects a remarkable percentage of the population, impacting on quality of life. The study of the tear film stability is essential for the dry eye characterisation. The Break-Up Time (BUT) is a clinical test which computes the time the first tear film break-up appears. Besides the time, break-up properties can be related to specific aspects of the tear film that could affect dry eye severity. This work describes a fully automatic methodology to compute the BUT measurement and evaluate the dynamics of break-up areas. This methodology has been tested on a data set consisting of 18 tear film videos, achieving similar results to the manual annotations marked by the experts. This analysis provides useful additional information for the tear film assessment.



## 1. Introduction

The tear film is a complex and dynamic trilaminar structure comprising an outer lipid layer, a middle aqueous layer and an inner mucous layer (Holly & Lemp, 1977). It covers the anterior surface of the cornea playing an essential role in the maintenance of ocular integrity health (Guillon, Maissa, & Styles, 1998). Abnormalities in any of the layers can lead to tear dysfunction problems. Concretely, the lipid layer plays a major role in retarding the evaporation of the tear film during the inter-blink period, and consequently, a deficit of this layer can cause the dry eye syndrome (DES) (Graig & Tomlinson, 2007). The DES is a multifactorial disease of the ocular surface, which affects a significant percentage of the population, and worsens with age Javadi and Feizi (2011); Lemp (2008); Lowther (1977). The prevalence of this syndrome has been increasing in recent years, affecting up to 10–15% of normal population, and 18–30% of contact lenses users. Several factors, such as adverse environmental conditions, use of certain

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medications, or visual tasks that reduce blink rate have contributed to that increment (Fenga et al., 2008; García-Resúa, Lira, & Yebra-Pimentel, 2005). This disease alters some visual functions such as contrast perception and eye acuity, resulting in symptoms of discomfort and visual disturbance which impact on quality of life (Tutt, Bradley, Begley, & Thibos, 2000; Nichols, Begley, Caffery, & Jones, 1999).

The diagnosis of this condition is difficult due to its multifactorial etiology (Khanal, 2008). Normal tear film dynamics require adequate production of tears, retention on the ocular surface, and balanced elimination. Disruption of any of these processes can lead to the condition of dry eye (Tomlinson & Khanal, 2005). Thus, the composition and behaviour of the tear film provide crucial indicators, so the tear film assessment is essential for DES characterisation (Guillon, 1998). There are several clinical tests to evaluate the quality and stability of the tear film on the ocular surface. Among the different tests available, the Break-up Time measure has been widely used in clinical practice. It consists of measuring the time that the tear film remains stable without blinking (Cho et al., 1992; Cho & Brown, 1993; Lee & Kee, 1988). To perform this test, sodium fluorescein is instilled into the eye using a micro-pipette, and the tear film is observed with the help of cobalt-blue filter attached to a slit lamp biomicroscope, and a yellow filter to improve the visibility of the fluorescein emission (Elliott, Fandrich, & Simpson, 1998; Johnson & Murphy, 2005). The patient is instructed to blink three times naturally, without squeezing, in order to distribute the fluorescein over the cornea, and then, he/she maintains the eye open as long as possible (Begley et al., 2006). The BUT is measured as the time elapsed between the last blink and the first appearance of a dark spot on the surface of the cornea, which represents the evaporation of water and the break-up of the tear film. A low BUT measurement corresponds to a limited ocular surface wetting, and it is one of the main signs of an abnormal tear film.

The BUT test is affected by low repeatability mainly due to a subjective appreciation of the dark spots, the differences among the experts, and the variability of the tear film. The automation of the break-up assessment would reduce its subjective character, allowing a more accurate evaluation of the tear film stability. A preliminary approach for the automation of the BUT test was conducted in (Cebreiro, Ramos, Mosquera, Barreira, & Penedo, 2011; Ramos et al., 2012). This methodology provides a BUT measurement through an algorithm which consists of locating the different measurement areas from the video sequence, extracting the region of interest, and performing the BUT test over each measurement area. The BUT test only examines the appearance of the first dark spot in the tear film, regardless of the subsequent break-up dynamics. However, the first break-up could appear as a small point or as a large area and its size could increase faster or slower with time. This information is omitted in the BUT test, but it is relevant for understanding tear film instability and its relation to other ocular surface symptoms in dry eye syndrome (Begley et al., 2006). Even though this is an interesting research field, there is no automatic techniques for analysing the break-up evolution in the literature. Therefore, in this work, an automatic methodology is proposed for characterising tear film dynamics over the exposed corneal surface from the emergence of the first break-up in the tear film until the later blink. To this end, the BUT measurement is computed and the break-up areas are segmented in each video frame in order to analyse other break-up parameters, such as size or growing rate.

This paper is organised as follows. Section 2 describes the methodology developed for the break-up dynamics assessment. Section 3 summarises the results obtained with the methodology. Finally, Section 4 presents the conclusions and future work.

## 2. Methodology

Each tear film video has a duration of several minutes and contains different sequences of interest (SOIs). Each SOI consists of a set of frames between consecutive blinks where the patient maintains the eye open. This way, each SOI contains zero or one BUT measurements. Thus, after the initial full blink which marks the beginning of the SOI, the fluorescein spreads uniformly over the stable tear film. As time passes, the tear film loses stability, and dark areas appear related to the tear film break-up. These rupture zones evolve until the final blink, which marks the end of the SOI. A image processing methodology has been proposed in previous works to automatise this task (Cebreiro et al., 2011; Ramos et al., 2012). This methodology has several stages, as shown in Fig. 1.

The first stage consists of extracting the data of interest for break-up evolution assessment (Ramos et al., 2013). It comprises a step for locating the different SOIs and another step for extracting the region of interest (ROI) within each tear film frame. The ROI in each SOI frame corresponds to the visible part of the iris which may vary slightly throughout the sequence depending on the eye aperture and shadows due to outer parts of the eye like eyelids or eyelashes.

Once the SOIs are delimited and the ROI is extracted, a preprocessing stage is performed. First, the illumination issues are corrected by means of a contrast normalisation algorithm and, after that, a gray level analysis is performed in order to isolate the break-up areas. Finally, the main stage of this methodology is the tear film dynamics assessment. It consists of measuring the size and growing rate of the break-up areas from the first frame with dark spots until the final blink. For this purpose, the BUT measurement is computed first, and, after that, the break-up areas are segmented and analysed until the end of the SOI. These stages are explained in more detail in the following sections.

### 2.1. *Selection of sequences of interest*

The SOIs forming the tear film video are located as the areas between two consecutive blinks, which delimit the beginning and end of each SOI. These blinks correspond to transitions from closed to open eye and vice versa. If the eye is open, the bright part corresponding to the sclera occupies a significant percentage of the frame, as shown in Fig. 2 (left). Meanwhile, if the eye is closed, the eyelid takes up the entire frame, so, as a consequence, it presents a darker tonality, as shown in Fig. 2 (right).