

KINETIC TEAR INTERFERENCE IMAGE ANALYSIS

1. Ocular Surface Center Code: T 1001

2. Introduction:

Ocular surface health is maintained by a stable preocular tear film, which is made of lipids (primarily derived from meibum excreted from meibomian glands), aqueous fluid (secreted mainly by lacrimal glands), and mucins (secreted by ocular surface epithelial cells including conjunctival goblet cells) [reviewed in ^{1,2}]. After each eyelid blink the above-described tear components are spread over the ocular surface to form a tear film, which often breaks up into dry spots before the next blink. During the inter-blink interval, a stable tear film ensures ocular comfort, helps provide clear vision, and serves as a first line of defense against microbial infections. An unstable tear film is the hallmark of many dry eye states [reviewed in ³].

One requirement for maintaining a stable tear film is that the sufficient amount of superficial lipids must spread rapidly into a thin film with appropriate thickness and uniformity. Such a lipid film helps stabilize the entire tear film by lowering the air-fluid surface tension and preventing aqueous tear evaporation [reviewed in ^{4,5-8}].

Tear interferometry has been used as a non-invasive method to visualize and evaluate the tear lipid layer.^{9-11 12 13-15 16;17 18 19;20} Realizing that a random, non-time controlled single image of tear interference may not represent what exactly happens during the inter-blink interval, we have incorporated kinetic analysis to measure the speed and pattern of lipid film spread and resultant thickness and distribution²¹ [Goto and Tseng, manuscript submitted, 2001].

3. Method of Operation:

Instrument Set Up

To obtain tear interference images, we used the instrument, DR-1® (Kowa, Inc., Nagoya, Japan) the same as that used by Yokoi et al.^{18;19}. DR-1 has the advantages of acquiring an image including the entire central cornea, a sharp focus on the tear lipid without the iris background, a high quality 3 chip CCD camera, and a full speed NTSC video output. In this study, we set the magnification at 12x, which allowed observation of 8 mm in diameter of the cornea. To obtain kinetic recording, we link DR-1® video output with a frame grabber, i.e., FlashBus MV Lite® (Integral Technologies, Indianapolis, IN, USA), and digitize sequential video images as uncompressed AVI format using ImagePro 4.1® (Mediacybernetics, Silver Spring, MD, USA). The frame rate is set at 5.18 frames per sec. The record is done for 29 sec in one session, which generated 150 frames (131 mega byte video file). A representative blink, which started with a complete eyelid blinking and its inter-blink interval, is selected. These sequential video images are then extracted as uncompressed TIFF file, which can be made into a thumbnail composite and subjected to subsequent image analysis without the loss of image quality and change

in the color information. The instrumental set up is depicted in Figure 1. The examination room is set at the same light intensity (350 lux), humidity (45.2 – 54.0%), and temperature (21.0 – 22.7 °C). For each testing, the DR-1 light source intensity is set exactly the same in each patient at the level that patients does not have any complaint with the brightness from the DR-1 camera.

Pattern and Speed of Lipid Spread

The composite of thumbnail images allows us to discern the pattern of lipid spread before it reached a stable image. The lipid spread starts with a lipid film visible in the lower cornea adjacent to the lower lid margin, following an upward excursion of the upper lid. The spread pattern is recorded as horizontally propagating, vertically streaking, mixed horizontal and vertical pattern, or unclassified. The time interval in sec between time 0 to the time of the frame, which reaches the first stable lipid interference image is defined as the speed of lipid film spread to reach a stable image.

Distribution of the Lipid Film Thickness

Thickness measurements are performed by judging the color of the frame at 0.4 sec for both normal and ATD patients, and the frame which shows a stable image in LTD patients using two look up tables (LUT), one from a previous report²² and the other kindly provided from Kowa Company. To estimate the distribution of lipid film thickness, we measure three spots at the inferior cornea, central cornea and superior cornea, respectively, for both normal subjects and ATD patients. The variance among the thickness measurements of these three spots is used to judge the evenness (distribution) of the lipid film thickness. Because the look-up table is semi-quantitative, we also analyze the intensity histogram on a defined area of the entire 8 mm in diameter image, excluding the upper corneal area that was frequently covered by lashes. This measurement gives an average and standard deviation of the intensity with the brightness value ranging 0 to 255. Furthermore, the intensity of RGB spectrum is also displayed to evaluate whether the distribution of RGB color spectrum was uniform or not.

4. Interpretation:

Three major diagnoses can be made based on the pattern and speed of lipid film spread, and the thickness and distribution of the resultant lipid film. This test can give the diagnosis of normal, aqueous tear deficiency (ATD), and lipid tear deficiency. This information is summarized in the Figure shown below.

5. Clinical Uses:

- 1) To determine whether the tear film is stable (normal) or not using a non-invasive means
- 2) To differentiate those with unstable tear film (dry eye) into two types: lipid tear deficiency (LTD)²¹ and aqueous tear deficiency (ATD)²³ dry eye

- 3) To determine if punctal occlusion is effective in restoring a stable tear film with normal lipid film. If not, further therapies to restore the lipid film is necessary.
- 4) To determine if therapies to restore the lipid film is indicated in LTD patients. They include lid scrub to Demodex infection, hot compress, replacement of missing meibum lipids, etc.

6. Literature:

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