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Analysis of Ocular Surface Temperature in Patients with Dry Eye

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Abstract

Background: Ocular surface temperature (OST) has been widely investigated using the principle of recording the infrared radiation (IR) emitted by the ocular surface.OST changes have been reported in different ocular diseases, such as glaucoma, choroidal abnormalities, and dry eye.

Aim of Study: The objective of this study was to investigate the relationship between tear film evaporation rate and ocular surface temperature in patients with mild to moderate dry eye.

Material and Methods: Twenty-five patients with dry eye (average age, 42.61 ±9.77 years) were recruited for this study. An infrared camera was used to measure the ocular surface temperature. The geometric center of the cornea was estimated manually by drawing a circle with approximately 4-mm diameter at its center, and the mean temperature of this circle area was calculated. Thermal images of the ocular surface were continuously recorded for 60 seconds at a frame rate of 30Hz. The tear film evaporation rate was determined using a handheld closed chamber evaporimeter. Three measurements were obtained; then, the average value was calculated.

Results: The measured ocular surface temperature was lower in the dry eye group (33.74±0.058ºC) than in the control group (33.92±0.57ºC). The tear evaporation rate was significantly greater in patients with dry eye (77.37 ±23.07) than in the control group (49.53±15.36g/m^2/h).

Conclusion: This study demonstrates that the ocular surface of patients with dry eye is cooler compared to that of healthy individuals (<0.2ºC). The significantly increased tear film evaporation rate may explain the reduction in ocular surface temperature (OST) among patients with dry eye.

Key Words: *Ocular surface temperature – Tear film evaporation rate – Dry eye syndrome.*

Introduction

DRY eye is a multifactorial disorder of tear film and ocular surface that can lead to complications, including ocular discomfort, visual disturbance, ocular surface damage, and ocular inflammatory events **[1]**. Dry eye is one of the most common reasons for seeking medical care. It adversely affects the quality of life of patients and represents an economic burden due to the cost of health care and loss of work productivity **[2]**.

Evaporative dry eye is one of the main subtypes of dry eye disease that is caused by excessive water loss from the ocular surface **[1]**. An increase in tear film evaporation can lead to tear hyperosmolarity and instability, which play an important role in the core mechanism of dry eye **[3]**. Since 1980, a number of measuring techniques have been utilized to evaluate the tear film evaporation rate. Many studies have reported an elevated evaporation rate in both aqueous-deficient and evaporative dry eye **[4-6]**. Alterations in tear film evaporation rate could be due to meibomian gland dysfunction, eyelid disorders, or low blink rate **[7]**.

Ocular surface temperature (OST) has been widely investigated using the principle of recording the infrared radiation (IR) emitted by the ocular surface. Central corneal temperature ranges between 32.8°C and 35.4°C **[8]**. Another study that utilized the principle of IR thermography has reported an OST range of 33-36°C **[9]**. OST can be influenced by many internal and external factors, such as room temperature, air flow, age, and ocular abnormalities [10].

OST changes have been reported in different ocular diseases, such as postherpetic neuralgia, glaucoma, choroidal abnormalities, and dry eye [11].IR thermography has been used to analyze the OST during or after ocular surgical procedures. A higher OST has been found during and after photorefractive keratectomy and cataract surgery **[12,13]**.

Changes in the OST and tear film of patients with dry eye have been reported. Morgan et al., used IR thermography to record the distribution of OST. The mean central OST of patients with dry eye was higher (32.38°C) than that of normal subjects (31.94°C) **[14]**. In contrast, another study

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reported that patients with dry eye have lower OST and faster cooling rate. It has been shown that patients with dry eye have an average central OST of 34.13°C compared to 34.77°C in normal subjects [15].

The objective of this study was to investigate the relationship between tear film evaporation rate and OST in patients with mild to moderate dry eye.

Patients and Methods

All study procedures were reviewed and approved by the College of Applied Medical Sciences Ethics Committee, King Saud University. The study was conducted in agreement with the tenets of the Declaration of Helsinki, and subjects provided written informed consent.

Patients with mild to moderate dry eye were recruited from optometry clinics at the College of Applied Medical Sciences, King Saud University. The patients were included in the study if they have a break up time <5s (Oculus Keratograph 4), [16] Schirmer test <10mm per 5min, and Ocular Surface Disease Index score >13 [17]. The subjects were excluded if they wear contact lenses or had any ocular or systemic conditions that could influence the tear film. Twenty-five patients (average age, 42.61±9.77 years) with dry eye were recruited in this study. Twenty-five normal, age-matched, healthy volunteers with no evidence of dry eye were recruited as controls.

All test procedures were performed in a controlled environment at 20.96±0.46°C and 42±2% humidity. For the purpose of environmental adaptation, the subjects were requested to set in the room for 10 min before starting the investigations for OSTand evaporation rate.

Thermography:

An infrared camera was used to measure the OST (FLIR T1010, FLIR Systems, Surrey, UK). The camera is self-calibrating comes with a high definition detector (focal plane array, uncooled microbolometer) with resolution of 1024 x 768 pixels and image frequency of 30 Hz and can detect a temperature range between –40 and +150ºC. The geometric center of the cornea was estimated manually by drawing a circle of approximately 4-mm diameter at its center, and the mean temperature of this circle area was calculated (Fig. 1). Thermal images of the ocular surface were continuously recorded for 60s at a frame rate of 30Hz. Measurements obtained during and immediately post-blink were excluded. All temperature measurements were then exported to an Excel spreadsheet and 600 thermal values were selected with exclusion of the reading recorded immediately after blink.

Evaporimetry:

The tear film evaporation rate was determined using a handheld closed chamber evaporimeter (Vapo Meter, Delfin Technologies, Kuopio, Finland) [6]. This handheld portable device was fitted to a swimming goggle to measure the evaporation rate of the eye and surrounding skin. Two readings were taken; the first was taken with eyes open, and the second was obtained with eyes closed, which represent the evaporation rate from the surrounding skin only. Then, the second reading was subtracted from the first reading to calculate the magnitude of water (tear) loss from the ocular surface. Three measurements were obtained; then, the average value was calculated.

Statistical analysis:

All data were statistically analyzed using IBM SPSS Statistics (IBM corporation, Somers, NY, USA). First, a test of normality was carried out using Kolmogorov-Smirnov test. Normally distributed data were compared using Independent Sample p-test. Non-normally distributed data were compared using Mann-Whitney U test.

Results

The mean and standard deviation of OSTsand evaporation rates measured in the dry eye group and control group are shown in Table (1). Although the measured OSTs were lower in the dry eye group (33.74±0.058°C) compared with the control group (33.92±0.57°C), the parametric statistical tests showed no significant difference in OST between the two groups (p=0.26) (Fig. 2).

A boxplot of tear film evaporation rate is shown in Fig. (3). Unlike OST, the tear evaporation rate in the dry eye group (77.37±23.07g/m^2/h) was significantly higher than that in the control group (49.53±15.36g/m^2/h). Spearman's Rho test showed no statistically significant correlation between OST and tear evaporation in both study groups.

Table (1): The mean and standard deviation of ocular surface temperature and evaporation rate measured in control and patients with dry eye.

	Control	Dry eye
Ocular surface temperature (°C)	33.92±0.57	33.74±0.058
Tear Evaporation rate (g/m^2/h)	49.53±15.36	77.37±23.07

Fig. (1): Ocular thermogram displayed on PC screen with a circle of approximately 4mm represents the estimated geometric center of the cornea.

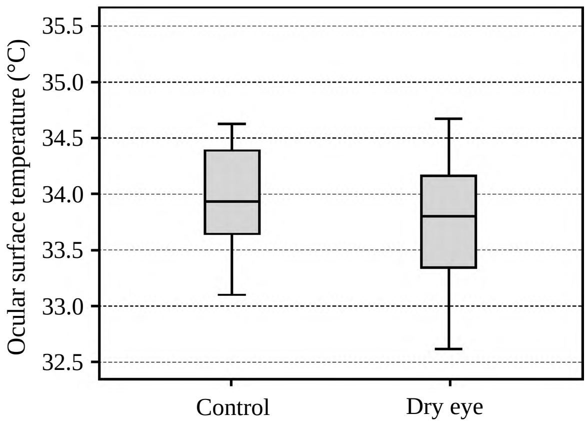

Fig. (2): Side-by-side boxplot for the ocular surface temperature of study and control groups.

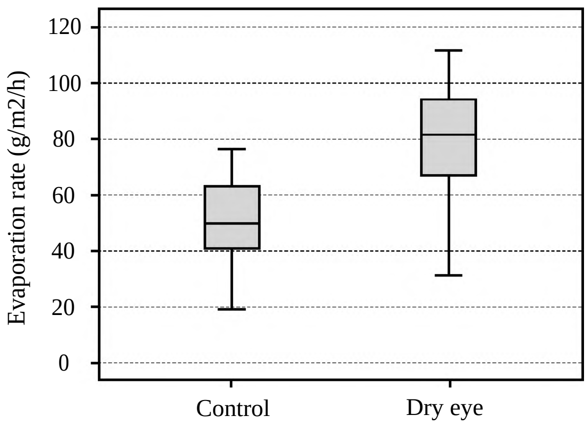

Fig. (3): Side-by-side boxplot for the evaporation rate of study and control groups.

Discussion

Numerous contact and noncontact techniques have been developed to measure the OST. Contact techniques, such as mercury-in-glass thermometers, thermistor probes, and liquid crystal contact lenses, have been used to measure the OST [9,18].

The first infrared measurement of OST was conducted by Mapstonein 1968. In the 1990s, Morgan et al., used second-generation infrared cameras to record the distribution of ocular temperatures [14]. Unlike infrared thermometers that provide a single temperature measurement, infrared thermograms record the distribution of temperatures using the IR emitted from the ocular surface. Infrared thermo-cameras utilize either scanning array or focal plane array photo sensitive detectors to produce a digital infrared thermograph.

OST measurement received considerable attention due to its well-established correlation with many ocular diseases, such as dry eye, carotid artery stenosis, unilateral exophthalmos, Graves' ophthalmopathy, bulbar conjunctival hyperemia, diabetic retinopathy, central retinal vein occlusion, glaucoma, and inflammation of the lacrimal drainage system [19,20,21]. Environmental factors, such as air flow and ambient temperature, could also influence the OST. A previous study has reported that the central corneal temperature decreased from 34.72±1.6°C to 31.9±1.6°C when the room temperature decreased by 4°C [22]. Another study reported a reduction of 4°C in OST when the ambient temperature decreased from 25 °C to 5°C [23].

In this study, infrared thermal imaging was utilized to monitor the OST of patients with dry eye. Patients with dry eye (33.74±0.058°C) had lower central corneal temperature than the control group (33.92±0.57°C). This is in agreement with previous studies that reported a lower corneal temperature by 0.2°C and faster cooling rate in patients with dry eye [24].

Craig JP et al., reported a greater difference in OST between patients with dry eye and normal subjects, where the OST was 0.58°C lower in patients with dry eye [25].

The observed reduction in corneal temperature could be attributed to the increase in tear evaporation rate in patients with dry eye. In this study, patients with dry eye showed a higher tear film evaporation rate. This correlates well with previous studies, suggesting that patients with aqueous or evaporative dry eye have higher tear film evaporation rates [26]. Excessive tear evaporation can be caused by many internal or external factors. One of the most common reasons for the increase in tear film evaporation is meibomian gland dysfunction, as the lipid layer works to decrease surface tension and minimize tear evaporation [27].

In contrast, studies have reported a higher OST in patients with dry eye. Morgan et al., suggested that patients with dry eye have a greater corneal temperature compared to normal subjects. The mean OST of patients with dry eyewas 0.44 °C lower **[14]**. Another study has shown that although patients with dry eye showed a faster reduction in OST following eye opening, they showed an increased OST **[28]**. A correlation between OST and ocular blood flow is well-documented. Moreover, an increase of 0.5 °C in ocular temperature has been noted in subjects with bulbar conjunctival hyperemia **[29]**. Dry eye is associated with signs of inflammation and eyelid and conjunctival hyperemia; therefore, the elevated OST seen in patients with dry eye could be caused by an increased ocular blood flow.

However, the differences in the reports could also be due to the use of different measuring techniques or differences in environmental temperature range over, which OST was observed. Moreover, a possible explanation for these conflicting results may be the variety of anatomical localization methods that were used for OST measurement.

Conclusion:

This study demonstrates that the ocular surface of patients with dry eye is cooler compared to that of healthy individuals (<0.2 °C). The significantly increased evaporation rate of tear film noted in this study may explain the reduction in OST among patients with dry eye. IR thermography can potentially provide clinicians with a readily available method to monitor ocular surface abnormalities.

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تحليل درجة حرارة سطح العين
فى مرضى جفاف العين

تشكل الطبقة الدمعية للعين خط الدفاع الأول لسطح العين وتقدم عدداً من الوظائف ومن أهمها ترطيب سطح العين وتقديم الحماية والتغذية اللازمة له. تتأثر الطبقة الدمعية للعين بعدد من العوامل الداخلية والخارجية المحيطة بالعين مما يؤدى إلى تأثر فى طبقات الدمع واختلال وظائفها.

الخلفية: يعتبر قياس درجة حرارة سطح العين من الوسائل الحديثة التى تستخدم مؤخراً لمراقبة صحة العين فى عدد من الحالات المرضية المتعلقة بالعين. تستخدم كاميرات الأشعة فوق الحمراء لقياس حرارة سطح العين بشكل امل وبدون أى اتصال مباشر مع العين من ما يوفر إليه آمنة وصحية لعمل مثل هذه القياسات.

الهدف من البحث: الهدف من الدراسة الحالية هى مراقبة درجة حرارة سطح العين وعلاقتها بمعدل تبخر الدمع فى الأشخاص الذين يعانون من أعراض متوسطة لمتلازمة جفاف العين. تم استخدام خلال هذه الدراسة كاميرا حرارية تستخدم تقنية التصوير باستخدام الموجات فوق الحمراء، تم قياس درجة حرارة العين عن طريق التصوير المباشر لمدة دقيقة كاملة بمعدل ٣٠ هرتز. كما تم مراقبة قياسات تبخر الدمع بواسطة جهاز قياس تبخر الجلد بعد أن تم تعديله بتركيب أطار نظارة واقية حول العين لقياس التبخر الناتج من سطح العين.

أظهرت نتائج الدراسة: انخفاض درجة حرارة العين فى مرضى متلازمة جفاف العين مقارنة بالعينة الطبيعية. كما اتضح من النتائج أن معدل التبخر الدمعى للعين يكون مرتفع بشكل ملحوظ فى مرضى جفاف العين. تظهر الدراسة الحالية الإمكانية الكبيرة لتقنية الكاميرا الحرارية لمراقبة ومتابعة أمراض سطح العين من خلال تتبع أنماط التغيير فى حرارة سطح العين.