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Comparison of noncontact infrared and remote sensor thermometry in normal and dry eye patients

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PURPOSE. *To evaluate the role of closed chamber infrared and remote sensor thermometry in normal and dry eye patients.*

METHODS. *The study was conducted on 51 dry eye cases (102 eyes), 26 men and 25 women aged 19 to 65 years (35.36±14.36), and 51 normal (102 eyes) age- and sex-matched control subjects. The criteria for dry eye were Schirmer-1 (<10 mm/5 min), FTBUT (<10 sec), and lissamine green score (>2). The remote sensor and infrared thermometry was done in closed chamber around the eye in closed and open eye positions.*

RESULTS. *In normal eyes, closed chamber infrared thermometry recorded temperature 34.77±0.37 °C in closed eye position and 35.02±0.39 °C in open eye position as compared to 27.91±2.46 °C in closed eye position and 28.01±2.46 °C in open position with remote sensor thermometry. The difference in temperature from closed to open position was 0.25±0.90 °C in infrared thermometry and 0.10±0.00 °C with remote sensor thermometry, which was statistically significant (p<0.0000). In dry eye, the infrared thermometry recorded 35.08±0.61 °C temperature in closed eye position and 35.53±0.63 °C in open eye position as compared to 27.41±2.48 °C in open and closed eye position with remote sensor thermometry. The difference in temperature from closed to open eye position was 0.45±0.14 °C (p<0.0000) with infrared thermometry as compared to no change 0.00±0.00 °C with remote sensor thermometry (p<0.0000).*

CONCLUSIONS. *Remote sensor thermometry proved better for diagnosis of dry eye disease as it showed no change in temperature under closed chamber in closed and open position (p=0.0000). Infrared thermometry was better in recording the absolute temperature from any point on the eye. (Eur J Ophthalmol 2005; 15: 668-73)*

KEY WORDS. *Thermometry, Remote sensor, Infrared, Dry eye*

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INTRODUCTION

Infrared thermometry was employed by Alio and Padron (1) to study the temperature of the anterior segment of the eye in normal individuals between 15 and 80 years of age, who noted a decrease with advancing age. Efron et al (2) used a wide field color coded infrared imaging device and noted that following a blink, the geometric center of cornea showed cooling at a rate of 0.03±0.02 °C per second (p=0.001). Mori et al (3) measured corneal temperature by infrared thermography and noted a K value of dry eye 5.6±2.9 °C per second, which was significantly less than the control group (9.3±1.5 °C per second; p<0.05). They further noted a decline in temperature in patients with dry eye that was significantly less than in normal subjects.

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Fig. 1 - *Remote sensor thermometer with a silicone closed chamber.*

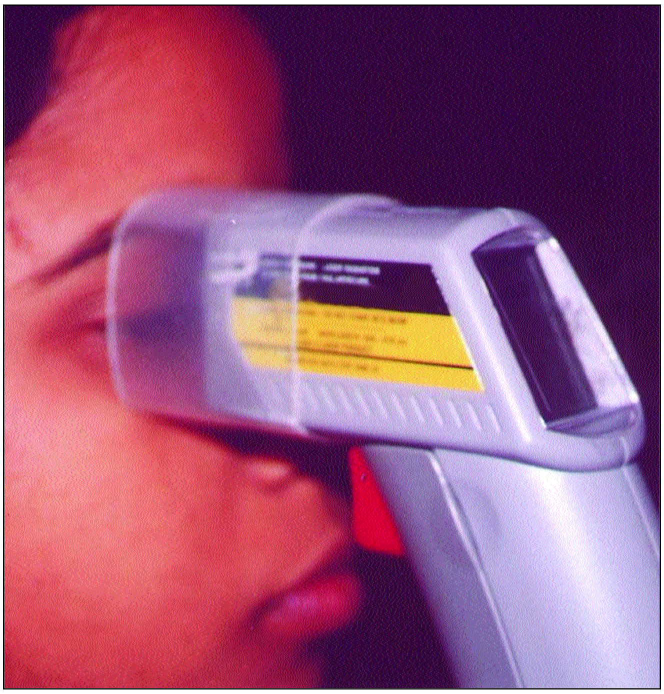

Fig. 2 - *Recording thermometer for infrared thermometry with a silicone closed chamber fitted on the mouth of the thermometer.*

Morgan et al (4) also measured the temperature of the cornea by infrared thermography and found a greater difference between the limbus and the center of the cornea in patients in dry eyes.

Morgan et al (5) subsequently recorded a mean temperature in dry eye 32.28±0.69 °C compared with 31.94±0.54 °C in control group ($p<0.01$). Infrared thermometry has been employed by Fujishima et al (6), who noted a decrease in corneal temperature after keeping the eye open for 10 seconds in dry eye as 0.21±0.06 °C compared to 0.61±0.28 °C in normal patients.

Singh and Bhinder (7) performed closed chamber noncontact thermometry in normal and dry eyes in a closed chamber and noted that the temperature from the closed to open eye position was 0.1 °C higher in normal as compared to no change in dry eyes.

Although some workers (8) have compared infrared thermometry temperature with sensor thermocouple for monitoring skin temperature, tympanic membrane temperature (9), and core body temperature (10, 11), no studies are available to evaluate infrared thermometry and remote sensor thermometry in the analysis of ocular surface temperature. The aim of the present study is to report the critical values of these methods of recording the temperature of the eye.

MATERIALS AND METHODS

The study was carried out at GGSI Eye Research and Cure Centre, after obtaining informed consent, in 51 patients with dry eye (102 eyes), of which 26 were men and 25 were women aged 19 to 65 years (35.36±14.36 years), and 51 (102 eyes) age- and sex-matched control subjects. The study included the use of remote sensor thermometry and infrared thermometry in closed and open eye position after opening of the eye for 5 seconds. The average of two readings was recorded as the correct value. The thermometry was measured in Celsius scale. In addition, other dry eye tests were also carried out, e.g., Schirmer-1 test, FTBUT, fluorescein stain test, and lissamine green test. A detailed slit lamp examination using 10x was carried out to note the lacunar folds, meibomian expressivity, metaplasia of meibomian ducts, and debris in the tear film. The criterion of diagnosis of dry eye was Schirmer-1 test (<10 mm), FTBUT (<10 seconds), and lissamine green (>2).

Infrared noncontact thermometry

Infrared noncontact thermometry was measured with a heat tracer thermometer device (MT_2 -Raytak, USA),

Fig. 3 - *Infrared thermometer.*

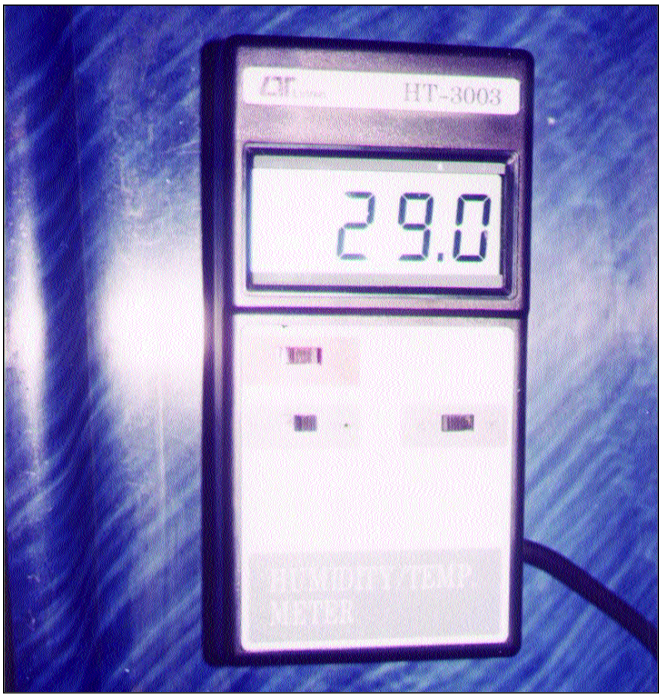

Fig. 4 - *LCD display for sensor thermometer.*

which is a small portable noncontact battery-operated infrared thermometer with a temperature range between -18 °C and 275 °C, accuracy of ±1 % of reading (±1 digit), reliability of ±0.5% of reading, spectral response of 7 to 18 µm, and response time 500 msec. This instrument exploits the inherent relationship between the temperature of a body and amount of electromagnetic energy that is emanated, expressed as radiant emittance (5).

All objects that have a temperature above absolute zero (-273 °C) radiate electromagnetic energy and when the lens of the heat tracer is pointed at a target, it collects and focuses the infrared band of the energy spectrum onto a detector. The latter responds by producing a voltage signal that is proportional to the amount of energy received, and therefore to the temperature of the target. This output is processed by the unit microprocessor and finally the temperature measurement is displayed. In our study the thermometer had a closed chamber with distance of 15 mm from the point of focusing of aiming laser and was handheld (Figs. 1 and 2). The resulting red cone shaped spot had a diameter of 2.5 mm on the target as the ratio of distance in spot was 8:1 and change in corneal temperature was automatically assessed every 500 msec. A closed chamber was devised which was rectangular and 40 mm x 30 mm. When the edge of the chamber was applied around the eye, the distance between the sensor probe and the eye was 15 mm. The infrared thermometry was used to record temperature in normal as well as dry eye patients on closing and opening of the eyes for 5 seconds and the average of two readings was taken.

Remote heat sensor thermometry

Remote heat sensor thermometry was used as a combined thermometry and humidity meter (HT3003-Lutron) (Figs. 3 and 4). There was a solid state capacitance heat sensor with a range of sensing 8 mm to 20 mm. It measured the temperature from 0 °C to 50 °C (32 °F to 122 °F), and is portable and battery operated. The sensor probe was round 40 mm diameter x 160 mm length, the temperature resolution 0.1 °C/0.1 F, and accuracy of ±0.8 °C. We used a closed chamber made of the silicone with its back sealed tightly on the probe and its mouth fitted with a special rubber sponge to make it airtight when it is placed around the eyes; the distance of the probe from the eye gets reduced from 20 mm to 15 mm. The first reading was taken with eyelid closed and the second reading was taken at the end of 5 seconds after opening of the eyes under the closed chamber. The readings were repeated twice and the average was taken as temperature.

The exclusion criteria for the study were intraocular surgery or severe ocular trauma 2 months preceding the tests, abnormality of lid position, patient currently wearing contact lens, history of dendritic keratitis, history of retinal detachment, exophthalmos, lid coloboma, lid entropion, enophthalmos, iridocyclitis, orbital cellulitis, and ocular growth.

Statistical analysis of the data was carried out using STATISTICA v. 5.0. Descriptive statistics were analyzed and t-test for independent samples was carried out in each. The total mean score of different factors was added in each group and compared with one another. p Value was calculated with t-test for independent samples. Regression analysis was used in the analysis.

RESULTS

The results with closed chamber thermometry were summarized in two groups of normal and dry eyes (Tabs. I and II).

In normal eyes the temperature in closed eye in infrared thermometry was higher (34.77±0.37 °C) as compared to remote sensor thermometry (27.91±2.46 °C). The temperature showed a significant statistical correlation (p=0.0000). Similarly, in open eye position, the temperature was higher with infrared thermometry (35.02±0.39 °C) than remote sensor thermometry (28.01+2.46 °C), which showed a statistically significant correlation (p=0.0000). The difference in temperature between closed and open eye position was 0.25±0.09 °C with infrared thermometry as compared to 0.10±0.00 °C with remote sensor thermometry, which was a statistically significant correlation (p=0.0000).

In dry eyes the temperature in infrared thermometry in closed eye position was 35.08±0.61 °C as compared to 27.41+2.46 °C with remote sensor thermometry, which showed a statistically significant correlation (p=0.0000). In open eye position, infrared thermometry showed a mean temperature of 35.53±0.63 °C as compared to 27.41±2.46 °C with remote sensor thermometry, which had statistically significant correlation (p=0.0000). The difference in temperature from closed to open eye was 0.45±0.14 °C in infrared thermometry as compared to 0.00±0.00 °C difference with sensor thermometry, which has statistically significant correlation (p=0.0000).

DISCUSSION

This study demonstrated the correctness and stability of absolute temperature readings with the closed cham-

TABLE I - CLOSED CHAMBER THERMOMETRY IN NORMAL EYE CASES

	Infrared Laser	Remote Sensor	p value
Close eye position	34.77±0.37 °C (34.40-35.20)	27.91±2.46 °C (20.40-32.60)	0.0000
Open eye position	35.02±0.39 °C (34.20-35.60)	28.01±2.46 °C (20.50-32.70)	0.0000
p value	0.045	0.8217	–
Difference between close and open eye positions	0.25±0.09 °C (0.20-0.40)	0.10±0.00°C (0.10-0.10)	0.0000

TABLE II - CLOSED CHAMBER THERMOMETRY IN DRY EYE CASES

	Infrared Laser	Remote Sensor	p value
Close eye position	35.08±0.61 °C (33.80-35.80)	27.41±2.46 °C (23.10-32.30)	0.0000
Open eye position	35.53±0.63 °C (34.20-36.20)	27.41±2.46 °C (23.10-32.30)	0.0000
p value	0.0130	0.9887	–
Difference between close and open eye positions	0.45±0.14 °C (0.20-1.00)	0.00±0.00°C (0.00-0.00)	0.0000

ber infrared noncontact thermometer as compared to the closed chamber remote sensor thermometer as the former was not required to be placed in direct contact with the hot body whose temperature was required and less affected by ambient conditions. Many workers (1-6) have carried out infrared thermometer measurements in normal and dry eyes and their observations as regards to the absolute temperature were comparable with our study. Their results could not be relied on as they pointed out the fallacies in their technique introduced by the unsteadiness of the examiner's hand, inability to keep the constant distance from the eye, wind and moisture currents, and variable angle of thermometer due to shifting site on the eye.

No studies are available in which infrared and remote sensor closed chamber thermometry have been compared. The remote heat sensor thermometer reports its own temperature (12) which is affected with the specific absorption rate (13) of the medium in which they are placed, thus measure the temperature of the medium. These remote sensor thermometers are influenced by junction current heating, heating of surrounding resistant tissue material, and eddy currents heating of wires in the oscillating magnetic field (14).

The closed chamber infrared temperature in normal eyes was higher (0.21±0.14 °C; p=0.0000) in closed eye (34.77±0.37 °C) and open eye position (35.02+0.39 °C) as compared to (0.10±0.00 °C; p=0.0000) closed (27.91±2.46 °C) and open (28.01±2.46 °C) eye position with remote sensor thermometry. Closed chamber infrared thermometry recorded in dry eyes an increase of temperature (0.45±0.14 °C; p=0.0000) from closed to open eye position as compared to no change (0.00±0.00 °C; p=0.0000) with remote sensor thermometry. The higher temperature in closed chamber infrared thermometry was due to a greater quantum of collection of emitted energy radiation (53%) by the sensor lens and a least effect of conduction and convention currents of evaporation. The temperature measured by remote sensor thermometry was the result of the total change in the closed chamber brought about by the evaporation of the tear fluid which being high in dry eye as compared to normal cases (7) tried to keep the temperature from closed to open eye position as constant (p=0.0000).

Closed chamber remote sensor thermometry was superior to closed chamber infrared thermometry in clinching the diagnosis of dry eye as it showed no increase in temperature from closed to open eye position as compared to 01 °C increase in normal eyes. However, closed chamber infrared thermometry showed an increase in temperature from closed to open eye as 0.25±009 °C in normal eyes as compared to 0.45±0.14 °C in dry eyes. As infrared thermometry records temperature from a single 2.5 mm point and due to evaporation, the temperature of the chamber does not affect the site of recording point temperature, which by losing more radiation as the less tears cover the recording site hence reads directly the temperature of the tissues as higher after 5 seconds of the opening of the eye. It appears that the total quantum of radiant energy released by opening the eye gets collected more with time in a closed chamber due to increased evaporation of tears in dry eye cases leaving behind a hot ocular surface. However, in sensor thermometry, the evaporation of tears in a closed chamber in dry eyes cools the chamber, leading to no increase in temperature on opening of the eye. This was due to increased rate of evaporation, which cools the probe, resulting in no increase of temperature. This observation is contrary to the observation of Fujishima et al (6) who noted a decrease in temperature after opening of the eyes after 10 seconds, which was 0.21±0.06 °C in dry eyes compared to 0.61±0.28 °C in normal eyes, which was due to multiple factors:

1) An increase in the evaporation of tears producing cooling effect at the site of recording;
2) Open ambient measurements;
3) Inconsistent site of recording;
4) Instability of the hand of the operator; and
5) Variability in distance of the thermometer from the eye

To overcome these fallacies in recording we devised a closed chamber made of silicone closely fitted in front of the mouth of the chamber so that it was 15 mm from the eye. This solved many problems as it gave stability to the placement of the probe around the eyes, gave a fixed point of measurement, and kept a definite distance of 15 mm from the eye. All the defects in measurement of temperature were corrected, which was seen by Fujishima et al (6).

The authors have no proprietary interest in any aspect of the article.

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