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# Closed chamber thermometry and humidity measurements in normal and dry eye patients: a pilot study

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PURPOSE. *To verify the diagnostic value of closed chamber thermometry and humidity measurement in normal and dry eye patients.*

METHODS. *In 20 patients (40 eyes) with dry eye and 20 normal sex- and age-matched controls (40 eyes), aged from 11 to 61 years (mean 37.52 yrs, standard deviation, (SD) 14.81) temperature was measured by infrared thermometry and humidity measured in a closed chamber 15 mm from the cornea. The temperature reading in °C and humidity in % (RH) were noted on closing and then opening the eye for five seconds.*

RESULTS. *The temperature rose significantly, by 0.11°C ± 0.02, between the closed and open eye positions ($p<0.000$) in normal eyes, but there was no change in dry eyes. The humidity in normal eyes in the closed position was 49.50 ± 4.67% and 50.03 ± 4.65% in the open position ($p<0.00001$). Humidity in the closed and open positions in dry eyes was 52.77 ± 7.13% and 53.59 ± 6.75% ($p<0.00000$). The difference between closed and open dry eyes was 1.25 ± 0.40%, compared to 0.54 ± 0.20% in normal controls ($p<0.005$). No relationship was found with age or sex.*

CONCLUSIONS. *Thermometry and humidity measurements in a dry eye patient had a 100% diagnostic value. The reading of no change in thermometry and more than 1% change in humidity were highly diagnostic of dry eyes. (Eur J Ophthalmol 2003; 13: 343-50)*

KEY WORDS. *Infrared, Thermometry, Dry eyes, Closed chamber, Humidity, Tear film break-up time (TBUT)*

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The criteria for diagnosis of a dry eye appear almost too simple and yet it often remains undiagnosed, causing physical discomfort and even visual impairment for a long time. Although there are many tests for tear film disorders (1-13), no single test can diagnose dry eyes. The Schirmer test gives a good clinical measure of tear flow but is fraught with many errors, including the quality of the paper used and the techniques employed, and is therefore still a gross test of an unphysiological variety.

The various dye dilution tests are subjective and involve sampling errors. The fluorometric technique of Maurice and Wright is also not suitable for clinical use. Tear film break-up time (TBUT) may vary in the same patient and is unreliable. Some workers (14-17) have tried to measure the evaporation rate of tears and others (1, 18-27). carried out thermometry in dry eyes. Their technique, however, did not take into account the changes induced in the eye by the environmental temperature so the results were often unreliable.

The present study made infrared thermometry and humidity measurements in a closed chamber around the eye in close and open eye positions and checked their usefulness in the diagnosis of dry eyes.

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## MATERIALS AND METHODS

The study was conducted in 40 dry eyes, 20 male and 20 female cases matched for sex and age with 20 normal subjects (40 eyes), ranging in age from 11 to 61 years (mean 37.52 ± S.D.14.81) at the G.G.S.I. Eye Research & Cure Centre, after obtaining written informed consent.

The patients all met the criteria for the diagnosis of severe dry eye syndrome, Schirmer test less than 5 mm, TBUT less than 5 seconds, phenol red-impregnated thread test less than 15 mm, rose Bengal and fluorescein staining score more than 3. Subjects with enophthalmos, exophthalmos, iridocyclitis, orbital cellulitis, ocular growths, severe purulent conjunctivitis or corneal ulcers were excluded.

Noncontact thermometry was done using a heat-sensor thermometer (HT-3003 Lutron, Hong Kong). This is a portable noncontact solid-state sensor with a temperature range of 0-60°C (32-140°F), accuracy 1% of the reading and reliability ± 0.8°C (1.5°F). This instrument exploits the inherent relationship between the temperature of a body and the amount of electromagnetic energy emitted, expressed as radiant emittance (23). All objects that have a temperature above absolute zero (-273°C) radiate electromagnetic energy, so the solid-state heat tracer (sensor), when pointed at a target, collects the energy on a detector. This responds by producing a voltage signal proportional to the amount of energy received, therefore to the temperature of the target. This output is processed by the unit's microprocessor and finally the temperature measurement is displayed.

Noncontact humidity was measured using a humidity meter. The humidity is measured with a probe with a high-precision thin-film capacitance sensor for fast response, not dependent on air movement. This is a portable noncontact solid-state sensor, with a round probe 20 mm in diameter and 160 mm long. The relative humidity (RH) measurement range is 10-95%. Accuracy at <70% RH is ±3.0% and above 70% it is ±3% of the reading + 1% RH.

To ensure accurate results, we devised a closed chamber with its back sealed tightly on the probe and its mouth fitted with a special rubber sponge to make it airtight when it was placed around the eye (Figs. 1-3). The tip of the sensor probe was kept 20 mm from the edge of the closed chamber. The chamber was round, and was 40 mm in diameter. When the edge of the chamber was applied around the eye, the distance between the sensor probe and eye was further reduced, from 20 to 15 mm.

The first reading of the eye temperature was recorded immediately after closing the eyes and positioning the closed chamber (Fig. 1). Then the patient was asked to open the eye for five seconds in the chamber and a second reading was taken. This was repeated twice and the average of two readings was used. The procedure was repeated in the second eye. The procedur for humidity reading was carried out in the same way.

All statistical data was recorded on a spreadsheet and analyzed using Microsoft Excel (Microsoft Corporation), Redmond, W.A., Software Version 9.0 (Office 2000) and the temperature and humidity values for normal and dry eyes were compared in the closed and open eye positions. Differences in temperature and humidity were subjected to ridge regression analysis and the Wilcoxon matched pairs test. The data was further analyzed for relationships between thermometry or humidity and sex.

The subjects were divided into two groups (group 1, 11-29 years and group 2, 30-61 years) for analysis of the relationship of thermometry or humidity with age.

## RESULTS

Table I shows the mean temperature in normal age- and sex-matched individuals and dry-eye cases, aged from 11 to 61 years (mean 37.52 ± 14.81), with the eyes closed or open inside a closed chamber. The differences in temperature were significant in both eyes. There was no difference in the temperatures in the closed and open eye position in dry eyes (Tab. II, Fig. 4), analyzed by the ridge regression test. However, the mean temperature of both normal eyes was 27.09 ± 1.36°C in the closed and 27.20 ± 1.36°C in the open position, while the mean temperature in dry eyes was 26.18 ± 1.04°C, and did not vary in the open and closed positions (Wilcoxon matched pairs test $p<0.005$).

Table I also sets out the mean humidity in all the normal age- and sex-matched individuals and dry-eye cases, with the eyes closed or open inside a closed chamber. There was a significant difference in humidity in the left eye, in the right eye and in both eyes. Dry

**Fig. 1 -** *The closed chamber of the thermometry apparatus in which the handle of the infrared sensor is placed.*

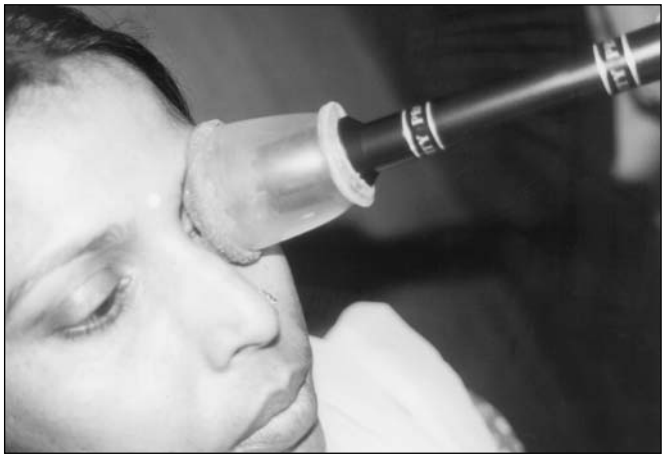

**Fig. 2 -** *The closed chamber applied to the closed eye of the patient.*

eyes showed a significant change in humidity in the closed and open positions (Fig. 5).

Table III shows the mean humidity in 40 normal and 40 dry eyes; the differences in mean humidity in dry eyes in the closed and open positions, and compared to normal eyes, was highly significant.

Table IV compares the temperatures in relation to age in normal (p=0.45 closed and p=0.44 open) and dry eyes (p=0.35 closed and p=0.35 open); the differences were not significant. Similarly the humidity values (Tab. V) did not show any significant relationship to age in normal (p=0.97 closed and p=0.96 open) and dry eyes (p=0.08 closed and p=0.08 open).

Table VI compares the temperatures in relation to sex in normal eyes (p=0.06 closed and p=0.06 open) and dry eyes (p=0.45 closed and p=0.45 Open); the differences were not significant. Similarly the humidity values (Tab. VII) did not show any relation to sex in normal (p=0.17 closed and p=0.18 open) and dry eyes (p=0.13 closed and p=0.11 open).


**Fig. 3 -** *General apparatus for thermometry.*

## DISCUSSION

In this study, corneal temperature was measured in a closed chamber placed around the eye, using a non-contact infrared thermometer and humidity meter. The method was safe, reproducible and non-invasive and to date is the most reliable way of analyzing changes in eye temperature (23).

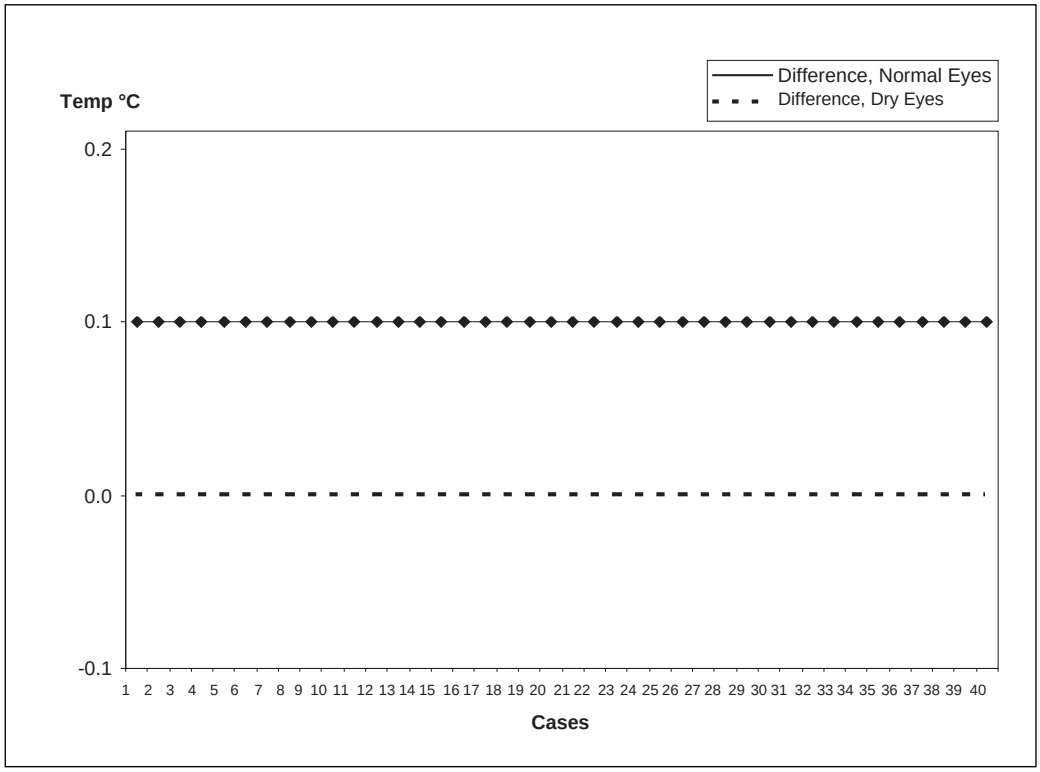


**Fig. 4 -** *The difference in temperature is 0.1°C between the closed and open eye positions in normal eyes but 0°C in dry eyes.*

Infrared thermometry has been employed by Fujishima et al (1) who noted that the corneal temperature change after keeping the eyes open for five seconds in dry eye was 0.21 ± 0.06°C, compared to 0.61 ± 0.28°C in normal patients (P=0.0001). Alio and Padron (18) also noted changes in the temperature at various points of the eye in 96 cases 16 days to 80 years old, with a decrease in temperature with age. Efron et al (19) noted the temperature of corneal center was 34.4 ± 0.7°C, which was coldest, and it rose by 0.45°C as it reached the limbus. Mori (20) et al measured corneal temperature by infrared radiation thermography and noted a k value of dry eye (5.6 ± 2.9°C per second) which was significantly less than in the control group (9.3 ± 1.5°C per second; p<0.05). They too noted the decline in corneal temperature in patients with dry eye was significantly less than in normal subjects. Morgan (21) et al also measured the temperature of the cornea by infrared thermography and found a greater difference between the limbus and center of the cornea

**TABLE I -** MEAN DIFFERENCES OF TEMPERATURE AND HUMIDITY IN NORMAL AND DRY EYES IN THE OPEN AND CLOSED POSITIONS

| | Temperature (°C) | | | Humidity (%RH) | | |
|---|---|---|---|---|---|---|
| | No. of cases | Normal | Dry eyes | No. of cases | Normal | Dry eyes |
| Left eye | 20* | 0.11±0.03 | 0.00±0.00 | 20* | 0.55±0.18 | 1.18±0.38 |
| Right eye | 20* | 0.10±0.00 | 0.00±0.00 | 20* | 0.53±0.22 | 1.32+0.42 |
| Both eyes | 40$^{+}$ | 0.11±0.02 | 0.00±0.00 | 40$^{+}$ | 0.54±0.20 | 1.25±0.40 |

$^{+}$p<0.000000 *p<0.000089
p value, Wilcoxon matched pairs test
p<0.05 is significant

**TABLE II -** CLOSED CHAMBER MEAN TEMPERATURE (°C) IN NORMAL AND DRY EYE

| **Normal eye** | **No. of cases** | **Closed** | **Open** | **p** |
|---|---|---|---|---|
| Left eye | 20 | 27.24±1.34 | 27.35±1.34 | <0.000000 |
| Right eye | 20 | 26.95±1.40 | 27.05±1.40 | <0.000000 |
| Both eyes | 40 | 27.09±1.36 | 27.20±1.36 | <0.000000 |
| **Dry eye** | **No. of cases** | **Closed** | **Open** | **p** |
| Left eye | 20 | 26.19±1.08 | 26.19±1.08 | <0.000000 |
| Right eye | 20 | 26.10±1.00 | 26.10±1.00 | <0.000000 |
| Both eyes | 40 | 26.18±1.04 | 26.18±1.04 | <0.000000 |

p value from ridge regression results
p<0.05 is significant

**TABLE III -** CLOSED CHAMBER MEAN HUMIDITY (% RH) IN NORMAL AND DRY EYES

| **Normal eye** | **No. of cases** | **Closed** | **Open** | **p** |
|---|---|---|---|---|
| Left eye | 20 | 50.06±4.83 | 50.60±4.83 | <0.000000 |
| Right eye | 20 | 48.93±4.56 | 49.46±4.51 | <0.000000 |
| Both eyes | 40 | 49.50±4.67 | 50.03±4.65 | <0.000000 |
| **Dry eye** | **No. of Cases** | **Closed** | **Open** | **p** |
| Left eye | 20 | 54.93±7.66 | 55.73±7.33 | <0.000000 |
| Right eye | 20 | 51.91±6.62 | 52.77±6.26 | <0.000000 |
| Both eyes | 40 | 52.77±7.13 | 53.59±6.75 | <0.000000 |

p value from ridge regression results
p<0.05 is significant

**TABLE IV -** CLOSED-CHAMBER TEMPERATURES (°C) IN RELATION TO AGE IN NORMAL AND DRY EYES

| **Normal eye** | **Closed** | **Open** | **p** |
|---|---|---|---|
| Group 1 (11-29 yrs) | 27.27±1.09 | 27.38±1.09 | <0.000000 |
| Group 2 (30-61 yrs) | 26.94±1.56 | 27.04±1.56 | <0.000000 |
| p | 0.45 | 0.44 | |
| **Dry eye** | **Closed** | **Open** | **p** |
| Group 1 (11-29 yrs) | 26.35±1.17 | 26.35±1.17 | <0.000000 |
| Group 2 (30-61 yrs) | 26.04±0.92 | 26.04±0.93 | <0.000000 |
| p | 0.35 | 0.35 | |

p value from ridge regression results
p<0.05 is significant

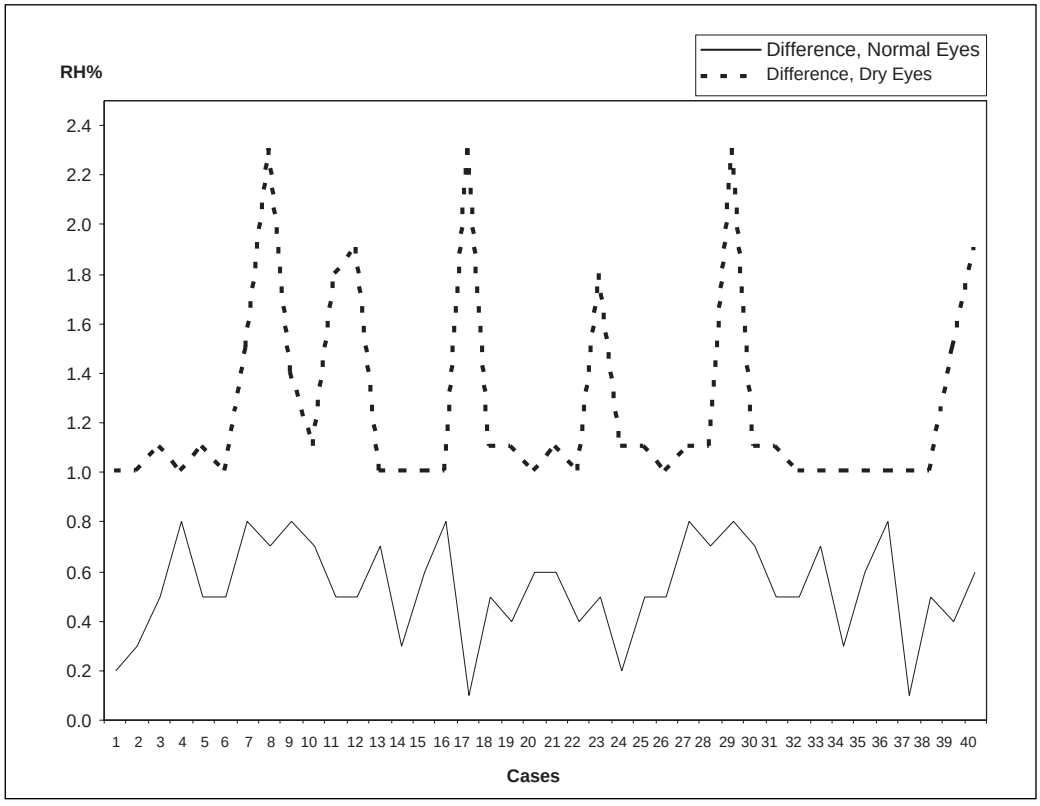


**Fig. 5 -** *The difference in humidity between the closed and open eye positions in normal eyes is less than 1%, but it is more than 1% in dry eyes.*

in patients with dry eye. Morgan (22) et al subsequently recorded a mean temperature in dry eye groups of 32.38 ± 0.69°C compared with 31.94 ± 0.54°C in the control group; p<0.01).

These temperatures (1,18-22) were all recorded in an open atmosphere so the readings cannot be relied on completely, as evaporation from tissue raises the temperature. However, we recorded temperature and humidity in a closed chamber positioned around the eye, when the eye was closed and then opened for

**TABLE V -** CLOSED-CHAMBER HUMIDITY (% RH) IN RELATION TO AGE IN NORMAL AND DRY EYES

| **Normal eye** | | | |
|---|---|---|---|
| | **Closed** | **Open** | **p** |
| Group 1 (11-29 yrs) | 49.46±6.40 | 49.99±6.38 | <0.000000 |
| Group 2 (30-61 yrs) | 49.52±2.72 | 50.06±2.69 | <0.000000 |
| p | 0.97 | 0.96 | |
| **Dry eye** | | | |
| | **Closed** | **Open** | **p** |
| Group 1 (11-29 yrs) | 54.96±6.56 | 56.21±6.65 | <0.000000 |
| Group 2 (30-61 yrs) | 50.63±6.70 | 51.79±6.69 | <0.000000 |
| p | 0.08 | 0.08 | |

p value from ridge regression results
p<0.05 is significant

five seconds. Dry-eye patients had an average temperature of 26.18 ± 1.04°C for closed and open eyes, compared to 27.09 ± 1.36°C for the closed normal eye and 27.20 ± 1.36°C for the open eye (p<0.005). Moreover, the temperature did not change in five seconds of opening the dry eye, whereas in the normal eye there was a highly significant difference (0.11 ± 0.02°C, p<0.00000). The lack of change in the temperature of dry eyes when open or closed in the closed chamber is due to increased evaporation compared to normal eyes, and needs further evaluation.

In conclusion, we found that infrared closed-chamber thermometry is non-invasive, quick and a most reliable tool for diagnosing dry eye. We found that the humidity measurement in a closed chamber permitted a valuable diagnostic conclusion. The difference in humidity was 1.25 ± 0.40% in dry eyes from the closed to open positions as compared to 0.54 ± 0.20% in normal eyes (P<0.005). Instead of calculating the coefficient of tear evaporation the humidity itself had diagnostic value. A difference in humidity of more than 1% from the closed to the open eye position in five seconds in the closed chamber was diagnostic of dry eyes. No such conclusions have been drawn from any previous work. The higher RH in the closed chamber indicates a high tear evaporation rate, which can be helpful in establishing the severity of dry eyes and may even provide a basis for a new classification. This

**TABLE VI -** CLOSED-CHAMBER TEMPERATURE (°C) IN RELATION TO SEX IN NORMAL AND DRY EYES

| **Normal eye** | | | |
|---|---|---|---|
| | **Closed** | **Open** | **p** |
| Male | 27.49±1.19 | 27.60±1.93 | <0.000000 |
| Female | 26.69±1.43 | 26.79±1.43 | <0.000000 |
| p | 0.06 | 0.06 | |
| **Dry eye** | | | |
| | **Closed** | **Open** | **p** |
| Male | 26.05±1.29 | 26.05±1.29 | <0.000000 |
| Female | 26.31±0.71 | 26.31±0.71 | <0.000000 |
| p | 0.45 | 0.45 | |

p value from ridge regression results
p<0.05 is significant

**TABLE VII -** CLOSED CHAMBER HUMIDITY (% RH) IN RELATION TO SEX IN NORMAL AND DRY EYES

| **Normal eye** | | | |
|---|---|---|---|
| | **Closed** | **Open** | **p** |
| Male | 48.49±4.43 | 49.04±4.41 | <0.000000 |
| Female | 50.51±4.80 | 51.02±4.79 | <0.000000 |
| p | 0.17 | 0.18 | |
| **Dry eye** | | | |
| | **Closed** | **Open** | **p** |
| Male | 54.26±5.99 | 55.55±5.97 | <0.000000 |
| Female | 50.90±7.49 | 52.01±7.55 | <0.000000 |
| p | 0.13 | 0.11 | |

p value from ridge regression results
p<0.05 is significant

study showed that the evaporation rate of the tears was higher in dry eyes than the normal eye, which agrees with previous studies (14-17).

We did not find any significant relationship between temperature and humidity and the sex and age of the patients. This finding, together with the combined results, further enhances the diagnostic value of this procedure in dry eyes.

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