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Relationship of symptomatology with closed chamber infrared thermometry and humidity in dry eyes

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PURPOSE. *To evaluate the relationship of symptoms of dry eye with closed chamber infrared thermometry and humidity measurements.*

METHODS. *The authors studied 54 patients (108 eyes) with dry eye disorders of different grades of clinical severity (mean age 35.75±14.37 years), 31 cases (62 eyes) with normal eyes (mean age 33.68±14.42 years), and 10 cases (20 eyes) with epidemic conjunctivitis (mean age 33.68±14.42 years). The symptoms and the clinical tests (Schirmer-1 test, fluorescein tear break up time, Lissamine green stain; closed chamber infrared thermometry and humidity) were used to establish the diagnosis of dry eyes. The closed chamber humidity difference was used to classify the groups of dry eye.*

RESULTS. *The authors noted no temperature difference from closed to open eye position in dry eyes as compared to 0.10±0.00 ºC difference in normal eyes and epidemic conjunctivitis. Four groups of cases were identified by difference in values of humidity: Group 1 = <0.9 relative humidity (RH)% to 1 RH%; Group 2 = >1 RH% to 1.5 RH%; Group 3 = >1.5 RH% to 2 RH %; and Group 4 = >2 RH%. The symptomatology was measured in the eyes using Oxford scale (0-4) and correlated with the humidity groups. The grading of symptoms with the humidity showed a statistically significant relationship (p<0.0001) in each group. The severity of the symptoms showed an increase in frequency and severity from Group 1 to Group 4, which was statistically significant (p<0.0001). The mean sum total of global symptomatology score was statistically significant (p<0.0001): 3.43±0.31 in Group 1, 4.65±0.42 in Group 2, 8.56±0.78 in Group 3, and 13.35±1.21 in Group 4. However, total symptomatology score in epidemic conjunctivitis did not show a statistically significant value (p=0.20).*

CONCLUSIONS. *The closed chamber humidity and thermometry measurements showed statistical correlation in all four groups of dry eyes to total mean symptomatology score (p<0.001) and showed an increase in value with increasing severity of symptoms. However, all individual symptoms fail to show any conclusive relationship. (Eur J Ophthalmol 2005; 15: 186-95)*

KEY WORDS. *Fluorescein tear break up time, Fluorescein staining score, Infrared, Closed chamber, Humidity, Thermometry, Dry eyes, Symptomatology*

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INTRODUCTION

Dry eye is a chronic inflammatory condition of the eye that results from the dysfunction or disease of ocular surface and tear secreting glands (1), which fail to remove the used tears from conjunctival sac and replace them with fresh tears, leading to accumulation of certain cytokines (2-7) that make the precorneal film unstable with appearance of the various dry eye symptoms. The symptoms have been evaluated by various

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authors (8-15) on individual scores of symptomatology. Schein et al (8) and Bjerrum (9) have used one or more symptoms being present often or all the time as a criterion for diagnosis of dry eyes in a population-based study. McCarty et al (10) mentioned the existence of any severe symptom not attributed to hay fever as a diagnostic symptom of dry eyes.

Shimmura et al (11) used self-reported history of dry eyes as sufficient proof for diagnosis. Moss et al (12) and Lin et al (13) have followed the above criterion. Williamson et al (14) and Leibowitz et al (15) have noted the incidence of various symptoms of dry eye in their cases ranging from 22.5% to 88%. Others (15-19) have evaluated these cases on the basis of sicca score 0-4 or 1-4 (0=normal, 1=mild, 2=moderate, 3=severe, 4=very severe) to record the severity of the symptoms in cases of dry eyes.

Murube and Rivas (20, 21) have used six clinical grades 0-5 (0=normal, 5= severe) and showed a great correlation with six histopathologic grades of metaplasia of the conjunctiva in 138 cases of dry eye and 31 control eyes. All the above authors have correlated the various tear function diagnostic tests of low sensitivity and specificity with the symptomatology. However, few authors performed infrared thermometry alone (22) to study the temperature of anterior segment of the eye in normal individuals between 15 and 80 years of age who noted a significant decrease in temperature with advancing age. Kocak et al (23) measured five consecutive readings of corneal temperatures in 10 healthy subjects with noncontact infrared thermometry within 45 minutes and 5 days and noted a reliability of 97.92% and 85.35%, respectively. They noted that corneal temperature varied throughout the day. Efron et al (24) 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 0.033±0.024 ºC per second ($p<0.0001$). Mori et al (25) measured corneal temperature by infrared thermography and noted a K value of dry eye (5.6±2.9 ºC per second) that was significantly less than the control group (9.3±1.5 ºC per second; $p<0.05$). They also noted a decline in the temperature in patients with dry eye that was significantly less than in normal subjects. Morgan et al (26) also measured the temperature of the cornea by infrared thermography and found a greater difference between the limbus and the center of cornea in patients with dry eye.

TABLE I - NUMBER (%) OF NORMAL SUBJECTS AND PATIENTS WITH ALTERED TEAR TESTS

Group	Symptomatology	Schirmer-1	FTBUT	LG	Thermometry	Humidity
0	None	1 (1.61)	2 (3.22)	30 (48.38)	62 (0)	62 (0)
1	Sometimes	1 (9.10)*	5 (45.45)*	4 (36.3)*	11 (100)*	11 (100)*
2	Half of the time	4 (9.10)*	12 (27.27)	8 (18.18)	44 (100)*	44 (100)*
3	Mostly	6 (24)*	16 (64)*	20 (80)*	25 (100)*	25 (100)*
4	Always	18 (64.29)*	24 (85.74)*	24 (85.71)*	28 (100)*	28 (100)*

*$p<0.05$
FTBUT = Fluorescein tear breakup time; LG = Lissamine green staining

Morgan et al (27) subsequently recorded temperature in dry eyes as 32.28±0.69 ºC as compared with 31.94±0.54 ºC in the control group (p<0.0001). Infrared thermometry has been employed by Fujishima et al (28) and Tsubota et al (29), who noted that change in the corneal temperature after keeping the eyes open for 10 seconds in dry eyes was 0.21±0.06 ºC compared to 0.61±0.28º C in normal patients (p<0.0001).

Evaporation of tears was recorded by some research workers (30-33), who noted that evaporation coefficient in normal eyes was less as compared to dry eyes.

We failed to find any work in which closed chamber combined infrared thermometry and humidity had been performed in the diagnosis of dry eyes except that of Singh and Bhinder (34). The aim of the present study is to detail a highly sensitive and specific role of infrared thermometry and humidity measurement in such cases and to correlate them with the symptomatology of dry eye diseases.

MATERIALS AND METHODS

Consecutive patients who attended the G.G.S.I. Eye Research & Cure Centre from 1999 to 2003 formed the subject of study. The study was comprised of 54 cases (108 eyes) of dry eyes, 27 male and 27 female, ranging from mild to very severe degree, and ranging in age from 10 to 73 years (mean 35.75 ± SD 14.37). The controls consisted of 31 (62 eyes) normal cases (16 male and 15 female) with age ranging from 10 to 70 years (mean ± SD 33.68±14.42) and 10 cases (20 eyes) of epidemic conjunctivitis of matching age and sex.

The symptoms were recorded in each case by a questionnaire consisting of symptoms of irritation (gritty sensation), itching, redness, pain, photophobia, tearing, frequent blinking, stickiness, discharge, blurred vision, dryness, and tiredness of eyes. The patients were told to grade their symptoms on an Oxford scale score from 0 to 4 as follows:

Grade 0: Normal, no symptoms.

Grade 1: (Mild) Symptoms of dryness, itching, irritation occasionally.

Grade 2: (Moderate) Symptoms of dryness often in daily life with few clinical signs.

Grade 3: (Severe) Severity of symptoms increased and always present, along with clinical reversible signs.

Grade 4: (Very severe) Intensity of symptoms worse, signs worse.

TABLE II - RELATIONSHIP OF RH% HUMIDITY DIFFERENCE WITH SYMPTOMS SCORE OF 11 DRY EYES IN GROUP 1

			Score			
Symptoms	**%**	**N**	**Range**	**Mean**	**SD**	**p value**
Itching	36.36	04	0-2	0.45	±0.69	0.018
Irritation	45.45	05	0-3	0.55	±0.69	0.044
Redness	27.27	03	0-1	0.27	±0.47	0.000
Pain	36.36	04	0-2	0.45	±0.69	0.018
Photophobia	0.00	00	0-0	0.00	±0.00	—
Lacrimation	54.55	06	0-2	0.90	±0.94	0.078
Stickiness	0.00	00	0-0	0.00	±0.00	—
Blurred vision	36.36	04	0-1	0.36	±0.50	0.0005
Dryness	0.00	00	0-0	0.00	±0.00	—
Blinking	18.18	02	0-2	0.36	±0.81	0.018
Discharge	9.09	01	0-1	0.09	±0.30	0.000
Total global score	100.00	11	0-3	3.43	±0.31	<0.001

RH= Relative humidity

In all cases, closed chamber thermometry and humidity were carried out first, followed by Schirmer-1 test, fluorescein tear break up time (FTBUT), and Lissamine green staining. The criteria for the diagnosis of dry eye were as follows: Schirmer-1 test, <10 mm/5 min; FTBUT, <10 s; Lissamine green staining, >2 out of 4; thermometry difference from close to open eye position 0.0 ºC; and humidity difference ≥1 relative humidity (RH)% (34) (Tab. I).

Noncontact thermometry

Noncontact thermometry was performed using a heat-sensor thermometer (HT-3003 Lutron, Hong Kong) already described (34). This is a portable noncontact solid-state sensor with a temperature range of 0 to 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 the temperature measurement is displayed.

Noncontact humidity

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. The tip of the sensor probe was kept 20 mm from the edge of the closed chamber.

The chamber was round and 40 mm in diameter. When the edge of the chamber was applied around

TABLE III - RELATIONSHIP OF RH% HUMIDITY DIFFERENCE WITH SYMPTOM SCORE OF 44 DRY EYES IN GROUP 2

			Score			
Symptoms	**%**	**N**	**Range**	**Mean**	**SD**	**p value**
Itching	47.73	21	0-3	0.80	±0.98	0.006
Irritation	63.64	28	0-3	0.89	±0.87	0.016
Redness	34.08	15	0-3	0.59	±0.90	0.00001
Pain	29.55	13	0-3	0.50	±0.85	0.00001
Photophobia	04.54	02	0-1	0.05	±2.00	0.00001
Lacrimation	15.19	07	0-3	0.25	±0.69	0.00001
Stickiness	18.18	02	0-2	0.09	±0.42	0.00001
Blurred vision	11.36	05	0-2	0.23	±0.64	0.00001
Dryness	20.45	09	0-2	0.41	±0.82	0.00001
Blinking	29.54	13	0-2	0.34	±0.57	0.00001
Discharge	27.27	12	0-3	0.50	±0.93	0.00001
Total global score	100.00	44	0-3	4.65	±0.42	<0.001

RH= Relative humidity

TABLE IV - RELATIONSHIP OF RH% HUMIDITY DIFFERENCE WITH SYMPTOM SCORE OF 25 DRY EYES IN GROUP 3

Symptoms	%	N	Score Range	Mean	SD	p value
Itching	60.00	15	0-4	1.12	±1.39	0.016
Irritation	60.00	15	0-4	1.16	±1.40	0.024
Redness	60.00	15	0-4	1.16	±1.28	0.0006
Pain	52.00	13	0-4	0.92	±1.22	0.00001
Photophobia	28.00	07	0-4	0.56	±1.08	0.00009
Lacrimation	40.00	10	0-4	0.80	±1.19	0.00001
Stickiness	32.00	08	0-2	0.36	±0.57	0.00005
Blurred vision	31.81	14	0-3	0.96	±0.98	0.00007
Dryness	20.00	05	0-3	0.40	±0.86	0.00001
Blinking	16.00	04	0-3	0.24	±0.66	0.00001
Discharge	64.00	16	0-4	0.92	±0.86	0.00001
Total global score	100.00	25	0-4	8.56	±0.42	<0.001

RH= Relative humidity

TABLE V - RELATIONSHIP OF RH% HUMIDITY DIFFERENCE WITH SYMPTOM SCORES OF 28 DRY EYES IN GROUP 4

Symptoms	%	N	Score Range	Mean	SD	p value
Itching	85.71	24	0-4	1.68	±1.33	0.005
Irritation	85.71	24	0-4	1.75	±1.35	0.012
Redness	50.00	14	0-4	1.18	±1.40	0.0001
Pain	46.43	13	0-4	1.39	±1.64	0.002
Photophobia	42.86	12	0-4	1.00	±1.36	0.0001
Lacrimation	78.57	22	0-4	1.68	±1.21	0.003
Stickiness	28.57	08	0-2	0.57	±0.92	0.0001
Blurred vision	89.29	24	0-3	1.43	±1.00	0.0001
Dryness	53.57	15	0-3	0.89	±1.03	0.0001
Blinking	39.29	11	0-3	0.54	±0.79	0.0001
Discharge	85.71	24	0-4	1.24	±1.36	0.002
Total global score	100.00	28	0-4	13.35	±1.21	<0.001

RH= Relative humidity

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. Then the patient was asked to open the eye for 5 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 procedure for humidity reading was carried out in the same way. The calibration of the infrared thermometer and humidity were carried out with the guidelines given by the manufacturers. The exclusion criteria for the study were as follows: 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, or ocular growth.

Statistical analysis

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

RESULTS

Demographic data are summarized in Tables I through VII. We noted that the other tear function tests detected the dry eyes in 85.71% of eyes in Groups 3 and 4 as compared to only 45% in early cases (Tab. I). However, infrared thermometry and humidity detected dry eye in 100% of the cases. The temperature in closed eye position was 27.91±2.47 ºC (20.40-32.60) and open eye position was 28.02±2.47 ºC (20.50-32.70) in normal eyes as compared to 25.72±1.83 ºC (23.90-31.80) in closed and open eye position in dry eyes (Tab. VII).

Infrared thermometry showed a difference of 0.10 ºC from closed to open eyes in normal and epidemic conjunctivitis eyes ($p<0.0001$) compared to no difference in temperature in dry eyes (Tab. VII; $p=0.86$).

The closed chamber humidity measurements did not show any correlation among the normal, epidemic conjunctivitis, and dry eyes (Tab. VI).

However, the change in mean humidity difference from closed to open was 0.51±0.17 RH% in normal and 0.54±0.17 RH% in epidemic conjunctivitis eyes, without any statistical correlation ($p=0.89$). The humidity difference was 0.9 RH% to 4 RH% in dry eyes (mean 1.65±0.59 RH%).

The value of humidity difference between open to closed eye was closely related to the severity of the dry eye ($p<0.0001$). Based on thermometry and humidity difference the dry eye cases were classified into the following four groups (Tab. I):

Group 1 (Mild): Thermometry difference between clos- ed and open eye was 0.0±0.0 ºC. Humidity difference from closed to open eye position was 0.99±0.03 RH% (0.9-1.0 RH%).

Group 2 (Moderate): Thermometry difference between closed and open eyes was 0.0±0.0 ºC. Humidity difference was ≥1.0 RH%-1.5 RH% (1.21±0.14 RH%).

Group 3 (Severe): Thermometry difference between closed and open eyes was 0.0±0.0 ºC. Humidity difference was ≥1.5-2.0 RH% (1.82±0.14 RH%).

Group 4 (Very severe): Thermometry difference between closed and open eyes was 0.0±0.0 ºC. Humidity difference was >2.0 RH% (2.44±0.41 RH%).

The mean score of itching, irritation, redness, pain, photophobia, stickiness, discharge, and blurred vision showed an increase with increasing severity of the dry eyes from Group 1 to Group 4 ($p<0.0001$; Tabs. II-V).

However, the score of feeling of dryness, lacrimation, and blinking did not show any significant correlation with the severity of the disease.

Interestingly, the mean global symptom score showed an increase with an increasing severity of the dry eyes with a significant correlation ($p<0.0001$) as compared to no correlation in epidemic conjunctivitis ($p=0.57$) (Tabs. V and VI).

DISCUSSION

In the literature on dry eyes, researchers have reported results of various tear tests in established cas-

TABLE VI - RELATIONSHIP OF HUMIDITY MEASUREMENTS AND THE DIFFERENCE FROM CLOSED TO OPEN EYE POSITIONS IN FOUR GROUPS OF DRY, NORMAL, AND EPIDEMIC CONJUNCTIVITIS EYES

	Humidity measurements		**Humidity difference**		
Group	**Closed**	**Open**	**p value**		**p value**
0	47.43±7.42 (32.00-64.90)	48.02±7.36 (32.60-65.50)	0.659	0.51±0.17 (0.10-0.9)	1.000
1	50.17±5.50 (44.5-58.8)	51.16±5.50 (45.50-59.80)	0.708	0.99±0.03 (0.9-1.0)	<0.001
2	41.79±6.84 (30.00-56.30)	43.01±6.84 (31.10-57.80)	0.411	1.21±0.14 (1.1-1.5)	<0.001
3	42.69±8.22 (31.20-56.70)	44.51±8.23 (33.20-58.70)	0.438	1.82±0.14 (1.6-2.0)	<0.001
4	50.68±9.01 (33.30-64.00)	53.12±9.00 (35.50-66.50)	0.315	2.44±0.41 (2.1-4.0)	<0.001
Epidemic conjunctivitis	52.96±4.15 (45.00-58.70)	53.47±4.19 (45.60-59.00)	0.698	0.54±0.17 (0.30-0.90)	<0.600

es of dry eyes (Groups 3 and 4). However, they failed to diagnose cases of Groups 1 and 2 because no test exists with enough sensitivity and specificity to detect these groups.

Murube and Rivas (20, 21) followed a clinical classification of grade 0-5 and the criterion on which they based the diagnosis of dry eyes was the presence of altered tear tests – the Schirmer-1 test (<10 mm), FT-BUT (<10 s), rose bengal staining (>4 score), and osmolarity (>310 mosm/L) – but they failed to detect dry eyes in 93.93% of Grade 1, 85% of Grade 2, 69.70% of Grade 3, 31.8% of Grade 4, and 13.64% of Grade 5 cases.

To explore dry eye, some researchers (22-29) have used infrared thermometry in normal and dry eye patients and noted a decrease in corneal temperature with advancing age (19), with a blink (20) and diurnal temperature variation (23). However, the above studies were conducted in an open environment; hence the results of the studies are not reliable. In the study performed by Singh and Bhinder (34) and the present study, no change in the temperature of dry eyes from closed to open eye position was noted, compared to 0.11 ºC increase in temperature in epidemic conjunctivitis and normal eyes, which was a highly significant observation in this study.

Similarly, several authors (30-33) noted rate of evaporation of tears as 14.7±6.4 x 10(-7) g/cm^2/s in normal as compared to 47.6±20.1 x 10(-7) g/cm^2/s in dry eyes (30) after making calculations with a complicated formula.

We noted the high diagnostic value of closed chamber measurement of humidity (34) difference from closed to open eye positions. A closed chamber mean humidity difference was 0.51±0.17 RH% in normal eyes and 0.54±0.17 RH% in epidemic conjunctivitis as com-

TABLE VII - RELATIONSHIP OF THERMOMETRY MEASUREMENTS AND THE DIFFERENCE FROM CLOSED TO OPEN EYE POSITIONS IN 4 GROUPS OF DRY, NORMAL, AND EPIDEMIC CONJUNCTIVITIS EYES

	Thermometry measurements		Thermometry difference		
Group	**Closed**	**Open**	**p value**		**p value**
0	27.91±2.47 (20.40-32.60)	28.02±2.47 (20.50-32.70)	0.799	0.10±0.00 (0.1-0.1)	1.000
1	30.32±1.28 (27.20-31.50)	30.32±1.28 (27.20-31.50)	0.986	0.00±0.00 (0.0-0.0)	<0.001
2	28.48±2.47 (23.10-30.30)	28.47±2.48 (23.10-32.30)	0.986	0.00±0.00 (0.0-0.0)	<0.001
3	26.71±1.83 (23.20-30.20)	26.71±1.84 (23.10-30.20)	0.988	0.00±0.00 (0.0-0.0)	<0.001
4	25.72±1.83 (23.90-31.80)	25.72±1.82 (23.90-31.70)	0.994	0.00±0.00 (0.0-0.0)	<0.001
Epidemic conjunctivitis	27.45±2.34 (23.10-29.70)	27.55±2.35 (23.20-29.80)	0.893	0.10±0.00 (0.1-0.1)	<0.100

pared to >0.9-4.0 RH% difference in dry eyes (1.65±0.59 RH%; Tab. VI). Based on the humidity difference, four groups of dry eye disease were classified (Group 0 = normal; Group 4 = very severe).

We noted different grades of symptomatology score in different stages of dry eyes that were statistically significant (p<0.0001).

The severity of dry eye has been previously based on an Oxford scale 0-4 (15-19). Different workers have noted different symptom score in severe dry eyes. Stevenson et al (17) noted a symptom score of 1-2.7 but Wright and Vogel (16) noted it as 0.45-2.72; Leibowitz et al (15) noted 1.47-1.86 symptom score in 106 severe dry eye cases and Hill (19) noted a symptomatology score of 0.15 to 1.28 in their cases.

In this study we found the above type of scoring to be faulty and inconclusive because of different use of guidelines of severity of dry eye and no comprehensive picture of dry eye stage. Hence we resorted to total global mean symptom score of the group as a highly valuable scale (Tab. II). Group 1 had the least global mean sum total symptomatology score (3.43±0.31) and was thought to represent the earliest stage in the dry eye process (Tab. II), which passed on to Group 2, Group 3, and Group 4, in which the global mean sum total score increased to 4.65±0.42, 8.56±0.78, and 13.35±1.21, respectively.

Comparison of the global mean symptom score of each group showed a steady increase and bore a significant statistical relationship in all the groups (p<0.000). However, the score lacked specificity, as epidemic conjunctivitis also showed a score of 10.2±0.43 (p=0.57 by Wilcoxon matched pair test) in the present study. Correlation of symptomatology and severity of grade showed group compatibility in 95/108 (87.96%) of the dry eyes (p<0.0001) but mis-

matched with 9 eyes of Group 3 (8.33%) and 4 eyes of Group 4 (3.70%), as the symptoms were milder in comparison to the high humidity values. It became obvious that the symptomatology of dry eye was not as confirmatory as the difference in humidity RH%, which showed 100% reliability in dry eye disease.

The present study led to several conclusions: 1) individual symptom score did not have a specificity and sensitivity to diagnose dry eye disease; 2) the individual symptomatology did not match the severity of dry eye disease; 3) the severity score by itself did not prove useful for diagnosis of dry eye. Indirectly, the study showed that closed chamber humidity and thermometry difference from closed to open eye had 100% specificity and sensitivity to diagnose dry eye disease. This single test is reliable, consistent, quick, repeatable, and noninvasive in the early detection of dry eye disease.

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