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TEMPERATURE TIME COURSES ASSOCIATED WITH CONTACT LENSES

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Although contact lenses have been in use for more than seventy-five years[1] they present to us nearly as many physiological mysteries as confronted the first fitter. The design and final adjustments of these lenses, until a comfortable high acuity result is achieved, are in the final analysis nearly always empirically based; that is, types of adjustments which accomplish the desired ends with some repeatibility are retained, those which do not are eliminated.

It is unfortunate that the fitter seldom has the satisfaction of knowing why his adjustment is successful, what basic physiology he has influenced, whether he has struck upon a design which now allows a tolerable pO_2 or pCO_2 level for the ocular secretions, or if his lens now permits particular metabolic processes to operate normally, or if he has indirectly altered the pH of the tears, or a number of other possibilities.

A contact lens fitter twenty years from now may routinely measure the pertinent physiological characteristics of his patients in advace and not only raise himself above empirical design and adjustments, but may also be able to determine the prognosis for a successful fit before his patient may suffer the expense and discomfort associated with an inevitable failure.

Obviously, before the physiological approach to lens fitting can be successfully employed a great many questions will have to be answered. The major one is what constitutes the pertinent physiology associated with tolerable wearing conditions? Studies directed toward answering this question are currently in progress in this laboratory. The principal factors being studied are the time courses of lens temperatures and the time courses of pO_2, pCO_2, and pH of the ocular secretions associated with corneal and scleral contact lenses.

This paper is a brief description of temperature time courses from pilot studies on animals which preceded the human studies now nearing completion. Among the questions asked in this study were the following: how long is required for an eye to reach temperature stability following the insertion of a lens: what ranges of temperature are associated with a contact lens in place on the eye: what effect does closing the eye naturally have on the lens temperature: how much of a temperature rise, if any, is associated with forced closing of the eye or squeezing the lids: and does the size of the lid aperture influence the lens temperature?

METHODS

Six rabbit eyes were studied, the animals being young adult males of 2 Kg. average weight. The rabbit was selected for this investigation because of its low blink rate and because of its docile nature permiting trials to be made under anesthetic-free conditions.

Five measurements of the principal meridians of each cornea were made and the rectal temperature of each animal recorded without anesthesia. This data is shown in Table I.

Under general anesthesia (urethan) the animals were given identifying tattoos and impressions were made of each cornea by standard techniques.* From resulting dental stone positives two methyl methacrylate lenses were made for each eye, one 15 mm round (corneal) and the other 23 mm round** (scleral). The edges of all the lenses were made round, no secondary curves being used. The thickness of these lenses was approximately 0.6 mm, sufficient to envelop a Veco 32A11 thermister element within its surfaces at the center of the lens.

The output of the thermister was introduced into a Sanborn Model 850-1500A amplifier and Model 297 recorder via a Yellow Springs Model 41 six-channel telethermometer unit. The records were a continuous graphical plot of lens temperature vs. time. The vertical dimension of the lid aperture was recorded in millimeters throughout the runs as well.

During the trials the animal was anesthetic-free, being restrained by a holding box from the neck and below. The test lenses were washed carefully, thoroughly exposed to wetting solution (Barnes-Hind Nº 651) and inserted into the eye at room temperature. A minimum of one hour separated the trials on one eye, although most trials for a given eye were made on different days.

* A somewhat similar approach was made by Fick (1888) on rabbit eyes using plaster of paris ofr the casting material2

** To permit maximum circulation of ocular fluids between the lens and eye the sclerals were made with superior and inferior haptic bearing surfaces similar to the Dutterfield Parascleral lens design.

Direct temperature calibrations of the sensing and recording system were made for each trial by placing the lens-thermister unit in water baths of known temperatures, measurer with an N.B.S. compared thermometer. Tre room temperature and relative humidity were also noted. These averaged 25°C and 40% respectively.

RESULTS

Forty-eight short-term (average, 20 minutes) temperature trials were recorded for the six eyes. Fours trials on each eye were made with a scleral lens and four with a corneal lens. Each trial contained four sub-units:

1) the initial stabilizing time course

2) a forced blink time course

3) a closed eye time course

4) and the final stable characteristics of temperature and lid aperture before removing the lens.

Although the time constants, associated stable and maximum temperatures, related lid apertures and other features of these time courses have been processed (means, standard deviations, linear and semilog correlations) by an IBM 704 computer, the analysis of the data is not yet complete and only a general description of the findings will be given here.

Figure 1 is a plot of results typically obtained with both corneal and scleral lenses. It is a twenty minute temperature time course for a corneal lens with the associated lid aperture measurements.

Initial Stabilizing Characteristics

An initial rise in temperature associated with the insertion of the lens is clearly evident in Figure 1, the eye being closed an the obicularis oculi muscles active. The maximum temperature reached was 35.8°C (96.4°F). The elapsed time between insertion (I) and reaching a stable temperature of 33.3°C (92°F) was 3-½ minutes. This stable temperature was accompanied by a lid aperture of 8 mm vertical dimension, the average for these animals without lenses being about 12 mm.

Forced Blink Experiment

Once stable temperature was demonstrated a forced blink experiment was done. During the interval labeled FB in Figure 1, the eyelashes of the eye were repeatedly touched encouraging the animal to close his eye hard to prevent a forcing object from entering. An abrupt rise in lens temperature resulted, slowing just before plateaning in 1-¼ minutes. The maximum temperature reached was 36.8°C (98.2°F) or a temperature range of 3.5°C (6.3°F) was traversed in that period. The rise time constant was 15 seconds.

(92°F) was reached two minutes after the forced blink stimulus was removed. The final stable temperature in this case was 32.8°C (91°F), below the starting temperature and was reached after 3-¾ minutes, with a decay time constant of 42 seconds.

Closed Eye Experiment

After once again reaching a stable temperature a closed eye experiment, CE in Figure 1, was done in which the nasal canthus of the eye was subjected to the continuous light pressure from the bristles of a small brush. This pressure encouraged the animal to keep his eye closed but not in an intense manner as in the forced blink experiments.

In these trials the maximum temperatures reached were less than in the forced blink series, as might be expected. In this example the temperature was 33.5°C (96°F). The total rise time here was 60 seconds and the rise time constant, 21 seconds. The range was 2.8°C (5°F). The total time to return to the starting temperature here was 4.7 minutes, the decay time constante being 63 seconds.

Terminal Temperature

Just before removing the test lens, R in Figure 1, a final stable temperature was recorded for comparison with the initial stable temperatures of the trial. The final stable temperature in this case was 32.6°C (90.7°F) after 19.5 minutes. In these short-term trials little difference was noted between the initial and final resting temperatures.

Lid Aperture and Temperature

The precise relationship of lid aperture to lens temperature is not yet clear. It can be seen, however, in the closed eye experiments, in which the activity of the obicularis oculi are minimal, that the highest stable temperatures are associated with a zero lid aperture while the lowest stable temperatures occury when the lid aperture is largest, 10 to 12 mm. Initial human trials in which the lid aperture can be subjectively controlled suggest a rigid relationship between this factor and temperature.

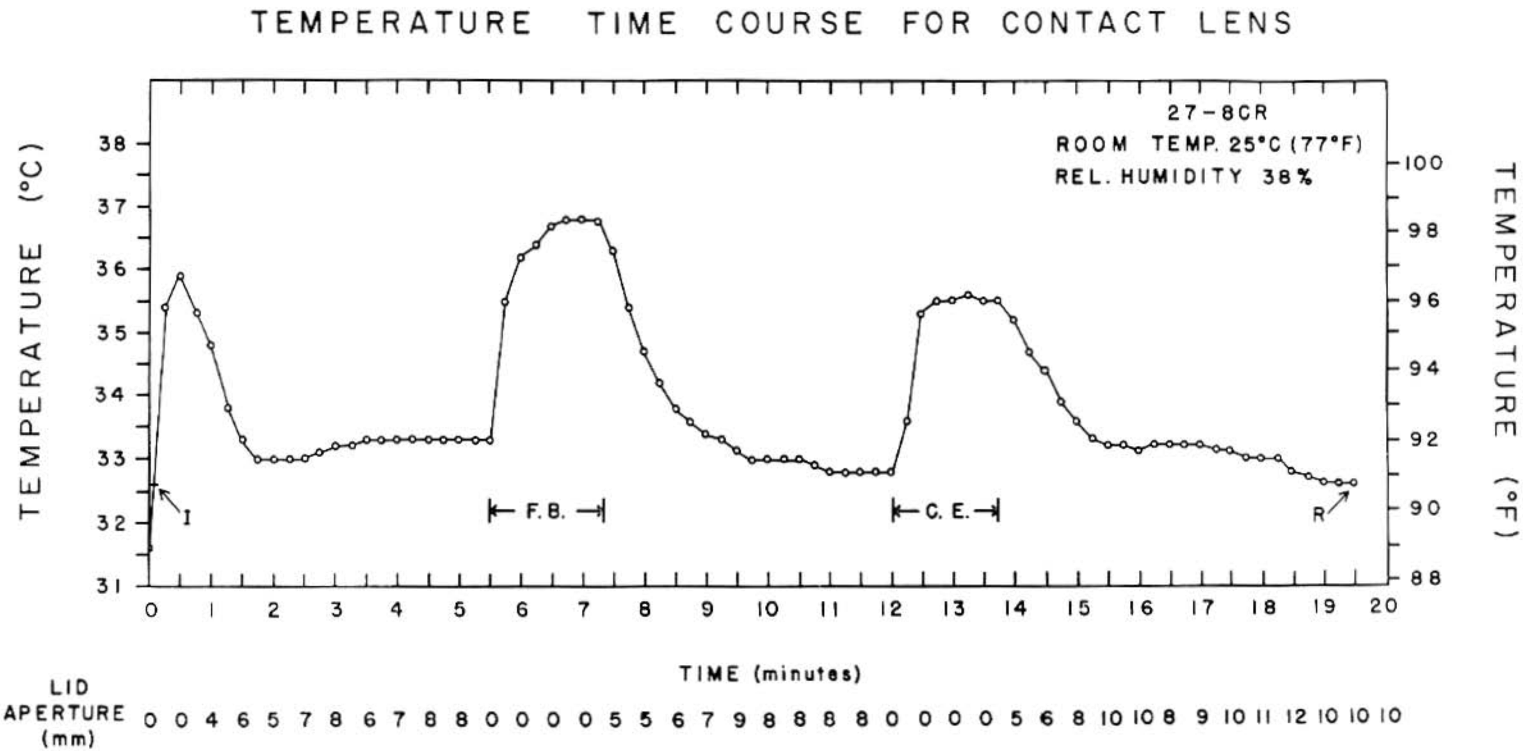

Fig. 1. Complete time course of a corneal lens temperature experiment. (I) is the insertion, (FB) the period during which the lids were kept forcibly closed by the animal, (CE) the period of natural lid closure, and (R) removal of the lens. Associated vertical lid apertures are shown below.

DISCUSSION

What Is Being Measured?

The first and most difficult question to be dealt with are: what factory contribute to the lens temperatures being measured here and what is their relative influence? The following constitutes a partial list: muscle heat, insulation properties of the lens material, insulation properties of the lids, lid aperture, ocular secretion temperatures and circulation rate, corneal temperature and vascular conditions of the adnexa. In addition, room temperature, relative humidity and lens fit surely have some effect on the lens temperatures measured. It may eventually be possible to fractionate this composite with such techniques as forced blink vs. closed eye experiments in which the activity of the obicularis is obviously different.

Initial Stability Time

Returning to the questions whose answers were initially sought from this and the other pilot experiments, it has been found that initial stable temperatures could be reached within a minute occasionally, but sometimes required as long as seven minutes depending on how soon blinking could be overcome and the eye able to maintain a constant lid aperture dimension. Usually some initial squeezing of the lids occurred causing an initial rise in temperature as in the cited record, but in a few cases with swift, smooth insertions, the temperatures never rose above the initial stable temperature previous to reaching equilibrium.

Temperature Ranges Associated With Contact Lenses

A considerable range of temperatures was found associated with these lenses. The resting temperatures were invariably below the measured body temperature of 40.2°C, even the maximum temperatures recorded in the forced blink experiments were never found to exceed 39°C. The lowest resting temperature recorded was 29.3°C. The maximum range of temperatures found in the complete study was just short of 10°C or 18°F. The most common resting temperatures were 32 to 34°C (89 to 93°F). Low temperatures associated with the naked cornea have, of course, been known for some time[3] as well as long-term variations[3] and may have a significant influence on the composite lens temperatures measured here.

Effect of a Closed Eye on Lens Temperatures

A closed eye of course constitutes an environment considerably different than an open eye for a contact lens. Among the alterations probably affecting lens temperature are the insulation properties of the lids, the heat contributed by lid circulation, the impedance of evaporation from the lens anterior surface and, probably the slowing of ocular fluid circulation because of the absence of blink activity and normal eye movements.

Even when a minimum of obicularis activity is present a considerable rise in temperature is consistently recorded and remains stable as long as the eye remains closed. In the typical example here the rise was about 75% that if a forcefully closed eye. The normal closed eye temperatures were never found to reach those of the forced blink trials in a given eye as is not unexpected.

Temperatures as high as 35.1°C at the corneal apex for an eye without a lens in place have meen reported previously[3].

Temperatures Associated With Excessive Lid Activity

The maximum temperatures recorded were, as mentioned earlier, associated with forced closing of the eyes. The total rise times and the rise time constants for this activity were also the shortest seen as well as the total decay times and decay time constans. Those for natural closed eye conditions were longer in nearly every case for a given eye.

A maximum temperature of 38.0°C has been previously reported for a rabbit cornea without a lens in place on application of moist heat and diathermy[3].

Lid Aperture and Temperature

Although correlations of lid aperture and lens temperature have not yet been completed, a significant relationship appears to be present between the two. Initial human trials in wich lid aperture can be subjectively controlled indicate a firm relationship between this factor and temperature. The natural lid aperture of a patient, as well as that dictated by the presence of a lens in his eye, may prove important in his prognosis for a comfortable fit because of temperature.

The Use and Interpretation of Lens Temperatures

Most certainly the temperature of the eye, and of the lens, secondarily, are reflections of muscle activity and of metabolic processes of proximal tissues to it. The measured temperature may also be influenced by the chemistry of the tears on these tissues following a prolonged or irritating wearing period. The useful interpretation of lens temperatures awaits, however, the catalging of responses associated with defined forms of ill fit which can be compared with data from successful cases. It is evident that considerable temperature changes do take place in the eye and can be measured. It wold, indeed, be strange if they did not reflect physiological processes useful in determining the prognosis of fit and the may become a useful component in a physiological profile done routinely in the fitting of patients in the future.

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SUMMARY

1. From six eyes studied in pilot animal experiments lens temperatures of 29 to 39°C, a range of 10°C (18°F), were measured.

2. Considerable temperature rises were associated with forced lid activity, changes of 3.5°C (6°F) were not uncommon. The time courses and time constants were given for a sample case.

3. Closed eye conditions were also found to cause a considerable rise in temperature, but never as great as for the forced lid activity. In neither experiment were the maximum temperatures ever as high as the body temperature of the animal. The time courses and time constans associated with a closed eye example were given.

4. The lid aperture appears to have a significant influence on the resting temperature of an eye as reflected by lens temperatures measured.

Animal Number	Right Eye Principal Meridians (D)		Left Eye Principal Meridians (D)		Body Temperature (rectal °C)
21	47.72/86°	45.97/176°	46.22/116°	43.72/26°	40.2
24	47.30/86°	45.50/176°	46.19/107°	46.39/17°	40.1
27	44.67/70°	42.94/160°	45.67/96°	42.22/6°	40.3

ABSTRACT

Temperature time courses accompanying corneal and scleral lens wear were measured for six eyes under varied conditions. Time constants, elapsed times, lens temperatures, and palpebral aperture dimensions associated with stabilization following insertion, forced lid and natural closed eye conditions are discussed and sample data given.

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