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Ex vivo heat retention of different eyelid warming masks

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ABSTRACT

Purpose: Meibomian gland dysfunction (MGD) appears to be the most common cause of evaporative dry eye, in which the meibum has an altered chemical structure that increases its melting point. Eyelid warming masks slowly transfer heat, preferably between 40 and 45 °C to the inner meibomian glands, in an attempt to melt or soften the stagnant meibum. This ex vivo study evaluates the heat retention properties of commercially available masks over a 12-min interval.

Methods: Five eyelid-warming masks (MGDRx EyeBag®, EyeDoctor®, Bruder®, Tranquileyes™, Thera°Pearl®) were heated following manufacturer's instructions and heat retention was assessed at 1-min interval for 12 min on a non-conductive surface. A facecloth warmed with hot tap water was used as comparison.

Results: All masks reached above 40 °C within the first 2 min after heating and remained so for 5 min, with the exception of the facecloth, which lasted only 3 min and quickly degraded to 30 °C within 10 min. The Bruder® and Tranquileyes™ reached >50 °C, after heating and the Bruder® maintained >50 °C for nearly 6 min. The MGDRx EyeBag®, and Thera°Pearl® had the most stable heat retention between 2 and 9 min, remaining between the targeted temperature.

Conclusions: Heat retention profiles are different for commercially available eyelid warming masks. This ex vivo study highlights that despite the popularity of the time-honored facecloth, it is poor at retaining the desired heat over a 5–10 min interval. Clinical studies need to corroborate these results, remembering that ocular tissue parameters may be factors to consider.

1. Introduction

The most common cause of evaporative dry eye appears to be meibomian gland dysfunction (MGD) [1–3]. It is estimated that the prevalence of MGD is 38.9%, increasing with age [2,4,5]. Each eye possesses approximately 60 meibomian glands (25–40 on the upper eyelid and 20–30 on the lower eyelid), which, under normal circumstances, should secrete a clear, liquid oil, called meibum [6,7]. These glands are squeezed by the action of a normal blink to release the meibum, which is subsequently distributed by the action of the lids onto the ocular surface, to minimize the evaporation of the underlying tear film layers [2,8].

In patients with MGD, the meibum has an altered chemical structure that increases its melting point compared to the physiological 32 °C [2,9,10]. The exact melting point of meibum in those suffering from MGD has yet to be determined, as the chemical composition of the secretions is variable and in turn affects its physical attributes [11]. Despite this variability, the melting point for meibum in obstructed meibomian glands is reported to be between 32 and 45 °C [11]. The resulting meibum in patients with MGD is stagnant and thickened. Even if the melting point of the meibum in MGD is below that of body temperature at 37 °C, rendering the meibum liquid, hyperkeratinization [7] of the terminal duct and orifice of the gland prevents the meibum from being secreted. Consequently, the meibum accumulates in the gland ducts [7] and the force exerted by a simple blink is insufficient to release it onto the ocular surface, resulting in the underlying tear film being more vulnerable to evaporation. Patients with MGD, and hence evaporative dry eye, are typically more sensitive to evaporation effects from air currents resulting in decreased tear film stability [12,13].

Although management of MGD is not globally standardized, warm compresses are regarded as a primary therapy [2,6,14,15]. The therapeutic purpose of the warm compresses, placed on the closed eyelids, is to slowly transfer the heat from the compress, through the eyelid tissues to ultimately reach the inner meibomian glands, in an attempt to melt or soften the stagnant meibum. Ocular massage is typically advocated [14] following warm compress therapy to empty the ducts and pierce through the obstructive orifices of the meibomian gland, eventually increasing the lipid layer of the tear film [14]. Although the exact temperature for warm compress

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therapy in unknown, temperature of 40 °C [10] to 45 °C [16] have been advocated. Warm compresses have been shown to reduce dry eyes in patients with MGD by improving symptoms, tear film stability, tear evaporation, tear film lipid layer thickness and decreased meibomian gland orifice obstruction [10,17–20].

Despite its frequent recommendation by eye care practitioners (ECP), warm compress treatments are poorly standardized. In practice, typical recommendations include daily heating of the eyelids for 5–10 min using a warm wet facecloth, heated rice bags or even a hard boiled egg [2,6,14,15,21]. These methods have relatively unknown temperature behaviors, which establishes a rationale for the present study. ECPs note that patients are often noncompliant with the recommendations, which results in suboptimal and ineffective therapy leading to premature discontinuation of treatment [14]. This can make warm compress treatment frustrating for both ECPs and patients. Blackie et al. [16] reported reheating facecloths every 2 min to maintain a constant heat above 45 °C for at least 4 min, to be effective for MGD. This would require a patient to be near a heating source (a sink or microwave oven) for the full 4 min, which may not always be convenient.

To render some treatment options more patient-friendly and potentially improve compliance, several companies have developed commercially available warming eyelid masks that claim to maintain a constant temperature throughout the recommended 5–10 min [22–26]. Although commercially available eye masks have existed for a long time, these newer masks are taking into consideration the new knowledge of the temperature needed to soften the meibum, a fact that was not previously considered. Hence experimentation with different heat-retaining fillers for these eye masks has made them novel in the marketplace.

It is of clinical interest to evaluate how well each of these eyelid masks retains the target temperature of 40–45 °C over a 10-min interval. That being said, in order to remove the variability of eyelid thickness, tissue heat retention and distribution in human subjects, a control study was undertaken first. To that end, the objective of this ex vivo study was to evaluate and compare the heat retention properties of commercially available eyelid warming masks over a 12-min interval.

2. Materials and methods

Five eyelid-warming masks and a warm facecloth (Table 1) were selected for this study to investigate their heat retention properties. The selected masks were the MGD Rx Eyebag®, The Eye Doctor®, Bruder eye hydrating compress, Tranquileyes™, Thera°Pearl® Eye-essential mask and a facecloth.

To remove any influences from eyelid heat absorption, retention and distribution differences in human subjects, an ex vivo control study was performed using a non-conductive surface as a substrate. A 12 × 12 × 1″ block of polystyrene rigid insulation board (Foamular®, CAN/ULC-S701, Type 3, CCMC 13431-L, Owens Corning, Canada) [27] was used due to its non-conductive properties and *R*-value of 5. An *R*-value is a measure of thermal resistance of a material or the capacity of a material to resist heat flow [28–30]. The *R*-value is used regularly in the construction industry to choose appropriate building materials that will reduce heating and cooling costs. Increasing *R*-values have greater insulating effectiveness and are typically more expensive [31]. For example, single pane glass, which is typically a poor insulator, has an *R*-value of 0.91. Softwoods, typically used for flooring, have *R*-values of up to 1.25. Blown fiberglass to insulate walls have an *R*-value between 3.7 and 4.3 depending on its thickness and polystyrene board (the substrate that was chosen for this study) has an *R*-value of 5.0 with a higher capacity to resist heat flowing through it. The experiment was conducted in a closed space protected from drafts. The room temperature and the insulator temperature were monitored to ensure environment stability.

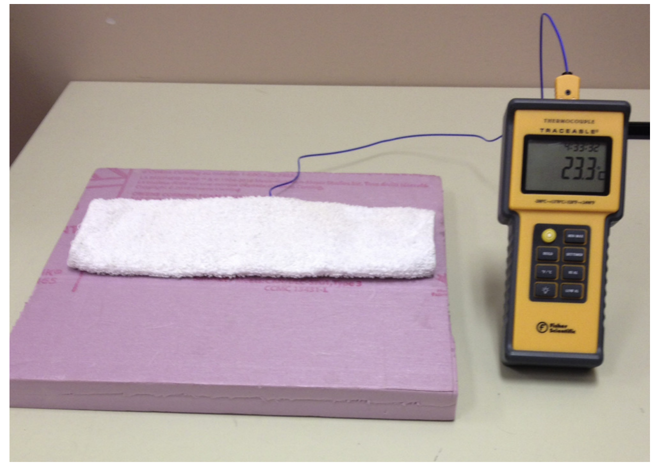

Fig. 1. Experiment arrangement (non-conductive 1″ thick insulated polystyrene board, thermometer and evaluated mask).

Each mask was left at ambient room temperature for several hours prior to the study. The temperature of each mask was then measured at 2 min (−2) and at 1 min (−1) prior to inserting in the microwave oven to establish baseline measures. Each eyelid mask was sequentially heated with a microwave oven following the manufacturer's instructions. The same microwave oven was used for each procedure (Sharp Carousel 1100W). The eye mask was placed onto the Styrofoam board within 5–10 s of heating and its temperature was measured using a digital thermometer probe (Fisher Scientific Traceable Total-Range) placed underneath it, between the mask/cloth and the board, as shown in Fig. 1. The digital thermometer complies with ISO/IEC calibration and has a resolution of 0.1 °C. Once the mask was placed on the board (time = 0), the temperature was measured at 1-min interval for 12 min. The procedure was repeated three times for each mask and the measurements were averaged and standard errors (SE) were calculated and plotted for comparison.

The facecloth was heated using room temperature tap water heated for 20 s in the microwave oven to simulate hot tap water. The excess was wrung out, and the facecloth was folded to obtain three layers (to simulate an "at-home" procedure), and placed directly on the polystyrene board to be measured similarly to the other warming masks. Statistical analysis was performed using the non-parametric Mann–Whitney *U*-test at an alpha level of 0.05 using SPSS (version 17.0 for Windows).

3. Results

Three trials per mask were recorded, averaged and plotted with standard error (SE) in Fig. 2. All masks reached a temperature above 40 °C within the first minute, with the exception of the Thera°Pearl® which took 2 min. Three masks (MGDRx EyeBag®, The Eye Doctor®, Thera°Pearl®) had the most stable heat retention over an 8-min interval, maintaining at the desired temperature of 40–45 °C. The Bruder® and Tranquileyes™ reached the highest temperatures of 54 °C and 49 °C, respectively within the first minute and maintained that temperature for the first 2 min before slowly decreasing. The Bruder® mask maintained a temperature above 50 °C for the first 6 min and, although slowly decreasing afterwards, was not able to reach below 40 °C at the 12-min mark. The Tranquileyes™ maintained a temperature above 40 °C for the first 4.5 min and subsequently held the targeted temperature for another 6 min. After the 10-min mark, Tranquileyes™ fell below the desired range.