Warm Compresses and the Risks of Elevated Corneal Temperature With Massage

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Purposes: To quantify the changes in corneal temperature resulting from intensive warm compress (WC) application with minimal pressure and to review the significance of these changes within the context of the peer-reviewed literature.

Methods: WC were applied intensively and unilaterally at 45 ± 0.5°C for 30 minutes with the contralateral eye serving as a control. Outer upper eyelid and central corneal surface temperatures were measured using an Infrared pyrometer at baseline. The WC were removed for repeat measurements of the outer upper eyelid surface and central corneal temperatures every 2 minutes and replaced with a new WC heated to 45 ± 0.5°C. Lid and corneal temperatures were monitored for 10 minutes after the final WC application.

Results: The mean age of the subjects was 37.1 ± 15.0 years (n = 12). The mean maximum outer upper lid temperature of 42.2 ± 1.3°C was reached after 6 minutes. The mean maximum corneal temperature of 39.4 ± 0.7°C was reached after 8 minutes of heating. The control eye showed no significant change in temperature from baseline throughout the experimental period.

Conclusions: These data show that WC use for lid warming, even when only minimal contact pressure is applied, also transfers significant heat to the cornea. Corneal temperatures reach peak temperature after about 8 minutes of WC application. Recent reports discussing the increased potential for transient and long-term corneal molding subsequent to the heat and pressure of WC application are briefly reviewed.

Key Words: warm compresses, safety, meibomian gland dysfunction, dry eye

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The application of warm compresses (WCs) with gentle pressure may be indicated for a multitude of ophthalmic conditions, such as internal or external hordeola,[1] blepharoconjunctivitis,[1] meibomianitis, orbital or preseptal cellulitis,[2,3] acute dacryocystitis,[4] meibomian gland dysfunction (MGD),[5] and ocular rosacea.[6] When used for infective indications such as external hordeolum or acute dacryocystitis, the presumed purpose of heat is to bring about vasodilatation and increase blood flow, which in turn increases the circulation of naturally occurring immune compounds and prescribed antibiotics to the affected area. However, when used for indications such as posterior blepharitis/meibomianitis, internal hordeolum, MGD, and ocular rosacea, WC must administer enough heat to also liquefy the hardened or abnormally viscous meibomian secretions, whether located on the lid margin or inside the meibomian glands.[7–9]

The application of pressure, even mild pressure, is an integral component of conventional WC use and that of its modern avatars, which administer heat to the eyelids through conduction. Mild pressure improves the apposition of the heating surface to the lid and periocular skin and therefore improves the efficacy of heat transfer.[8,10] For indications such as meibomianitis, MGD, or chalazia, the recommendation of WC application is typically accompanied by moderate to firm massage as the purpose is to express the meibomian secretions (liquefied by the prior application of heat) and thus clear any obstruction due to hardened or more viscous meibomian secretions.[7–9]

Under normal conditions, corneal temperature seems to be maintained by heat transfer from the tear film and the limbal vasculature, but primarily from the aqueous humor.[11] When the eye is open, evaporation, convection, and radiation all result in heat loss from the front surface of the eye.[12] During WC application, there is heat transfer directly from the palpebral conjunctiva to the precorneal tear layer and anterior cornea, especially when the conjunctiva is pressed against the cornea and there is an inhibition of heat loss from the anterior surface because the eye is closed.

Recently, there have been reports of a possible connection between the application of WC with ocular/lid massage and the induction of topographical corneal irregularities and visual and/or refractive changes.[13,14] A comprehensive review of literature indicated that the application of heat with pressure has the potential to produce greater changes in corneal surface asymmetry or regularity indices compared with when pressure alone is applied.[13] For example, the application of heat using hard-boiled eggs to treat MGD was found to induce corneal irregularity.[15]

Although we know that WCs have long been prescribed for various reasons, it is only in the past few decades that obstructive MGD has been recognized and described as a highly prevalent disease entity[9,16,17] and that WC, together with moderate to firm massage, has become widely known as the mainstay therapeutic option for MGD.[5,9,16–20] In addition,

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obstructive MGD is a chronic progressive condition.[21,22] Thus, WC are likely to be prescribed for continuous use for extended periods, such as months if not years.

Furthermore, the recent paradigm shift in understanding that MGD is likely the leading cause of dry eye[21,22] has resulted in greater recognition and diagnosis of MGD.[23] Thus, going forward, MGD is likely to be treated much more frequently and aggressively than has been previously observed. Notwithstanding the availability of alternative treatments, WC use is likely to continue to have wide application for MGD and other conditions for which they have become standard. The goals of this article were to assess how much the cornea could be heated during WC application and to discuss the potential safety concerns with the use of WC in the context of recent literature reports on the effect of heat and pressure on the cornea.

METHODS

Following the tenets of the Declaration of Helsinki, subjects who met the inclusion criteria were enrolled and fully consented according to the Good Clinical Practice (GCP) guidelines. An independent clinical research ethics committee approved the study. Inclusion criteria were limited to healthy individuals older than 18 years. The rationale for these minimal inclusion criteria was to include a spectrum of individuals of varying ages and life styles, for whom WCs might be prescribed. Exclusion criteria included any ocular pathology, including the adnexal tissues, for which the application of heat and/or pressure of any form would be contraindicated.

For each subject, the right eye was chosen to be the experimental eye (the eye exposed to the WC) and the contralateral eye served as the control. The WC was a white cotton cloth (50 × 50 cm) soaked with tap water at room temperature (mean, 23.2 ± 0.2°C) and folded so that it measured approximately 12.5 × 6 cm and was 16 layers thick.[8,14] Once the excess water was removed, the compress was heated using a Model 220H Sharp carousel microwave (Sharp Electronics Corporation, Mahwah, NJ). Every time a compress was heated, the temperature of the region of the compress in contact with the eyelids was measured and confirmed to be 45 ± 0.5°C before the application of the compress.[8,14] This was determined with a Model OS-611 infrared pyrometer (Omega, Stamford, CT). Measurements of the outer upper lid surface and cornea were made by placing the handheld sensor of the pyrometer 10 mm from the center of the upper eyelid and cornea. For the corneal measurement, subjects were instructed to hold their eyes open without blinking for a few seconds after removal of the WC while the pyrometer probe was held over the central cornea.

Three baseline temperature measurements were recorded from the centers of the outer upper lid and corneal surfaces of the experimental and control eyes before the application of WC. Subjects were next instructed to hold the WC over the experimental right eye to establish and maintain gentle contact of the WC with the closed eyelid. They were instructed to use only the minimal amount of pressure necessary throughout the procedure. Nothing was applied to the closed contralateral control eye.

To maintain a more uniform WC application temperature, every 2 minutes, the WC was removed for temperature measurements of the eyelid and cornea and was immediately replaced with one that was heated to 45 ± 0.5°C. In clinical practice, patients are instructed to reheat a cooling WC to optimize heating efficacy, but we do not expect them to achieve the continuity achieved in this study. For this study, we were interested in approximating the possible effect of diligent at-home WC application and the possible effect of devices that provide a continuous form of a heat (as discussed below) in the treatment of MGD. The 2-minute cycles over 30 minutes for this study were based on our findings for the maximum WC cooling time,[8] and lid and corneal temperatures were measured only once every 2 minutes to limit the duration of open eye and keep tissue cooling to a minimum. Subjects were monitored throughout the procedures, ensuring that WCs were positioned correctly and that no rubbing or rotating motions were produced during the applications.

Descriptive statistics are reported as means ± SD. Analysis involved the D'Agostino and Pearson omnibus normality test at the significance level of $\alpha = 0.05$, paired t tests at the significance level of $\alpha = 0.05$, and repeated-measures analysis of variance with Bonferroni corrections where applicable (Graphpad Prism, LaJolla, CA).

RESULTS

The data analyzed all passed the D'Agostino and Pearson omnibus normality test at the level of $\alpha = 0.05$. The mean age of the subjects was 37.1 ± 15.0 years (n = 12, 7 women and 5 men), with an age range of 21 to 60 years. The maximum outer upper lid temperature of 42.2 ± 1.3°C was reached after 6 minutes and was significantly higher than baseline ($P < 0.0001$) but did not change significantly in the control eye ($P > 0.05$, Figs. 1, 2). The maximum measured central corneal temperature of 39.4 ± 0.7°C was reached after 8 minutes and was significantly higher than baseline ($P < 0.0001$), whereas the control eye did not change significantly ($P > 0.05$, Figs. 3, 4). There were no significant differences between test and control lid or corneal

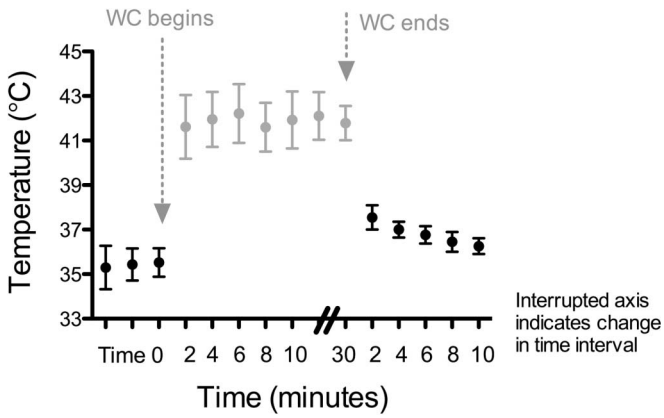

FIGURE 1. Test eye: the mean outer upper eyelid temperatures from baseline through 30 minutes of WC heating.

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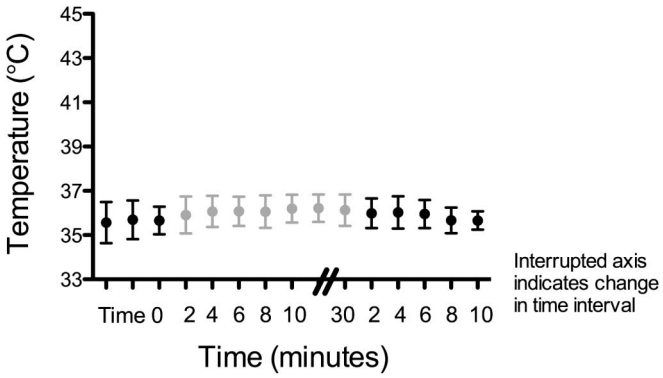

FIGURE 2. Control eye: the mean outer upper eyelid temperatures from baseline through 30 minutes while the test eye was being heated with a WC.

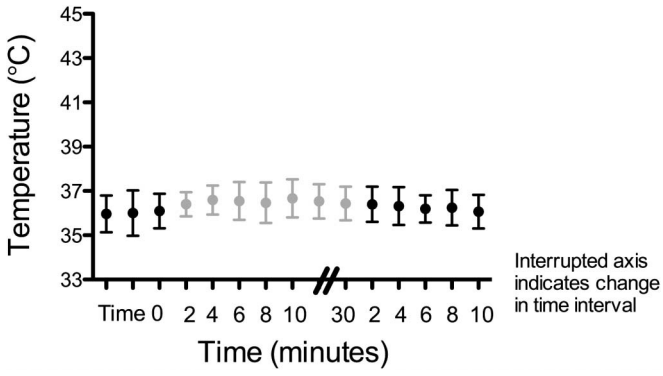

FIGURE 4. Control eye: the mean corneal temperatures from baseline through 30 minutes while the test eye was being heated with a WC.

surface temperatures eyes at baseline ($P > 0.05$ for all comparisons, Table 1).

DISCUSSION

The results of this study show that the lid and corneal temperatures are significantly elevated during WC use. The finding that the maximum measured central corneal temperature of 39.4 ± 0.7°C was reached after 8 minutes may be an underestimation, given that some heat loss could have occurred with eye opening, during each measurement. In the absence of eye opening, higher temperatures may be reached in a shorter period when continuous heating methods are used. However, heat application by a patient using WC at home may not reach this temperature when the cycle of reheated WC is not followed as diligently.

In this study, only minimal pressure was used to maintain contact between the WC and the outer eyelid surface. Relatively, unimpeded blood flow in the lid and the palpebral conjunctiva in particular under these conditions allows heat to be drawn from the lid tending to reduce the overall heating efficacy of the compress.[7,8] The apparent partial dependence of corneal temperature on blood flow is indicated by the finding that, compared to the central cornea, temperature is higher in the extreme peripheral cornea adjacent to the limbal vasculature.[24] In the treatment of MGD, WC are ordinarily applied with pressure and followed by massage once the compress is removed to promote the mobility of sebum through the meibomian gland ducts and orifices; however, the amount of pressure is not standardized. With even gentle massage, Kessing's[25] space under the tarsal region of the lid appears likely to be more completely collapsed, bringing the warmer lid vascular tarsal conjunctiva into unnaturally close contact with the cornea.[13,26] The close contact facilitates enhanced heat transfer from the heated and dilated vasculature of the palpebral conjunctiva to the cornea so that corneal temperatures may be higher when massage is applied. In addition, massage and rubbing may also elevate corneal temperature and compound the effect of WC applications because they involve a cyclic pattern of unloading and increased loading of the viscoelastic cornea by distending intraocular pressure (IOP) forces.[13,27]

Given the association between rubbing-related corneal trauma and keratoconus,[27] patients with keratoconus or at risk for developing keratoconus who require treatment involving WC and massage would need to be shown the methods of massage, which avoid mechanical trauma to the cornea.[13,28–30] In addition to patients with keratoconus, myopes may also have increased risk of complications associated with WC. For example, myopic corneas have been found to be thinner than hyperopic corneas,[31,32] and thinner corneas have been shown to have increased distensibility.[33] Another consideration for patient selection for WC therapy is the elevation of IOP by lid massage. Light fingertip touch on adnexal skin that transmitted a corresponding light compressive force to the eye was found to approximately double IOP.[34] Hence, lid massage associated with WC could be contraindicated for any

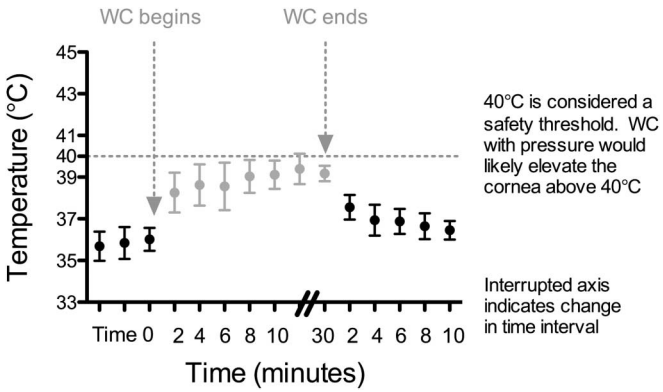

FIGURE 3. Test eye: the mean corneal temperatures from baseline through 30 minutes of WC heating.

TABLE 1. Baseline Temperatures (Mean ± SD) for Test and Control Eyes ($P > 0.05$ for Comparisons Between Test and Control Eyes)

Corneal Temperature		Outer Upper Eyelid Temperature	
Control Eye	Test Eye	Control Eye	Test Eye
36.02 ± 0.9	35.85 ± 0.7	35.64 ± 0.8	35.42 ± 0.8

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patient with glaucoma[35] or other IOP-related diseases, such as keratoconus[36] and axial myopia (unpublished data).

Alternatives to WC for heating the glands in the treatment of MGD and which do not prescribe additional manual pressure over the eyelids during treatment are currently available.[28,29] In general, the prescription of WC should include assessment of the risk for adverse consequences. Corneal deformation and associated visual degradation may result if patients are not screened for such consequences and then subsequently monitored in order that any such changes can be detected at an early stage.

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