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BRIEF REPORT

Evidence-Based Strategies for Warm Compress Therapy in Meibomian Gland Dysfunction

Gladys Lee

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ABSTRACT

***Aim*:** Despite promising results from technological therapies like intense pulsed light application, warm compress therapy is a mainstay in meibomian gland dysfunction (MGD). However, applying warm compresses (WC) to the eyelids is palliative rather than curative and not always dispensed with specific instructions. The range of eyelid warming treatments available and lack of clear directives for use creates uncertainty for patients accustomed to explicit dosage information. This report examines data from clinical studies across the past 20 years to identify effective protocols for three types of WC—hot towel, microwavable eye mask, and self-heating eye mask (EM).

***Method*:** Literature search for studies on WC and MGD published between 2004 and 2023 in English was conducted. Studies wherein hot towel, microwavable EM, and self-heating EM were used in a treatment arm were included and those wherein they served only as control or were used in conjunction with another intervention were excluded. 20 resulting studies were separated into 3 groups: 5 on temperature profiles of WC, 6 with single application of WC, and 9 with repeated applications. Study methods and outcomes were tabulated, and a qualitative review was performed, attending to WC protocol and efficacy, as indicated by measures of tear film, meibomian gland health, and dry eye questionnaires.

***Results*:** Data from the aforementioned studies revealed that each method can achieve target eyelid temperature of 40 °C. A single application of WC—ranging from 5 to 20 min—can significantly improve tear quality, while repeated applications significantly relieve symptoms associated with dry eyes from MGD and, in most studies, significantly improve meibomian gland health. Hot towels, however, require frequent reheating to maintain eyelid temperatures above 40 °C, rendering them relatively ineffective in longitudinal studies. Microwavable EM retain heat well across 10 min and were found to improve tear break-up time and/or meibomian gland score. Self-heating EM have variable activation times and were typically applied for longer periods, showing benefits akin to microwavable EM in short-term studies. Studies monitoring compliance indicate greater deviation from protocol with higher application frequencies or longer-term use. Evidence suggests superior heat retention and therapeutic effects

G. Lee
Division of Ophthalmology, Brown University, Providence, RI, USA

G. Lee
Private Practice, New York, NY, USA

G. Lee (✉)
New York, USA
e-mail: gladys_lee@alumni.brown.edu

on specific contributing factors in MGD (such as Demodex) with moist–heat compress.
Conclusion: Considering decreased patience adherence to therapy with increased usage frequencies, and balancing needs to provide succinct instructions for various compress types, an advisable strategy is for patients to apply a moist–heat generating EM (microwavable or self-heating) to each eye for at least 10 min, prepared according to manufacturer's instructions.

Keywords: Meibomian gland dysfunction; Evaporative dry eye; Warm compress; Eyelid warming therapy

Key Summary Points
Improvements to tear film, meibomian gland function, and dry eye symptoms from warm compress (WC) therapy are critically affected by WC type, treatment duration and frequency, and patient compliance.
Patient-applied WC is widely available while office-based treatments can be limited by cost and access.
The variety of WC combined with frequent lack of directives for use can create uncertainty for patients accustomed to explicit dosage information and therapeutic protocols.
Hot towels retain heat poorly and require frequent reheating to keep eyelid temperatures above 40 °C, rendering them relatively ineffective for long-term use.
An advisable strategy is for patients to apply a moist-heat generating eye mask (microwavable or self-heating) to each eye for at least 10 min once a day.

INTRODUCTION

Meibomian gland dysfunction (MGD) is defined by impaired flow of meibum from meibomian glands. Exam is often characterized by decreased tear break-up time, foamy tear film and telangiectasia at the lid margin, and thickened meibum, which, when expressed, can range from an opaque viscous liquid to a soft solid of toothpaste consistency [1, 2]. Since lipids are critical to the tear film, the reduced delivery of lipids from meibomian glands in MGD leads to a deficiency in the tear film that increases its surface tension and causes it to evaporate quickly [3, 4]. Patients with MGD often suffer from dry eyes in addition to experiencing grittiness, itching, and redness of eyelids. When inadequately treated, the physiologic changes from MGD can lead to ocular surface damage [1, 3, 4].

Decreased secretion and thickened state of meibum have been attributed to ductal epithelial hyperkeratinization and meibocyte abnormalities and are influenced by age, environmental conditions, hormone, diet, medication use, and ocular microbiome [1, 3]. Consequently, the treatment for MGD is as multifaceted as the contributing factors, with existing and ongoing studies establishing the efficacy of office-based procedures, such as intense pulsed light (IPL) and meibomian gland expression, both proving effective in reducing intraductal inflammation and improving meibomian gland function whether used independently or in tandem [4–9]. Nevertheless, a mainstay in MGD therapy continues to be at-home application of warm compress (WC) to alleviate symptoms and improve gland health by increasing meibum delivery [4–7]. Meibum is a composite of wax, cholesterol esters, triglycerides, phospholipids, and hydrocarbons, with increasing age and disease associated with greater percentages of ordered hydrocarbons [10]. Due to its composite nature, meibum lacks a consistent melting point. It melts between 19 and 45 °C, healthy meibum occupying the lower end of that wide range and thickened meibum the higher [3, 4, 8, 11]. Therefore, while healthy meibomian gland lipids remain fluid below average body temperature of 37 °C, the melting range for thickened meibum often exceeds body temperature. This may explain the solid phase of meibum in MGD. Although the temperature required to melt thickened meibum associated

with MGD is not definite, multiple studies have identified the temperature of therapeutic efficacy, or, target temperature, for WC to be ≥ 40 °C [6, 11, 15].

Procedural treatments to decrease meibum viscosity or meibomian gland inflammation, particularly IPL, whether performed alone or in conjunction with meibomian gland expression, have emerged as effective therapeutic treatments for MGD. These are promising options now and for the future, but their adoption is limited by patient access due to availability and cost [4, 7]. This continues to leave WC therapy as the first-line treatment for most patients. However, recommendations to apply WC to the eyelids, while frequent and effective [6, 7], are not always accompanied with precise instructions, and some of the instructions given may not adequately account for what trials show is necessary to make an impact on symptoms and/or meibomian gland health. Beyond the traditional option of hot towels, the marketplace offers myriad options for eye masks and eyelid warming devices. Labels and packaging can confuse patients. Some eye masks are marked as applicable for "dry eye", but supply "moist heat"; others double as ice packs so that both "hot" and "cold" appear on packaging. Some masks require connection to an electrical source or docking station; others need extended activation time before use. With discovery of additional therapeutic functions for WC (e.g. aiding sleep or mental health [12, 13]), and novel ways to extend the effects of WC through secretagogues such as menthol [14], new options will continue to emerge. Clinicians should recognize that instructions to "apply warm compress" is inadequate given the choices available. They must also consider the influences of device cost, ease of use, and efficacy on patient compliance.

The range of eyelid warming treatments available and the frequent lack of directives for use can create uncertainty for patients accustomed to explicit dosage information for drug prescriptions, or more definite instructions for other therapies. Consequently, this report uses data from clinical studies across the past 20 years to identify effective protocols for the application of three types of widely available WC—hot towel, microwavable eye mask, and self-heating eye mask (EM).

METHOD

Searches were conducted March 4, 2024, on PubMed using terms "(warm compress) AND (meibomian gland)" and "(eyelid warming) AND (meibomian gland)" for studies published between 2004 and 2023 in English. Studies wherein hot towel, microwavable EM, and self-heating EM were used in a treatment arm were included and those wherein they served only as control or were used in conjunction with another intervention were excluded. 20 resulting studies were separated into 3 groups: 5 on temperature profiles of WC, 6 with single application of WC, and 9 with repeated applications. Study methods and outcomes were tabulated and a qualitative review was performed, rating the studies using the scale adopted by the American Academy of Ophthalmology's Preferred Practice Pattern® guidelines, which are based on the Scottish Intercollegiate Guideline Network [7, 15]. The review attended to WC protocol and efficacy, as indicated by measures of tear film, meibomian gland health, and dry eye questionnaires.

This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by the author.

RESULTS

Temperature Profiles

Data on temperature profiles of WC and eyelids are compiled from 5 studies [16, 17] (level of evidence: I) [18–20] (III). Profiles of WC used in studies evaluating therapeutic effects are highlighted and their in vitro temperature and effects on outer eyelid temperature are detailed in Table 1. One consistent finding is that hot towels, though initially able to exceed 40 °C, retain heat poorly, raising eyelid temperature above 40 °C for only the initial minute, then dipping

Table 1 Temperature profile of warm compresses compiled from studies [16–20]

Type of WC	Temperature of WC				Temperature of eyelid			
	1 min	2 min	5 min	10 min	1 min	2 min	5 min	10 min
Hot towel								
Not reheated	≥ 40°	≥ 40°	< 40°	< 40°	< 40°/ ≥ 40°	< 40°	< 40°	< 40°
Reheated every 2 min	≥ 40°	≥ 40°	≥ 40°	≥ 40°	≥ 40°	≥ 40°	≥ 40°	≥ 40°
Microwavable								
Dry heat:								
EyeBag®	≥ 40°	≥ 40°	< 40°/ ≥ 40°	< 40°/ ≥ 40°	< 40°	< 40°/ ≥ 40°	< 40°/ ≥ 40°	< 40°
Moist heat:								
Bruder®	≥ 40°	≥ 40°	≥ 40°	≥ 40°	< 40°/ ≥ 40°	≥ 40°	≥ 40°	< 40°/ ≥ 40°
Thera° Pearl®	< 40°	≥ 40°	≥ 40°	< 40°	< 40°/ ≥ 40°	≥ 40°	≥ 40°	< 40°/ ≥ 40°
Self-heating								
Dry heat: EyeGiene®	≥ 40°	45° (peak)	< 40°	< 40°	< 40°	< 40°	< 40°	< 40°

Temperature in Celsius. < 40°/ ≥ 40° indicate differing results from different studies

WC Warm compress

below target temperature within 2 min [16–18]. When freshly heated towels are changed at two-minute intervals, eyelid temperature can be maintained in the target range [16, 19].

Microwavable EM sustain higher temperatures far longer than hot towels, with most bringing eyelid temperatures above 40 °C within 1–2 min [17–19]. Results varied as to the extent of heat retention and the resultant heat transfer to the eyelids by different models, but there appears to be a distinction between dry- and moist–heat generating EM [16, 18, 19]. For instance, results were mixed for EyeBag®, a dry-heat generating EM, with some studies finding it either unable to stay above 40 °C, or for the eyelid temperature to do so, after 5 min [18, 20]; whereas findings on Bruder® and Thera°Pearl®, both moist–heat generating EM, were more homogenous across multiple studies, each model demonstrating the ability to keep eyelid temperatures above 40 °C at 5 min and maintaining them close to 40 °C at 10 min [17–19].

Based on data recorded for EyeGiene®, a self-heating EM, WC of this type can also reach temperature above 40 °C [20]. The temperature rises more steeply and takes longer to reach peak temperature than microwavable EM. Studies of EyeGiene® did not demonstrate its ability to maintain eyelid temperature above 40 °C across a 10-min span [19, 20]. However, this data stands in contrast to that noted by Ishikawa et al., which used the self-heating Hot Eye Mask from Kao corporation in Japan and reported the EM to "[maintain] the ocular surface at approximately 40 °C for 20 min" [21]. A third model of self-heating EM from Zhenshiming company in China used by Zhou et al. was cited as taking about "3 min to warm up to 35 °C, and maintaining temperature over 35 °C for an average of 30 min, during which the mean temperature was 40.7 °C" [23].

Therapeutic Potential

Searches yielded 6 clinical studies evaluating effects of a single application of WC [21–26]. Results are summarized in Table 2. The 6 studies encompass 8 study groups, 4 using microwavable EM, 3 self-heating EM, 1 hot towel. Treatment duration was 5, 10 or 20 min, with 2 groups assessed after 5 min, 4 after 10 min, and 2 after 20 min. Hot towels were folded and heated to 42 °C, then reheated every 2 min [24] (I). Self-heating or microwavable EM were

Table 2 Clinical studies—single warm compress application [21–26]

Year author	Level of evidence	*N*	Type of WC	Application	Significant outcomes ($p < 0.05$)	Other outcomes/notes
2023 Ishikawa	I	200	Self-heating (Kao corp mask) $n = 100$	20 min	Increased tear break-up time Increased tear meniscus height Improved meibomian gland score Increased conjunctival hyperemia Increased corneal blur time^	^Improved intraoperative visibility
2022 Park	II	26	Microwavable (Bruder®)*	10 min	Increased tear film lipid layer thickness	Partial blink rate, frequency ($p > 0.05$) *Mechanical decompression after WC in 2nd part of study, not included here
2021 Zhou	I	37	Self-heating (Zhenshiming co. eye mask)	20 min	Increased tear film lipid layer thickness Increased tear break-up time Improved meibomian gland score Increased glands with liquid secretion Decreased partial blink rate + frequency	Glands with clear secretion ($p > 0.05$)
2018 Tan	I	31	Hot towel (reheated)	5 min	Increased tear film lipid layer thickness Increased tear meniscus height	Tear break-up time ($p > 0.05$)
		31	Microwavable (Bruder®)	5 min	Increased tear film lipid layer thickness Increased tear meniscus height	Tear break-up time ($p > 0.05$)
2018 Turnbull	I	81	Microwavable (EyeBag®) $n = 28$	10 min	Increased tear break-up time—severe MGD grp (> 40% MG dropout) Increased lipid layer grade	Tear break-up time-mild grp ($p > 0.05$) Tear meniscus height ($p > 0.05$) Tear evaporation rate ($p > 0.05$)
2015 Wang	I	41	Self-heating (EyeGiene®) one eye	10 min	Increased tear break-up time Increased tear lipid layer grade Increased tear meniscus height	Degree of difference in measured outcomes to contralateral eye ($p > 0.05$)
		41	Microwavable (EyeBag®) contralateral eye	10 min	Increased tear break-up time Increased tear lipid layer grade Increased tear meniscus height	Degree of difference in measured outcomes to contralateral eye ($p > 0.05$) Preferred over EyeGiene® ($p < 0.05$)

N = number of participants in the study, *n* = number of participants in the group

WC Warm compress, *MGD* meibomian gland dysfunction

prepared according to manufacturer's instructions. All studies reported ambient temperature, with some specifying temperature and humidity ranging between 22 and 25 °C and 35–50%, respectively. No adverse events were reported.

All studies—5 randomized controlled trials (RCTs) [21, 23–26] (I) and 1 cohort study [22] (II)—found significant improvement in tear quality—either increased tear film lipid layer thickness or increased tear break-up time. One study with a 5-min application found equivalent efficacy between a hot towel reheated every 2 min and a microwavable EM (Bruder®) [24] (I). Another study with a 10-min application

found equivalent efficacy between a self-heating (EyeGiene®) and a microwavable EM (EyeBag®) [26] (I). Whereas microwavable EM were studied using 5 or 10 min application times, self-heating EM were typically studied using 10 or 20 min application times. Notably, one of two studies using self-heating EM with an application period of 20 min yielded the greatest number of significantly improved outcomes, which included increased tear film lipid layer thickness, increased tear break-up time, improved meibomian gland score, increased number of glands with liquid secretion, and decreased partial blink rate and frequency [23] (I).

Therapeutic Efficacy

Searches yielded 9 clinical studies evaluating effects of repeated applications of WC [27–35]. Results are summarized in Table 3. The 9 studies encompass 14 study groups, 8 using microwavable EM, 3 self-heating EM, and 3 hot towels, with two groups reheating towels as part of the protocol. Study periods ranged from 2 weeks to 6 months. Participants in microwavable EM groups were given device-specific heating instructions, some studies further directing patients to adjust heating time based on microwave power and cautioning against excessive heating. No adverse events were reported.

All studies—RCTs of level I evidence—found significant decreases in dry eye symptoms with repeated use of WC. Most studies also found significant improvement in meibomian gland health and/or tear quality. For studies involving microwavable EM, most protocols called for 10-min applications once or twice daily. Two short-term studies (2–4 weeks) used a protocol of 5 min twice daily found numerous improvements in tear film, meibography, and symptoms [29, 32], whereas results from long-term studies (2–6 month) were more disordered. In one study, a protocol of 10 min twice daily for 3 months resulted in decreased symptoms but no objective improvements [34], while less time-intensive protocols—one calling for 10-min applications twice daily for 2 weeks followed by one daily treatment for 6 weeks [33]; another for 10–15 min application once daily for 6 months [35]—led to improved tear break-up time and decreased corneal staining in addition to improved symptoms, with the former also identifying decreased *Demodex* quantity with the use of a moist–heat generating EM.

Self-heating EM were used in fewer longitudinal studies (3 out of 9). Two models were applied for either 10 or 15 min. Like microwavable EM, short-term studies yielded numerous improvements across all efficacy measures with 10- and 15-min applications daily [27, 28], though similar improvements were not found in a long-term study (3 months) calling for 10-min applications twice daily [34].

All studies longer than 2 weeks, except for Artia et al., included information about participant compliance, with many noting decrease in compliance across the study period [30, 33, 35]. In Ngo et al. 4-week study, in which a microwavable EM was used for 10 min twice daily, compliance decreased from 91% in the first 2 weeks to 81.6% in last the last 2. In Tiechnor et al.'s 4-week study—hot towel for 10 min twice daily; microwavable EM for 10 min twice daily; microwavable EM for 10 min once daily—compliance was 79.6, 86, and 90.2%, respectively. Microwavable EM groups in this study had comparable outcomes, both groups showing improved meibomian gland scores. In Murphy et al.'s 2-month study, the protocol stood out for having two parts—WC was applied for 10 min twice daily for 2 weeks, then decreased to once daily for 6 weeks. This study also included 3 groups: hot towel (reheated), the microwavable dry heat EyeBag®, and the microwavable moist heat OPTASE™. The compliance was 77.92, 86.81, and 85.45%, respectively.

DISCUSSION

Data from longitudinal studies are encouraging, pointing to significant benefits from minimal use of WC. Treatment sessions of 10 min once daily or 5 min twice daily yielded consistent subjective improvement in symptoms and measurable improvements in meibomian gland and tear film health. But the type of WC, duration

Table 3 Clinical studies—repeated warm compress applications [27–35]

Year author	Level of evidence	*N*	Type of WC	Application	Significant outcomes ($p < 0.05$)	Other outcomes/notes
Study duration: 2 weeks						
2023 Meng	I	50	Self-heating (EyeGiene®) $n = 25$	15 min q.d.	Increased tear break-up time$^{\pm\dagger\dagger}$ Decreased corneal staining$^{\pm\dagger\dagger}$ Improved meibomian gland score$^{\pm}$ Increased glands with liquid secretion$^{\pm}$ Decreased symptom severity$^{\pm\dagger\dagger}$	Tear film lipid layer thickness ($p > 0.05$) Partial blink rate (decreased, no p) Meibomian gland dropout ($p > 0.05$) $^{\pm}$1-month, †2-month, ‡3-month eval No mention of diary to log usage
2020 Sun	I	45	Self-heating (Kao corp mask) $n = 22$	10 min q.d.	Increased tear break-up time Decreased corneal staining Decreased symptom severity	Meibomian gland score ($p > 0.05$) Meibomian gland dropout ($p > 0.05$) No mention of diary to log usage
2014 Bilkhu	I	25	Microwavable (EyeBag®)	5 min b.i.d.	Increased tear film lipid layer thickness Increased tear break-up time Increased tear meniscus height Decreased tear osmolarity Increased meibomian gland area Improved meibomian gland score Decreased symptom severity	1 participant reported transient eyelid stinging on the first 4 occasions Ocular comfort checked by text b.i.d. Maintenance of increased ocular comfort at 6-month follow-up, greater score for those who continued occasional use No mention of diary to log usage
Study duration: 4 weeks						
2019 Ngo	I	25	Microwavable (EyeBag®) $n = 12$	10 min b.i.d.	Decreased symptom severity	Tear break-up time ($p > 0.05$) Meibomian gland score ($p > 0.05$) Decreased compliance 2nd half study Phone questionnaires week 1 & 3 Attended visits week 2, 4, 8
2019 Tichenor	I	51	Hot towel (not reheated) $n = 17$	10 min b.i.d.	Decreased symptom severity (when data is combined with all groups)	Tear break-up time ($p > 0.05$) Tear film lipid layer thickness ($p > 0.05$) Meibomian gland score ($p > 0.05$) Symptom severity ($p > 0.05$) 79.6% compliance
			Microwavable (Bruder®) $n = 17$	10 min b.i.d.	Decreased blocked glands Decreased symptom severity (when data is combined with all groups) Increased comfortable time in contacts (when compared to hot towel group)	Tear break-up time ($p > 0.05$) Tear film lipid layer thickness ($p > 0.05$) Meibomian gland score ($p > 0.05$) Symptom severity ($p > 0.05$) 86% compliance
			Microwavable (Bruder®) $n = 17$	10 min q.d.	Decrease in blocked glands Decreased symptom severity (when data is combined with all groups) Increased comfortable time in contacts (when compared to hot towel group)	Tear break-up time ($p > 0.05$) Tear film lipid layer thickness ($p > 0.05$) Meibomian gland score ($p > 0.05$) Symptom severity ($p > 0.05$) 90.2% compliance Diary of symptoms; visits day 15 & 30
2015 Arita	I	10	Microwavable (Kiribai corp red bean mask)	5 min b.i.d.	Increased tear break-up time Decreased ocular surface staining Decreased Schirmer's Increased meibomian gland area Improved meibomian gland score Increased tarsal conjunctiva temp	Eyelid skin temp ($p > 0.05$) Multi-component study; results related to WC on subjects with MGD listed No mention of diary to log usage

Table 3 continued

Year author	Level of evidence	*N*	Type of WC	Application	Significant outcomes ($p < 0.05$)	Other outcomes/notes
Study duration: 2 months						
2020 Murphy	I	42	Hot towel (reheated) *n* = 12	10 min b.i.d. 10 min q.d.[§]	Decreased ocular surface staining Decreased symptom severity	Tear break-up time ($p > 0.05$) Tear osmolality ($p > 0.05$) Schirmer test ($p > 0.05$) Meibomian gland score ($p > 0.05$) *Demodex* quantity lash ($p > 0.05$) *Demodex* quantity microscope ($p > 0.05$) 77.92% compliance
			Microwavable (EyeBag®) *n* = 16	10 min b.i.d. 10 min q.d.[§]	Decreased corneal staining Improved meibomian gland score Decreased symptom severity	Tear break-up time ($p > 0.05$) Tear osmolality ($p > 0.05$) Schirmer test ($p > 0.05$) *Demodex* quantity lash ($p > 0.05$) *Demodex* quantity microscope ($p > 0.05$) 86.81% compliance
			Microwavable (OPTASE™) *n* = 14	10 min b.i.d. 10 min q.d.[§]	Decreased tear osmolarity Decreased corneal staining Improved meibomian gland score Decreased symptom severity Decreased *Demodex* quantity lash	Tear break-up time ($p > 0.05$) Schirmer test ($p > 0.05$) *Demodex* quantity microscope ($p > 0.05$) 85.45% compliance
						[§]b.i.d. 2 weeks, then q.d. 6 weeks Usage reported at visits week 2, 4, 8
Study duration: 3 months						
2014 Sim	I	75	Hot towel (reheated) *n* = 25	10 min b.i.d.	Decreased symptom severity Decreased symptom frequency	Tear break-up time ($p > 0.05$) Meibomian gland score ($p > 0.05$) Reheating protocol not specified
			Self-heating (EyeGiene®) *n* = 25	10 min b.i.d.	Decreased symptom severity Decreased symptom frequency	Tear break-up time ($p > 0.05$) Meibomian gland score ($p > 0.05$) 8 withdrawals, 3 citing device issues 4 of remaining participants reported inconsistent heat delivery from device
						Diary to log usage
Study duration: 6 months						
2011 Olafsson	I	70	Microwavable (Thera°Pearl®) *n* = 33	10–15 min q.d.	Increased tear break-up time Decreased corneal staining[‡] Decreased symptoms	Meibomian gland score ($p > 0.05$) Schirmer test ($p > 0.05$) Compliance decreased across time 3 only able to commit to 3 months 5 dropped @3 month, 2 @6 month Diary to log usage [‡]3-month, 6-month evaluation

N = number of participants in the study, *n* = number of participants in the group
WC Warm compress, *MGD* meibomian gland dysfunction

of application, and frequency of treatment are critical factors in achieving favorable results.

Patients should be informed of the target temperature for WC therapy and encouraged to apply a method capable of reaching 40 °C or higher and sustaining that temperature across at least 5 min. Hot towels, microwavable EM, and self-heating EM can all achieve this. There are, however, vast differences in their heat retention capabilities, which affect their functionality. Hot towels retain heat poorly and must be reheated every 2 min to maintain target eyelid temperature. Studies in which towels were not reheated did not demonstrate improved outcomes, and they were associated with lower compliance when compared to groups using other methods in the same studies [31] (I). Given these complications, if the goal is significant reduction in symptoms and improvement in gland health, hot towels are largely ineffective and impractical for routine use, however widely available [31, 33] (I).

Microwavable EM, particularly those that are moist–heat generating, retain heat sufficiently to show consistent results in sustaining eyelid temperature and improving symptoms. The study that demonstrated the greatest number of improvements from a microwavable EM (EyeBag®) was by Bilkhu et al. which used a protocol of 5 min twice daily for 2 weeks. Yet when the same EM was used in studies calling for longer applications across a longer period—such as the 4-week trial calling for 10-min applications twice daily [30] (I) or the 2-month trial calling for 10-min applications twice daily for 2 weeks, then decreasing to once daily for 6 weeks [33] (I)—fewer significant gains were measured. The differences in therapeutic effect most likely come down to compliance. Bilkhu et al. study stands out for closely monitoring participants' symptoms by text twice a day before each usage. By contrast, in the Ngo et al. study patients self-reported once a week for 4 weeks, while patients self-reported three times in 2 months in Murphy et al. Interestingly, Ngo et al. study notes how greater degrees of noncompliance were related to frequency rather than duration of use. Specifically, while the reported frequency of use decreased from 1.9 times a day to 1.7 times a day, the duration remained at 9.6 min. Highlighting this impact of dosing frequency on compliance is data from the study by Tiechnor et al. There, 2 protocols were used for the same microwavable EM (Bruder®)—one group applied WC twice daily; the other, once. The improvement in objective measures were equivalent in the two groups, but the latter group had higher compliance, which may translate to greater sustainability over time. It's possible that using the WC twice daily has potential for greater benefit, but that benefit may be negated by risk of lesser compliance. No study separated data for different tiers of compliance, which opens possibilities for future research linking outcome measures to compliance levels. Given the potential impact of compliance on outcome, technology-based treatments like IPL may be advisable for those whom adherence to at-home WC therapy is difficult, as well as for those with refractory disease.

With self-heating EM, the intrinsic temperature profile is both an advantage and a disadvantage. The preset temperature of an activated device removes operator influence and allows the EM to generate sufficient heat without the risk of burning. But between the delay to peak temperature and the controlled way heat is released, application time may need to be extended to achieve the same effects that a microwavable EM brings more quickly. Conversely, some self-heating EM appear to sustain desirable temperatures longer, possibly ensuring the melting of thickened meibum with one application. While hot towels and microwavable EM were used in some trials with 5-min applications, the minimum application time involving self-heating EM was 10 min. Data on self-heating EM were comparatively inconsistent—identifying more potential, compared to hot towels and microwavable EMs, to be beneficial in some studies and less in others, suggesting that outcomes are more dependent on the specific model of self-heating EM. This may be an area of device development that clinicians should become familiar with as advances in technology for the heating elements within spontaneously heating EM could have great potential in increasing their efficacy.

Choices between microwavable and self-heating EM can be guided mainly by convenience and comfort. For some patients, microwavable EM are more comfortable and cost effective, especially for those requiring long-term use. Microwavable EM, however, have been associated with skin burns [36, 37] and patients should be cautioned against heating the EM excessively. On the other hand, although some may take issue with the higher cost and deleterious environmental impact of single-use, disposable self-heating EM, they may be necessary for patients without microwave access or whose work or travel schedules demand a portable compress with spontaneous heating capability. Since self-heating EM do not require preparation, they may be optimal for patients for whom convenience is necessary for adherence to treatment. Another consideration for use of self-heating EM is one that combines their convenience with the numerous positive results found in single application studies, of increased tear film lipid layer thickness and tear-break up time and improved meibomian gland and questionnaire score. Accordingly, they might be used as an expeditious remedy for exacerbations of symptoms.

Both self-heating and microwavable EM are available in dry- or moist–heat generating options. Two potential benefits of a moist–heat generating EM are its superior temperature profile [17] (I), [19] (III) and its ability to reduce *Demodex* burden [33] (I). The superior heat retention profile of moist–heat generating microwavable EM has been discussed already. And although temperature data on self-heating EM is limited, a 2003 study by Mori et al. found that the moist–heat generating, self-heating EM from Kao corporation was able to bring eyelid temperature above 40 °C at 5 min, creating improvements across all objective measures while decreasing symptom severity [38]. The results of the studies by Ishikawa et al. and Sun et al. corroborated these findings. Similarly, in a study wherein Murphy et al. demonstrated improvement in signs of MGD with WC, additional benefit of reduction in quantity of *Demodex* was shown in the group that used a moist–heat generating, microwavable EM. Given the superior heat retention profile of moist heat EM, whether self-heating or microwaved—with the added benefit of increased efficacy in the treatment of MGD with Demodex, patients should be directed to use moist–heat generating EM when possible.

Hot towel, microwavable EM, and self-heating EM are three widely available WC that can improve tear break-up time and tear film quality with a single application, each effective in alleviating symptoms from MGD. When recommending WC as treatment for MGD, clinicians should recognize that patient compliance plays a critical role in the success of the treatment and that effectiveness requires maintaining eyelid temperatures through precise protocols. As with all medical interventions, patients are more likely to comply if they understand treatment goals, have clear instructions, and, ultimately, experience therapeutic benefits. Therefore, patients should be counseled carefully so as to minimize barriers to execution and to maximize results. Based on evidence that supports the benefits of a daily application of WC for at least 5 and as many as 20 min, as well as evidence that patient compliance is decreased with increased frequency of treatment, patients should be advised to apply a moist–heat generating EM—either microwavable or self-heating—for 10 min once per day. Patients can be encouraged to apply WC longer or more frequently in accord with their own inclination and symptoms, but the focus on a moist–heat WC capable of reaching and maintaining a temperature of ≥ 40 °C, applied for 10 min should be the point of emphasis.

CONCLUSION

It is possible for all 3 methods of WC to achieve target temperature of 40 °C. A single application—ranging from 5 min with hot towels or microwavable EM to 20 min of self-heating EM—significantly improves tear quality immediately following treatment. Repeated applications significantly relieve symptoms associated with dry eyes from MGD and, in most studies, significantly improve meibomian gland health and/or tear quality. Although hot towels can be effective, they retain heat poorly and require frequent reheating to keep eyelid temperatures above 40 °C, rendering them relatively ineffective in longitudinal studies. Microwavable EM

have stable heat retention and were found in 10-min applications to improve tear break-up time and meibomian gland score, in addition to relieving symptoms. Self-heating EM have device-specific variability in activation time and in their ability to sustain desirable temperatures, showing similar benefits to microwavable EM in short-term studies. Studies that monitored patient compliance indicate greater deviation from protocol with higher frequency of application and longer-term use. Though both microwavable and self-heating EM are available in dry- and moist–heat generating options, evidence suggests superior heat retention and therapeutic effects on specific contributing factors in MGD (such as Demodex) with moist heat compress.

Considering decreased patience adherence to therapy with increased usage frequencies, and balancing the need to provide succinct instructions for various compress types, an advisable strategy is for patients to apply a moist–heat generating EM (microwavable or self-heating), prepared according to manufacturer's instructions, to each eye for at least 10 min once a day.

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