ORIGINAL ARTICLE

A Randomized, Double-Blind Comparison Shows the Addition of Oxygenated Glycerol Triesters to Topical Mentholated Cream for the Treatment of Acute Musculoskeletal Pain Demonstrates Incremental Benefit Over Time

Robert Taylor Jr., PhD*; Tong J. Gan, MD†; Robert B. Raffa, PhD‡; Chris Gharibo, MD§; Marco Pappagallo, MD¶,**; Nicholas R. Sinclair, MD, PhD*; Charles Fleischer††; Aaron Tabor, MD‡‡

*NEMA Research, Naples, Florida; †Department of Anesthesiology, Duke University, Durham, North Carolina; ‡Temple University School of Pharmacy, Philadelphia, Pennsylvania; §Department of Anesthesiology and Pain Medicine, New York University School of Medicine; ¶New Medical Home for Chronic Pain, New York, New York, U.S.A.; **US Medical Intelligence, Grunenthal, Aachen, Germany; ††Always Healthcare, Naples, Florida; ‡‡Physicians Laboratories, Inc., Kernersville, North Carolina, U.S.A.

Address correspondence and reprint requests to: Robert Taylor Jr., PhD, 840-111th Avenue North, Suite #9, Naples, FL 34108, U.S.A. E-mail: robert.taylor.phd@gmail.com.

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■ **Abstract:**

Background: Topical analgesics are important products in the armamentarium for pain relief.

Methods and Findings: This study compared a topical analgesic product containing menthol to the same product with the addition of oxygenated glycerol triesters (OGTs) (also called essential oxygen oil) in 66 healthy adult subjects with acute musculoskeletal pain. Patients were randomized in a single-center, double-blind study to receive mentholated cream (MC) only or MC containing OGTs. Patients self-reported their pain intensity, lifestyle limitations, and evaluation of the mobility of the painful joint or muscle at baseline and three times daily over a seven-day course on a 100-mm visual analog scale (VAS). Patients in both groups experienced statistically significant pain relief

on Day 8 over baseline, with the MC plus OGT-treated group reporting statistically significantly greater pain relief than the MC group ($P = 0.016$). In addition, patients treated with the combination product experienced an incremental decrease in pain during each of the 7 days of treatment in addition, and they had lower VAS scores and greater lifestyle and mobility improvements than the MC group. Both products were well tolerated with no serious adverse events reported and no signs of significant skin reactions in either group.

Conclusion: Based on this study, a MC containing OGTs is safe, effective, and provided significantly better pain relief than MC alone. The combination of oxygenated glycerol trimesters and MC provided significant pain relief and offered continued improvement in pain relief over time. ■

Key Words: analgesia, topical, randomized controlled trial, oxygenated glycerol triesters, mentholated cream, acute musculoskeletal pain

INTRODUCTION

Pain is one of the most undertreated healthcare problems in the world.[1] Pain is among the most common reason for patients' seeking health care.[2] The goals in pain treatment depend on the nature of the pain: For acute pain, the goal is safe, effective, and rapid analgesia that allows mobilization and healing to take place.[3] For chronic pain, the goals are to reduce pain, minimize side effects, improve physical and psychosocial function, and limit end organ-related consequences of chronic treatment.[4] Many patients treat their pain using over-the-counter (OTC) analgesics, such as acetaminophen and nonsteroidal anti-inflammatory drugs (NSAIDs) that carry considerable end organ risk that is often proportional to their plasma levels, chronicity, and preexisting risk factors. For example, chronic use of acetaminophen (paracetamol) has been associated with liver failure, at repeated supratherapeutic levels and possibly even at relatively low doses and is one of the most common reasons for patients receiving hepatic transplantation.[5–8] Excessive amounts of acetaminophen may be taken by patients who are unaware of these risks. For instance, patients may not consider which OTC products contain acetaminophen or have multiple prescriptions that result in high cumulative doses of acetaminophen.[9,10] NSAIDs are effective, widely used, but associated with serious gastrointestinal, renal, and cardiovascular adverse events.[11–16] Care must be taken when using OTC agents to manage persistent pain.[17] In light of concern over OTC pain relievers, topical analgesics present an important option for the treatment of acute and chronic pain.[18,19]

Among several types of topical analgesics, creams containing menthol, a derivative of peppermint oil, have an initial cooling effect and then a localized warming effect secondary to increased localized blood flow.[20] Menthol for a long time has been considered a counter irritant, blocking pain signals sent by smaller nerve fibers by inducing signaling through larger nerve fibers, a theory known as the Gate-Control Theory.[21] More recently, menthol has been shown to act on specific cold (thermoceptive) and menthol-sensing receptors in sensory neurons known as TRPM8, which is an ion channel that regulates sodium and calcium ions.[22,23] Regulation of these ions governs the action potential of a nerve and thus regulates its signaling. In addition, this effect on pain sensitivity seems to be dose-dependent, with low doses decreasing sensitivity to pain (increase pain threshold) and high doses inducing a feeling of cold and increased sensitivity.[24,25] Unlike menthol, the analgesic properties of oxygenated glycerol triesters (OGTs) are not well understood. Currently, its ability to relieve pain may be due to its antioxidant and anti-inflammatory properties.[26] It is thought that oxygenated glycerol trimesters acts as a superoxide dismutase mimetic, scavenging free radicals and reducing the oxidative stress marker malondialdehyde, which has been associated with a number of pain conditions, including vascular pain,[27] acute coronary syndromes,[28] pain from pancreatitis,[29] peripheral neuropathy,[30] temporomandibular joint disease,[31] fibromyalgia,[32] acute abdominal pain,[33] and primary dysmenorrhea.[34]

This article reports a comparative effectiveness study of a mentholated cream (MC) topical analgesic with a novel OGT oil topical analgesic commercially from Europe recently made available in the United States (OxyRub™; Creomed, Naples, FL, USA).[26] In formulating the research question, the investigators hypothesized that the addition of OGT to menthol would enhance the analgesic effect of a mentholated topical analgesic in the treatment for acute musculoskeletal pain. By maintaining a constant concentration of menthol in both test products, a significant additive analgesic effect of OGT was able to be recorded.

METHODS

A randomized, double-blind, single-center study was designed to evaluate and compare the improvements in pain relief, physical functionality, tolerability, and

patient acceptance of two topical analgesic products in healthy patients with acute musculoskeletal pain. The IntegReview Ethical Review Board approved the clinical study protocol, the clinical study site (RCTS, Inc., Irving, TX, USA) and the investigator prior to commencement of the study. All patients provided informed consent and no patient entered the study prior to signing the informed consent. Subjects were enrolled during May/June of 2007 and final subject completed June 11, 2007. Study was funded by Laboratories of Carilene, but conduction of study, randomization of patients, and all statistical analysis was carried out by Reliance Clinical Testing Services (RCTS). The study has been registered with the NIH Clinical Trial Registration System (clinicaltrials.gov) under the study number NCT01387750.

Inclusion criteria allowed for men and women over the age of 18 and under 75 years of age in good general health (ascertained by questionnaire) with no dermatological disorders to enter the study whether they suffered from acute musculoskeletal pain, defined as arthritis, simple back pain, or muscle strains for ≤ 3 months. Patients had to agree to discontinue the use of any anti-inflammatory or analgesic medications two days prior to starting the study and agreed not to introduce any new personal care products (including cosmetics, skin care, hand care, body care, hair care, and personal hygiene products) during the course of the study. Inclusion criteria also required that patients agree to avoid sun exposure during the study and be able to comply with instructions and understand and furnish written informed consent. Exclusion criteria were visible skin disease, psoriasis, insulin-dependent diabetes, severe or chronic musculoskeletal pain, known hypersensitivity to topical analgesics or other pain relievers, and allergies to any components in the test articles. Individuals who had participated in a clinical trial within 28 days prior to the start of this trial were excluded. Also excluded were patients currently under treatment for asthma and women who were pregnant or might become pregnant. Individuals who had any of the following conditions at the site of medication application were also excluded: excessive dryness or redness of the skin, atopic dermatitis, and eczema. Any individuals taking prescription or OTC anti-inflammatory or NSAID drugs or topical, oral, or systemic steroids were also excluded.

Subjects were randomized using a randomization schedule. One group received a MC (1.25% menthol) and the other MC with OGTs (OGT-MC, 1.25% menthol + 98.75% OGTs). Both formulations had a similar look, feel, and odor. Patients and investigators were blinded to the formulation administered. Patients were asked to use a body map to identify the site of their most severe pain. Trained examiners inspected the site to insure it was free of abrasions or other skin condition that might have excluded the patient from use of topical products. Patients used a 100-mm visual analog scale (VAS) to assess pain intensity, limitation of activities because of pain at the identified pain site, and mobility of the painful area. These were self-assessed by the study subjects. On this scale, 0 was no pain or no limitation or unimpaired mobility; 100 mm was the most extreme pain, limitation, or loss of mobility imaginable. Mobility was self-assessed and no patient raised a question as to how to assess mobility in his or her particular case. Intrasubject change in self-assessments of severity of pain scores were measured using a 100-mm VAS. Patients were asked to identify the sites of their pain using a body map; sites of map could differ among patients. Pain intensity was measured each day of the study. Limitation of activity and mobility were assessed at baseline and on Day 8 (conclusion of study).

Patients were instructed to apply the topical product three times a day around meal times by applying a ''nickel sized'' amount of cream on their skin and rubbing it in a circular fashion until it was absorbed into the skin. Patients were asked to record their pain scores on the VAS about 30 minutes following application on the last day of the study. Patients were also asked to keep a daily diary to record comments or observations during the study. After seven days of treatment, patients returned to the clinic (Day 8) and evaluated their pain, limitation of activity, and mobility as they had done on the first day and a trained clinical evaluator inspected the application site for signs of skin reactions, dryness or erythema to assess tolerability. The evaluator inspected the area of application on Day 8 for signs of redness and rated the site on a scale from 0 to 4, with 0 being no observable signs of redness and 4 fiery redness with signs of edema. The area of application was likewise examined for signs of dryness using a scale from 0 to 3, with 0 being no observable signs of dryness and 3 large flakes and severe scaling.

Medication quantities were weighed to confirm compliance, and all patients were interviewed about their experiences, documentation, and any adverse events. Evaluations were performed by comparing the patients' pre- and post-treatment VAS ratings of their

acute pain intensity, limitations of activity directly associated with the acute pain, and mobility. In addition, tolerability data were collected and adverse events recorded.

Statistical Methods

Only those who fulfilled criteria for evaluable subject were included in the statistical analyses. An evaluable subject is defined as one who met all inclusion criteria, had not used any systemic or other unapproved topical skin care products or unapproved medications during the study, completed all evaluations, and complied with the treatment regimen. A patient sample size of 66 was necessary to achieve a confidence interval of 95% ($P < 0.05$). The following variables were assessed: severity of acute pain, severity of acute pain 30 minutes after application of study cream, limitation of activity (a subjective self-assessment of the degree to which their daily activities were restricted because of pain at the affected site), patient self-assessment of the mobility of the area of concern, and acceptability of the study cream. Activity limitation was defined to patients as the ability to perform adequately in their professional capacity, that is, during their normal workday activities or work they did at home. Values for severity of pain were collected from Day 1 through Day 8, inclusive, and were compared with baseline data (pretreatment data) using a paired difference t-test. Values for the limitation of activity and mobility were collected only on Days 1 and Day 8 and analyzed using a paired difference *t*-test. In addition, an analysis of variance was used to compare the treatments (A vs. B).

The significance of the responses to question on acceptability was determined using a binomial test with an a priori 50/50 distribution assumption. The responses were chosen from the following selections: strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, and strong disagree. Responses were pooled into two categories: Patients who agreed (success) and patients who did not agree (failure). Patients who neither agreed nor disagreed were placed in the failure category. Data were analyzed with a confidence interval placed at 95% ($P < 0.05$) using SAS software.

RESULTS

A total of 73 patients enrolled. Four patients were excluded: Three were excluded from the OGT-MC because of noncompliance (2 patients did not return on Day 1 and 1 patient did not return on Day 8) and one person enrolled into the MC group was excluded for taking exclusionary medications because of an unrelated injury (shoulder). A total of 69 patients completed the study. Figure 1 shows a CONSORT diagram summarizing the enrollment of the study. Patient demographics are provided in Table 1; there were no significant differences between the two groups in regards to men/women or ethnicity ($P > 0.05$). All baseline characteristics for all assessments between both groups were not significantly different ($P > 0.05$). Severity of acute pain at baseline was a mean ± standard deviation of 46.8 ± 16.8 mm (OGT-MC group) or 42.4 ± 18.2 mm (MC group) and had decreased in both groups to 19.0 ± 18.2 (OGT-MC) and 28.7 ± 26.0 mm (MC) on Day 8. See both Figure 2 and Table 2. By percentage, the OGT-MC group approached double the reduction in pain intensity at Day 8 (59.5% vs. 32.3%). The mean intrasubject decrease in pain was −27.8 mm (OGT-MC) vs. −13.7 mm (MC) from baseline to Day 8 (OGT-MC $P < 0.001$, MC $P = 0.010$). One-factor repeated measures were used to calculate the differences between the intrasubject variability in acute pain severity of OGT-MC vs. MC and found that the OGT-MC group had significantly reduced intrasubject improvements in pain severity compared with MC group ($P = 0.016$; Table 3).

In diaries kept for the duration of the study, less pain is recorded at all points from Day 1 to Day 7 compared with baseline for both groups during the course of the treatments. On Days 5 and 7, OGT-MC patients recorded less pain than MC patients ($P = 0.056$ and $P = 0.077$, respectively). The analgesic benefit of OGT-MC increased over time. At the conclusion of the study (Day 8), the OGT-MC group had a significant reduction in pain intensity (59.5% vs. 32.3%) compared with the MC group ($P = 0.016$; Figure 3).

At enrollment, the mean limitation of activity was evaluated as 38.5 mm (OGT-MC) and 36.5 mm (MC), and decreased by Day 8 to a mean of 15.4 vs. 23.9 mm, respectively, for an intrasubject decrease in −23.0 mm and −12.6 mm (see Figure 4). In this test, a decrease in value indicates an improvement in activity limitations, that is, less limitation. The OGT-MC group exhibited 59.9% improvement relative to baseline compared with a 34.4% improvement in the MC group ($0.05 < P < 0.1$; Table 4).

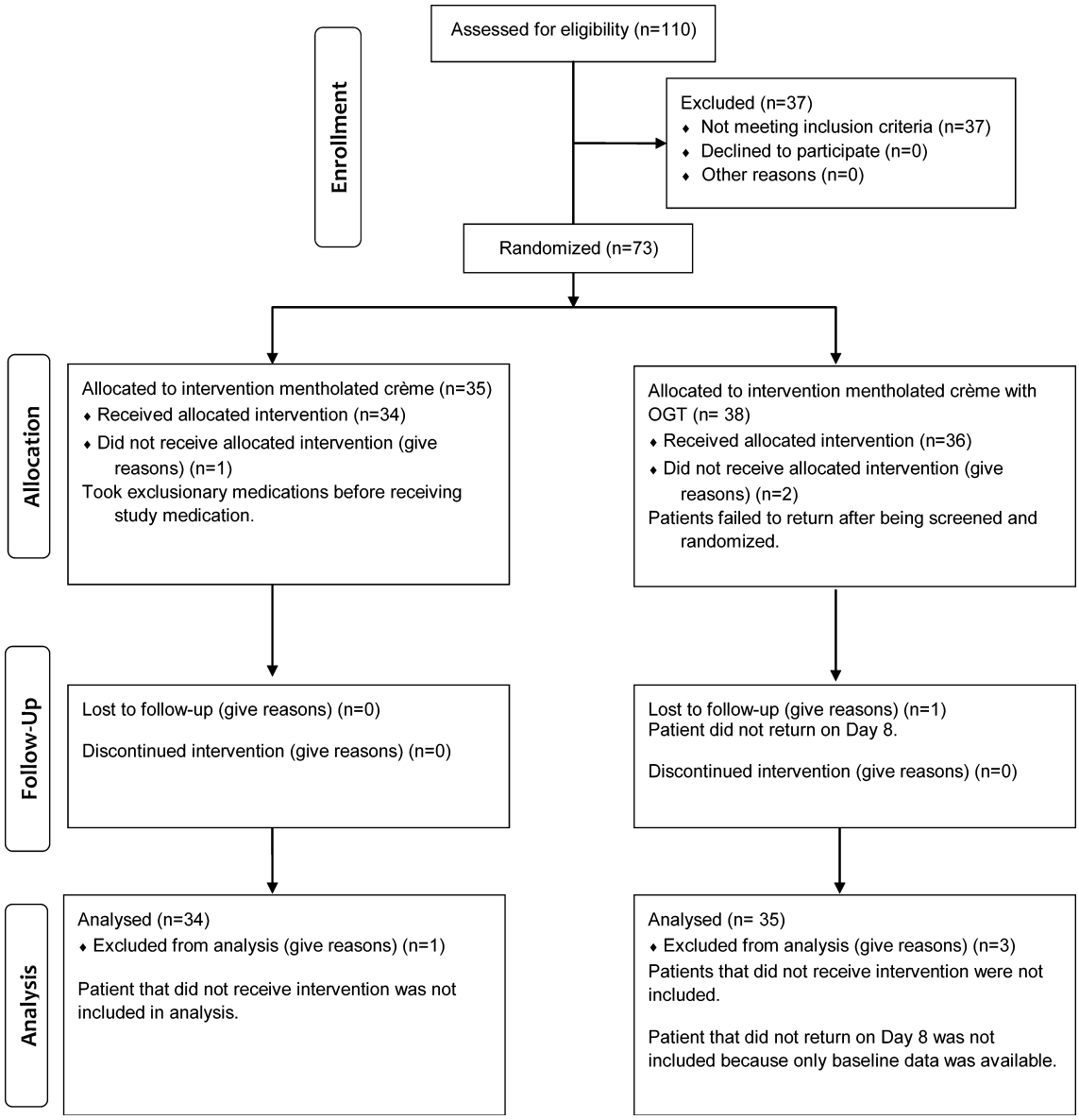

Figure 1. CONSORT diagram.

Table 1. Patient Demographics at Enrollment

	OGT-MC group	MC group
	Enrolled *N* = 38 *N* (%)	Enrolled *N* = 35 *N* (%)
Mean age	43.6 ± 14.2 years	42.9 ± 13.8 years
Females	28 (74)	26 (74)
Caucasians	19 (50)	18 (62)
African Americans	12 (32)	11 (17)
Hispanics	6 (16)	5 (20)
Other	1 (3)	1 (3)

MC, mentholated cream; OGT, oxygenated glycerol triester.

Patients evaluated their mobility impairment at baseline with mean values of 35.9 mm (OGT-MC) vs. 35.4 mm (MC), decreasing by Day 8 to 19.4 mm and 22.3 mm, respectively, with intrasubject changes of −16.5 and −13.0 mm, respectively. This reflects an approximately 10% improvement in mobility in the OGT-MC group vs. the MC group (NS) as shown in Figure 5. There were no differences in skin redness between groups.

Patients were also asked at the conclusion of the study whether or not they would continue to use the

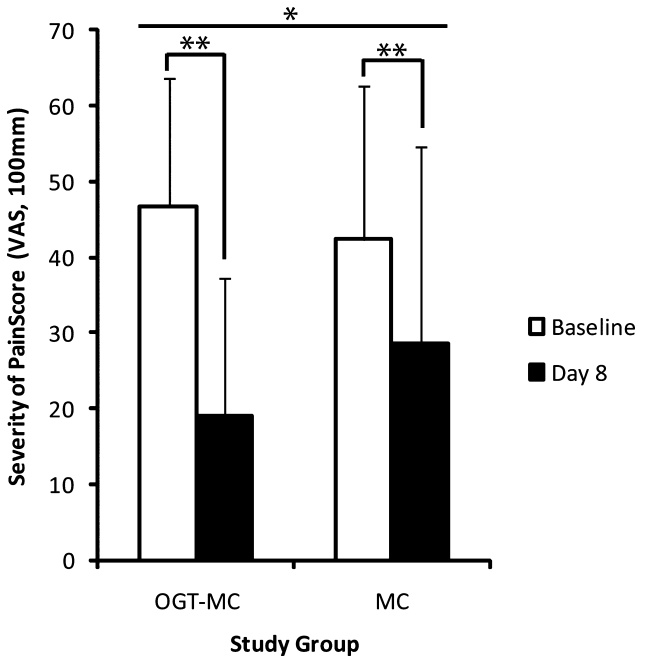

Figure 2. Subject's self-assessment of severity of pain. (**P < 0.001; *P < 0.05) at baseline and at the end of the study.

Table 2. Patient Self-Assessments of severity of Pain Scores Measured Using a Visual Analog Scale (100 mm)

	Severity of acute pain (VAS, mm)	
Descriptive statistics	OGT-MC	MC
N	35	34
Baseline		
Mean ± SD	46.8 ± 16.8	42.4 ± 20.3
Median	48.0	42.5
Day 8		
Baseline mean ± SD	19.0 ± 18.2	28.7 ± 26.0
Median	16.0	18.5
Change from baseline	−59.5%	−32.3%

SD, standard deviation; NS, not significant (P > 0.05); MC, mentholated cream; OGT, oxygenated glycerol triester; VAS, visual analog scale.

Table 3. Intrasubject Change in Self-assessments of Severity of Pain Scores Measured Using a Visual Analog Scale (100 mm)

	Severity of acute pain (VAS, mm)		
Descriptive statistics	OGT-MC	MC	*P* value between groups
N	35	34	OGT-MC > MC
Mean ± SD	−27.8 ± 20.8	−13.7 ± 26.3	P = 0.016
Median	−27.0	−13.5	
P value	<0.001	0.010	

MC, mentholated cream; OGT, oxygenated glycerol triester; VAS, visual analog scale.

product they just tested to treat their musculoskeletal pain. The significance of the responses using a binomial test assumed a 50/50 distribution. Respondents could choose the following: Strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, or strong disagree. Responses were then pooled into two categories, "success" (those who agreed either strongly or somewhat) and "failure" (those who chose any other answer). In the OGT-MC group, 27 of 35 respondents would prefer to continue to use the product compared with 21 of 34 of the MC group. Significantly, more patients in the OGT-MC said that they would continue to use the product (P < 0.0009) but the difference in the MC group was not significant (P = 0.1147).

Two adverse events occurred during the study. One patient experienced mild itching on the second day of application (OGT-MC product) which recurred on the fourth day. In both cases, itching persisted for around three minutes and resolved spontaneously. This adverse event was deemed to be related to the test product. A second adverse event occurred when a patient enrolled in the study dislocated his shoulder and was administered morphine and other analgesics in the emergency room, which excluded him from participation in the study. This patient was in the MC group, and the adverse event was unrelated to the test product.

DISCUSSION

Topical analgesics are effective pain relievers and are widely used for the treatment of acute pain. [35–37] Topical formulations appear to confer specific advantages because of their localized application.[38–40] Some of the most common topical analgesics available in the United States are those that use methyl salicylate, camphor, menthol, capsaicin, or some combination. This study was based on a product using menthol, a substance derived from peppermint oil and known to exert an initial cooling effect, increase localized blood flow, and exhibit good tolerability.[20]

There is a tendency among certain patients and even some clinicians to trivialize mild-to-moderate acute musculoskeletal pain. While acute and chronic pain are often defined in temporal terms, they may actually be different clinical entities.[41,42] The transition from acute to chronic pain is not well understood, but likely involves a complex sequence of events following the onset of acute pain.[43] Prompt and effective treatment for acute pain may be an important step in

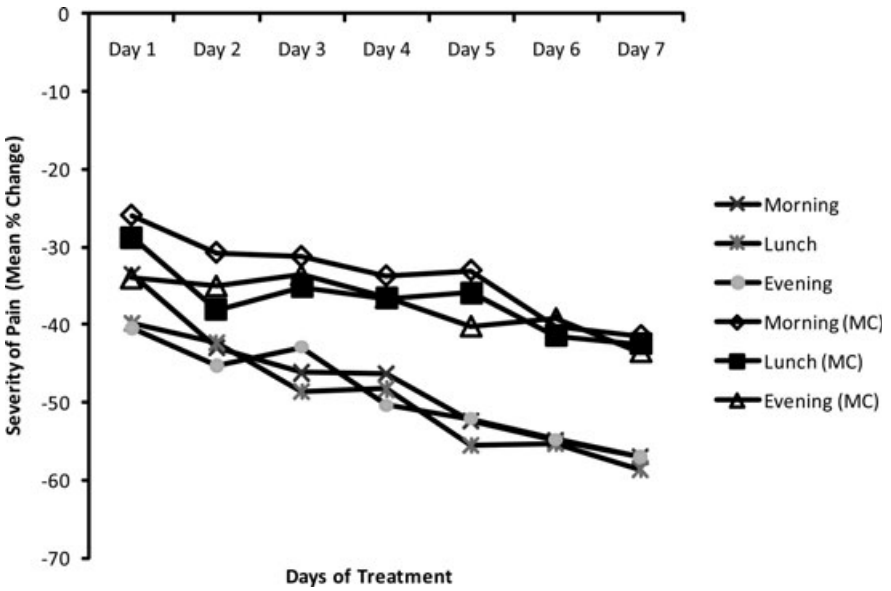

Figure 3. Subject's self-assessment of severity of pain over course of study (OGT-MC vs. MC).

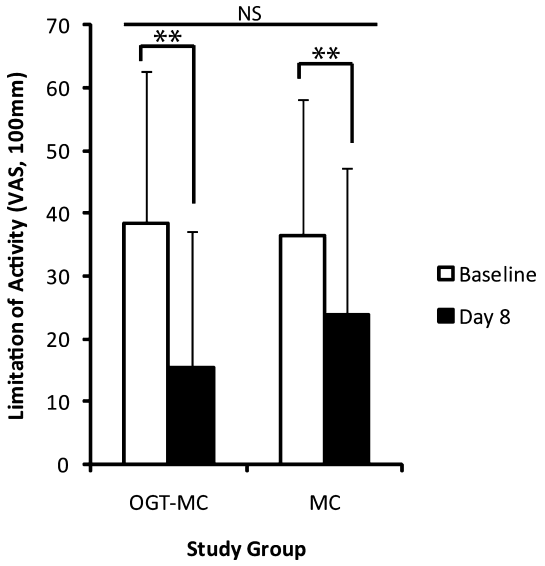

Figure 4. Subject's self-assessment of limitation of activity (**$P < 0.01$; NS $0.05 < P < 0.1$) Note that measures were made at baseline and at the conclusion of the study.

Table 4. Patient Self-assessments of Limitation of Activity Scores Measured Using a Visual Analog Scale (100 mm). Note that a Lower Score Indicates Clinical Improvement in Activity Level, i.e., Decrease in Limitations

	Limitation of activity (VAS, mm)	
Descriptive statistics	OGT-MC	MC
N	35	34
Baseline		
Mean ± SD	38.5 ± 24.2	36.5 ± 21.6
Median	33.0	33.5
Day 8		
Mean ± SD	15.4 ± 21.6	23.9 ± 23.3
Median	4.0	18.5
Change relative to baseline	−59.9%	−34.4%
Baseline Vs Day 8	<0.001	<0.001
P Value		
OGT-MC Vs MC	0.086	
P value		

Note that lower scores indicate most improvement, i.e., 0 mm = no limitation, 100 mm = most severe limitation.
MC, mentholated cream; OGT, oxygenated glycerol triester; VAS, visual analog scale.

interrupting the cascade of events that can lead to the chronification of pain.

Menthol creams as topical analgesics have been around for many years. Menthol's concentration-dependent analgesic properties have originally thought to be due to its counter-irritant ability. However, its recent identification as a partial agonist of TRPM8 ion channels [22,44] and TRPV3 ion channels,[45] through which it exerts its burning effects after initial cooling of the skin, have provided insight into possible pain reducing mechanism. Combining menthol with an additional analgesic, one which exerts its action through a different mechanism, offered greater pain relief then if used individually. OGT is a hyperoxygenated, peroxidized triglycerol-oxyester-rich oil or essential oxygen oil (equivalent terms). An OGT-product has been commercially available in Europe for over a decade and has recently become available in the United

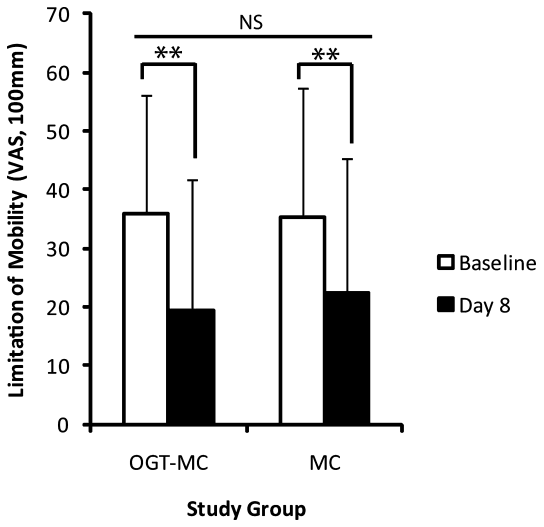

Figure 5. Subject's self-assessment of limitation of mobility. (**$P < 0.01$; NS $0.05 < P < 0.1$) Note that measures were made at baseline and at the conclusion of the study.

States (OxyRub™; Creomed). Although its exact mechanism of action remains to be elucidated, its analgesic and anti-inflammatory effects may involve the reduction in one or both of the mechanisms of lipid peroxidation of the arachidonic acid cascade.[46] Lipid peroxidation is pathological and reactive oxygen scavengers can be used pharmacologically to interrupt this process. Oxidative stress has been implicated in pain in preclinical studies.[30] An OGT oil has been demonstrated in clinical studies to be a safe, effective topical analgesic with 80% of patients reporting 75% or more reduction in pain using the oil ($n = 455$).[26] Thus, the research question behind this study was whether a MC containing OGTs (the OGT-MC product) would confer incremental benefit beyond that offered by the menthol topical analgesic (MC product), which served as a comparator or control. The literature contains few such studies of direct product-to-product comparisons, which can be useful in guiding clinical practice.[47,48]

The results of this article reveal that both groups experienced significant relief from baseline to Day 8 and that pain relief was significantly greater ($P = 0.016$) with the combination product (OGT-MC) than the menthol product (MC). As effective analgesia increased as the study progressed, it is possible that a longer study duration might have resulted in even greater pain relief for the OGT-MC group vs. the MC group. However, it cannot be determined from this study if this result was the maximum difference in analgesia or whether the difference would have been greater had the study continued.

Limitations in activity were self-assessed by patients using the VAS, where low scores indicate greater improvement (less limitation). The OGT-MC patients had a 59.9% improvement in the reduction of limitation compared with a 34.4% improvement of MC patients. Both groups showed improvement in limitation over the course of the study, but the improvement was greater in the OGT-MC group. These findings were not significant but may be clinically relevant. Patients were also asked to evaluate the mobility of the site of application using the VAS and both groups exhibited improvement over baseline, with the OGT-MC group showing nearly 10% improvement over the MC group (NS).

This article showed first that both MC and OGT-MC were safe and effective at relieving pain in acute musculoskeletal pain. Even though both products significantly reduced pain from baseline, the OGT-MC product offered significantly greater pain relief than the MC product. It is important to note that OGT did not adversely impact the tolerability of the comparator mentholated product. Both products were safe, well tolerated, and no serious product-related adverse events occurred. Thus, OGT may be seen to be at least equivalent to the MC product in terms of tolerability.

Effective analgesics can alleviate pain, but they may expose the patient to risks and adverse events. Thus, pain management is a balancing act between safety and efficacy. For that reason, the safe, topical OTC products are important agents to consider, particularly for patients with mild-to-moderate acute musculoskeletal pain.

LIMITATIONS OF THE STUDY

This was a single-center prospective study that enrolled patients with different types of musculoskeletal pain. This may be a limitation or a strength of the study, in that it evaluated patients with a variety of similar but not necessarily homogeneous pain syndromes. That significant pain relief occurred with MC was expected, but it was not expected that pain relief would improve with time. Rather, it was thought that pain relief would occur with each application and then abate, such that patients on Day 8 would receive about the same level of pain reduction as on Day 1 or Day 3. Instead, the OGT-MC product resulted in increasingly improved levels of pain reduction with time. The study duration of eight days is appropriate for acute pain treatment, but an extended length of time might have

allowed a greater degree of pain relief to emerge. In addition, the acute pain experienced may over time spontaneously reduce without any treatment. We tried to limit this effect in the study by randomizing subjects into two groups with the assumption that both groups would experience similar levels of spontaneous pain reduction.

Topical analgesics have been demonstrated to be safe and effective in relieving acute musculoskeletal pain.[35,36,49–52] It was anticipated that the MC product would significantly reduce pain over baseline in these patients, but incorporation of OGT and its additive effects were unknown. The use of OGT oil has been shown to be safe and effective in treating acute musculoskeletal pain.[26] It was hypothesized that the combination of MC plus OGT would likewise be safe and effective. The superior analgesic results obtained with OGT-MC are likely the result of the combined or additive benefits of the two products.

CONCLUSION

Our study compared a mentholated topical analgesic directly with a similar product that contained OGT, also known as essential oxygen oil, and found that the OGT conferred significantly greater pain relief than the comparator product (menthol only) over an eight-day course with healthy subjects treated for acute musculoskeletal pain with equivalent tolerability and adverse events. OGT-MC was also reported to improve mobility of the affected area and to reduce limitations on lifestyle activities attributable to the painful area when compared to MC. Both products conferred benefits to patients over baseline, but the OGT-MC conferred significantly greater pain relief which improved over time. This study supports previous findings that show OGT-MC to be a safe and effective topical analgesic and suggests that it may be a more effective pain reliever than a formulation based on MC alone.

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