Effects of 5 Days of Repeated Submaximal Clenching on Masticatory Muscle Pain and Tenderness: An Experimental Study

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*The hypothesis of this short-term study was that repeated episodes of clenching at submaximal bite force levels can induce a progressive increase in pain and tenderness in masticatory muscles. On each day for 5 consecutive days, 10 women clenched on a bite force transducer for 15 minutes at 25% of their maximal bite force. The development of pain, tenderness, and unpleasantness in the masticatory muscles was evaluated with use of 10-cm visual analog scales (VAS) and the McGill Pain Questionnaire (MPQ). Pain detection thresholds (PDT) and pain tolerance thresholds (PTT) to percutaneous pressure stimuli were measured in the masseter and anterior temporalis muscles. Maximal voluntary bite force to brief clenches were assessed. The results showed moderate levels of pain (mean ± SE; 5.3 ± 1.0), tenderness (5.2 ± 1.0), unpleasantness (5.8 ± 0.8), and MPQ scores (16.4 ± 4.9) immediately after the submaximal clenching task on the first day. The following days, the clenching tasks did not increase these scores; in contrast, there were significant decreases on day 5 in both pain intensity (−49.8% ± 14.6%), tenderness (−46.1% ± 14.2%), unpleasantness (−50.4% ± 8.5%), and MPQ scores (−45.8% ± 13.3%) (*P *< .05) when compared to day 1. The clenching procedure failed to induce a progressive increase in pain and tenderness in the masticatory muscles during 5 days. None of the evaluated parameters from this study suggested the start of a vicious cycle.*
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key words: muscle pain, postexercise muscle soreness, pain assessment, maximal voluntary bite force, pain-pressure threshold, bruxism

Muscle hyperactivity has long been thought to be the cause of pain in muscles. Once pain had developed, it was believed that this could in turn induce more muscle hyperactivity, setting up a vicious cycle. This hypothesis was formulated by Travell et al[1] and was later adapted to explain pain in the masticatory muscles.[2–5] However, the hypothesis has never been scientifically proven.[6,7] In addition, the available neurophysiologic data do not seem to support the vicious-cycle concept.[6] Furthermore, it is clear that not all patients showing evident signs of masticatory muscle "hyperactivity," eg, excessive tooth wear or hypertrophy of the masseter muscles, report pain in their muscles.[8–12] Thus, the causal relation between parafunctional activities, such as bruxism or tooth clenching, and masticatory muscle pain and tenderness is unclear.

A large number of experimental studies with various types of concentric or eccentric tooth clenching at submaximal or maximal bite force levels has shown that transient pain and tenderness may reliably develop in the masticatory muscles.[3,13–20] However, a sustained painful condition comparable to postexercise muscle soreness found in the limbs[21–24] has not been described in the aforementioned studies. All previous experimental studies with tooth grinding or tooth clenching have been performed during a single day, and it is conceivable that a more frequent loading of the muscles is needed to develop sustained pain and tenderness. Based on results from studies on nocturnal bruxism,[25] one would anticipate changes in the masticatory muscles to appear during a 5-day period.

The hypothesis to be tested in the present short-term study was that repeated episodes of concentric contractions at submaximal bite force levels lead to a progressive increase in pain and tenderness in the masticatory muscles of healthy subjects.

Materials and Methods

Subjects

Ten women (mean age ± standard error of the mean [SE], 24.2 ± 0.6 years) participated in the study. All subjects were in good health. None had a history or any complaints of temporomandibular disorders (TMD).[26] Manual palpation of the masticatory muscles was performed in accordance with the published guidelines[26] to verify the absence of pain and tenderness. None of the subjects showed more than mild occlusal wear or hypertrophy of the masseter muscles on voluntary contraction.[27] Informed consent was obtained prior to study inclusion, and the study had been approved by the local ethics committee in Aarhus. The subjects were free to withdraw from the study at any time without reason.

Experimental Protocol

On a separate day, subjects received training in assessment of pain detection thresholds (PDT) and pain tolerance thresholds (PTT) to pressure stimuli in the masseter and anterior temporalis muscles. In addition, they were instructed in the use of visual analog scales (VAS) and the McGill Pain Questionnaire (MPQ). The subjects were then scheduled to come to the Orofacial Pain Clinic, Royal Dental College, Aarhus, Denmark, each day for 5 days at the same time of the day and perform the submaximal clenching tasks. Each session lasted about 45 minutes and included measurement of PDT and PTT before the submaximal clenching task. The VAS and MPQ measures and maximal bite force were obtained before and after the clenching task. One week after the fifth day (day 12), all subjects were examined again.

Visual Analog Scales and the McGill Pain Questionnaire Measures

The subjects scored the pain intensity, unpleasantness, and tenderness on three separate 10-cm VAS with their jaws at rest. The extreme left was either "no pain at all," "no unpleasantness at all," or "no tenderness at all," and the extreme right was either "the worst imaginable pain," "the worst imaginable unpleasantness," or "the worst imaginable tenderness." A Danish version of the MPQ was used to calculate the total pain rating index (PRI[total]), which is the sum of sensory, evaluative, affective, and miscellaneous components of pain.[28,29]

Pressure Algometry

An electronic algometer (Somedic AB, Farsta, Sweden) was used for measurements of PDT and PTT. The methodology has been described previously.[30] In brief, the pressure application rate was kept constant at 30 kPa/s with use of visual feedback. The probe with a 6-mm diameter (28 mm^2) was applied perpendicular to the central part of the left and right masseter muscles midway between the upper and lower borders and 1 cm posterior to the anterior border. The left and right anterior parts of the temporalis muscle were stimulated 2 cm posterior to the lateral bony rim of the orbit and 2 cm above and directly perpendicular to a line drawn parallel to the superior edge of the zygomatic arch. During pressure stimulation, the subjects kept their teeth in the intercuspal position with minimum voluntary contraction in their jaw-closing muscles because increasing contraction levels have been shown to increase pain-pressure thresholds.[31] Subjects were seated in the upright position in a dental chair, and they focused their attention on the experimental task. They pushed a small thumb switch, which froze the display, when the PDT or PTT was reached. The PDT was defined as the amount of pressure applied (kPa) necessary for a subject to report pain. The PTT was defined as the maximal pressure (kPa) a subject was willing to accept. The PDT was measured at least three times, with 1 minute between each stimulus. The PTT was only measured once to reduce the number of exposures to high-intensity pressure stimuli.

Maximal Bite Force

A U-shaped bite force transducer (7 mm high, 1.1 × 1.1-cm bite area), which consisted of a 6-cm-long aluminum housing, was covered with plastic tubes to protect the teeth. Two strain gauges forming two legs of a direct-current wheatstone bridge circuit were mounted in the two bars of the bite force transducer that were outside the oral cavity.[32] The transducer was linear in the entire range of forces from 0 to 1,000 N. The transducer had been designed and constructed in a way that avoided variations in force as a result of different positions of the teeth and of temperature changes. The bite force was measured unilaterally between the right molars, and subjects were instructed to clench their teeth as hard as they could for 3 to 4 seconds. The maximal bite force was determined as the peak value and was stored on a display. This was repeated three or four times. Thirty to 45 seconds elapsed between measurements. Small occlusal indexes were made to guide the placement of the bite force transducer in the same position during each session.

Experimental Submaximal Clenching

The subjects clenched on their right side on the bite force transducer at 25% of their baseline (day 1) maximal bite force level. Lines representing this level and the upper and lower limits (± 5%) of the target window were displayed online to the subjects on a computer screen, and the subjects were instructed to keep the level as constant as possible for 15 minutes. The subjects were supervised all the time during this period and were encouraged, if necessary, to maintain the bite force level. All subjects were able to complete this submaximal clenching task.

Statistical Analysis

The raw data were tested for normality distribution with use of Komolgorov-Smirnov tests, and they were described with parametric statistics (mean ± SE). Changes in the raw data were also expressed in percentages of baseline values (day 1). Two-way analyses of variance with repeated measures (factors: effects of days; effects of submaximal clenching) were performed on the raw data. Levels of significance were adjusted for multiple comparisons with use of Student-Newman-Keul's correction (SNK). Significance was accepted at $P < .05$.

Results

Subjective Experience

The VAS and MPQ results are shown in Fig 1. The pain intensity showed no statistically significant effect of days ($F[4,9] = 1.95$, $P = .123$) but a statistically significant effect of submaximal clenching ($F[1,9] = 25.05$, $P < .001$) with a statistically significant interaction between the two factors ($F[4,9] = 3.27$, $P = .022$). The pain intensity after submaximal clenching on day 5 was significantly lower than that after clenching on day 1 (−49.8% ± 14.6%, SNK: $P < .05$). The unpleasantness was significantly affected by days ($F[4,9] = 0.024$) and submaximal clenching ($F[1,9] < 0.003$) with a statistically significant interaction between the two factors ($F[4,9] = 7.93$, $P < .001$). The unpleasantness measured after the submaximal clenching on day 5 was significantly lower than that after clenching on day 1 (−50.4% ± 8.5%; SNK: $P < .05$). The tenderness also showed a statistically significant effect of days ($F[4,9] < 0.003$) and submaximal clenching ($F[1,9] = 0.026$) with a statistically significant interaction between the two factors ($F[4,9] = 6.54$, $P < .001$). The tenderness described by the subjects on day 5 after the submaximal clenching was significantly lower than that after clenching on day 1 (−46.1% ± 14.2%, SNK: $P < .05$). Finally, the total pain rating index (PRI[total]) showed a statistically significant effect of days ($F[4,9] = 2.67$, $P = .048$) and submaximal clenching ($F[4,9] = 16.05$, $P < .003$) with a statistically significant interaction between the two factors ($F[4,9] = 5.36$, $P < .002$). The PRI(total) was significantly lower after the clenching on days 3, 4, and 5 as compared to day 1 (−31.4% ± 21.5%, −33.1% ± 18.1%, −45.8% ± 13.3%, SNK: $P < .05$). The words most frequently chosen by at least 40% of the subjects to describe the evoked sensation during a session included "tiring," "taut," "tight," and "annoying."

One week after the fifth day (day 12), none of the subjects reported any residual effects of the submaximal clenching tasks, and the VAS scores and the MPQ features had returned to baseline values. Manual palpation of the masticatory muscles failed to reveal any muscle pain or tenderness.

Pressure Algometry

There were no statistically significant differences between the left and right sides; thus, PDT and PTT were averaged across either side. The PDTs in the masseter and anterior temporalis muscles were not statistically different ($F[1,9] = 0.039$, $P = .847$), and there was no statistically significant effect of days ($F[4,9] = 1.333$, $P = .276$) (Fig 2). The PTTs in the masseter and temporalis muscles were not statistically different ($F[1,9] = 1.569$, $P = .242$), but there was a statistically significant effect of days ($F[4,9] = 2.832$, $P = .039$) (Fig 2). The PTT in the anterior temporalis muscle was significantly lower on day 2 than on day 1 (–16.7% ± 6.8%, $P < .05$) (Fig 2).

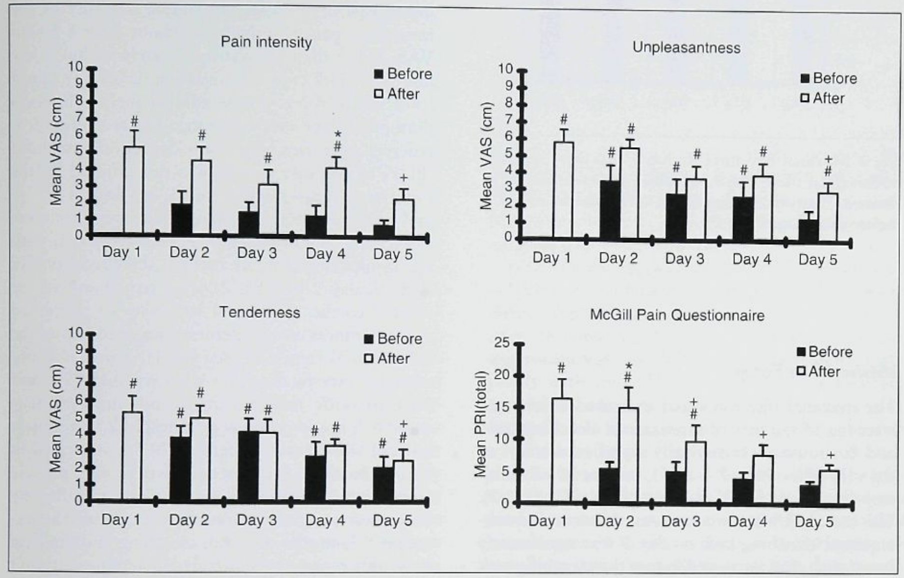

Fig 1 Subjective experiences described on visual analog scales and McGill Pain Questionnaire before and after submaximal tooth clenching on 5 consecutive days. Mean values (± SE) for 10 women. *Statistically significant difference between values before and after clenching; #statistically significant difference from day 1 before clenching (0 ± 0); +statistically significant difference from day 1 after clenching (SNK: $P < .05$).

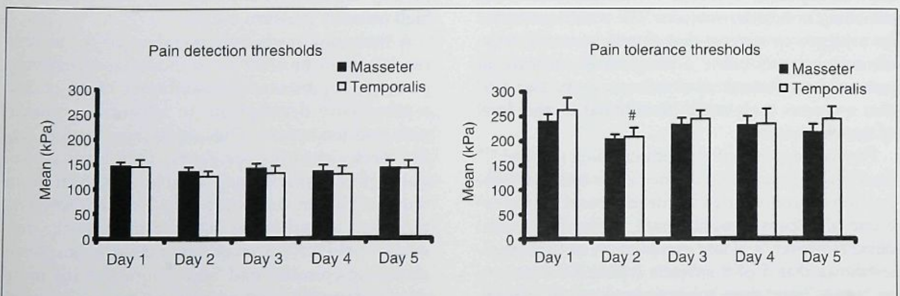

Fig 2 Pain detection thresholds and pain tolerance thresholds to pressure stimuli in masseter and anterior temporalis muscles during 5 days with repeated submaximal tooth clenching. Mean values (± SE) in 10 women. #Statistically significant difference from day 1 (SNK: $P < .05$).

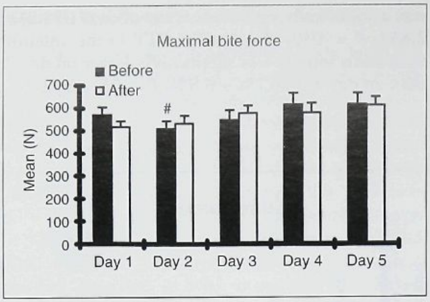

Fig 3 Maximal bite force during 5 days with repeated submaximal tooth clenching. Mean values (± SE) in 10 women. #Statistically significant difference from day 1 before clenching (SNK: $P < .05$).

Maximal Bite Force

The maximal bite force was measured before and after the 15 minutes of submaximal clenching task, and it showed a statistically significant effect of days ($F[4,9] = 3.00$, $P = .031$), but not of submaximal clenching ($F[1,9] = 0.648$, $P = .441$) (Fig 3). The maximal bite force measured before the submaximal clenching task on day 2 was significantly lower than that measured before the clenching task on day 1 (–9.2% ± 6.5%, SNK: $P < .05$).

Discussion

This study is the first to report on the effects of 5 days of repeated episodes of submaximal tooth clenching in healthy subjects. The results provided no evidence to suggest that simple isometric muscle activity may cause a progressive increase in pain and tenderness of masticatory muscles and that a vicious cycle could be initiated by this level of muscle activity.

Previous experimental tooth grinding studies[13,14] involving movement of the mandible (isotonic contractions) have reported the development of postexercise masticatory muscle pain lasting for several days. However, a closer examination of these studies shows that 5 of 9 subjects reported the pain to be "weak," and three subjects estimated the pain to be "moderate"; one subject did not even develop pain.[14] No information on pain intensity is provided for the days following, although it was reported that some subjects experienced pain in this period. A later study reproduced the short-term results from Christensen[14] but unfortunately did not provide any data for the days following.[17] Controlled studies of tooth clenching at various jaw positions (isometric contractions) have shown that transient masticatory muscle pain can be produced easily.[3,15–20] The maximum intensity of the immediate pain is quite high (about 8 on a 10-cm VAS),[20] but the pain resolves quickly within a few minutes. Clark et al[19,20] could not detect any significant masticatory muscle pain in their volunteers during the days after concentric and eccentric (protrusive) exercises. The pain detection threshold (PDT) to pressure stimuli was not affected by the experimental tasks in the studies of Clark et al,[19,20] and pain tolerance thresholds (PTT) were not measured. The lack of effect on PDT is consistent with our results; however, we found a small reduction in PTT on day 2 (see Fig 2). This reduction may be related to the significant increases in perceived unpleasantness and tenderness measured before the submaximal clenching (see Fig 1). Previous methodologic investigations have shown that PDT and PTT provide reliable and reproducible measures[33,34]; however, pressure thresholds in a muscle control site should preferably be incorporated in future studies. Studies on postexercise muscle soreness in limb muscles have shown significantly increased soreness scores the days after the exercise[21–24]; studies on tooth clenching and grinding have only reported the perceived pain intensity, and not the perceived unpleasantness and tenderness in the muscles.[19,20] Thus, the present study with prolonged submaximal clenching levels is the first to show that low levels of unpleasantness and tenderness can be induced in the masticatory muscles; however, these symptoms are not considered as pain by the subjects and may only be measured by high-intensity pressure stimuli.

A limitation in the interpretation of the present results could be that the standardized clenching paradigm represented an insufficient load to cause a progressive development of masticatory muscle pain and tenderness. Thus, long-term loading (eg, for weeks, months, or years) may have consequences on masticatory muscles different from those of the present short-term loading; however, there was no indication in the results that the outcome would have been different if the submaximal clenching episodes had been continued for more than 5 days. Postural activity in jaw-closing muscles of TMD patients (and asymptomatic subjects) is generally well below 5% to 6% of the maximal bite force level.[35,36] In fact, there is no evidence for an increased postural activity in a number of chronic muscle pain conditions such as TMD, fibromyalgia, tension-type headache, chronic lower-back pain, and postexercise muscle soreness.[7,37,38] Thus, it may be difficult to argue for a casual link between increased postural activity and muscle pain. Our submaximal clenching level at 25% of the maximal bite force clearly exceeded the postural level. It has been shown previously that both patients with common migraine headaches and asymptomatic control subjects can endure isotonic contractions at more than 25% of the maximal bite force for periods of about 15 minutes.[16,39] In contrast to results with masticatory muscles, there is evidence that some types of unaccustomed and submaximal muscle activity can cause pain and soreness in limb muscles.[21–24] Masticatory muscle activity during parafunctional activities such as bruxism or tooth clenching is frequently cited as potential factors for the onset, predisposition, or perpetuation of TMD (for a review, see Fricton[40]). The muscle activity engaged in these conditions is generally thought to be both forceful and sustained (for a review, see Dubner et al[41]). Results from several studies[42–46] in sleep laboratories have, however, indicated a total duration of nocturnal masticatory muscle activity that rarely exceeds 25 minutes. Furthermore, the studies imply that rather low to moderate forces ranging from 10% to 30% of the maximal bite force[46,47] were used, although brief bursts near maximal bite force levels may have occurred. From an overall view, the present experimental clenching paradigm may therefore have represented a considerable and clinically relevant load factor for the masticatory muscles, and significant levels of tenderness and unpleasantness were also induced. In addition, the use of words to describe the sensation in the masticatory muscles was similar to the choices made by patients with myogenous TMD.[48] However, the most important finding in the present short-term study is that there was no perpetuation of muscle pain or tenderness during the 5 days.

Natural activity of masticatory muscles during sleep is very heterogeneous and involves both rhythmic or sustained patterns with or without tooth contact.[49] Subsequently, it is difficult to directly compare the muscle activity of the experimental concentric clenching paradigm to that of natural complex activity patterns, which may contain intermittent episodes with eccentric contractions. It has been suggested that pain in the masticatory muscle of bruxers could represent a condition similar to postexercise soreness in limb muscles.[11,50,51] However, no experimental study has been able to replicate the natural complex pattern of muscle activity in bruxers and to induce sustained pain and tenderness in the masticatory muscles of healthy subjects. A recent study with dynamic eccentric contractions of the jaw-closing muscles was able to induce a significant reduction of PDT and PTT in the masseter muscles the day after exercise.[32] Experimental models with injection or infusion of hypertonic saline into the masticatory muscles have opened one part of the proposed vicious cycle, and they have led to studies on the sensory and motor effects of muscle pain.[48,51,52] Experimental models with induction of natural muscle activity may open another part of the vicious cycle and provide insight into the causal relation between complex patterns of prolonged muscle activity and pain. The present study represents such an initial approach.

Our results showed that 5 days of repeated episodes of a submaximal clenching task failed to induce a progressive increase in pain and tenderness. In contrast, the pain intensity, tenderness, unpleasantness, and MPQ scores decreased significantly with time. This supports and extends the conclusion stated by Clark et al[20] that acute experimental tooth clenching does not seem to be able to produce sustained pain in the masticatory muscles. Furthermore, it was suggested that a pre-existing pathologic condition in the masticatory muscle may be necessary to develop sustained muscle pain.[20] In this respect, it is interesting to note that some bruxers seem to have lower concentrations of total phosphate and phosphocreatine in their masseter muscles at rest than do control subjects, and that these bruxers increase their inorganic phosphate content during chewing significantly less than do control subjects.[12] These authors suggested that pain in the masseter muscle could be associated with less myosin-adenosine-triphosphatase activity during chewing and that the different phosphate metabolism patterns could be genetically controlled.[12] Identification of pathologic changes in painful masticatory muscles needs to be pursued in future studies.

Conclusion

The results from the present study have failed to support the hypothesis that 5 days of repeated episodes of submaximal tooth clenching leads to increasing levels of pain and tenderness in masticatory muscles. Thus, a vicious cycle was not initiated by short-term loading of healthy muscles without pre-existing pathology.

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Resumen

Estudio Experimental de los Efectos de Apretar los Dientes Repetidamente con una Fuerza Menor que la Máxima por 5 Días sobre el Dolor y la Sensibilidad de los Músculos Masticatorios

La hipótesis de este estudio a corto plazo fue que la acción de apretar los dientes repetidamente con una fuerza de mordida menor que la máxima puede inducir un aumento progresivo en el dolor y la sensibilidad de los músculos masticatorios. Diariamente por 5 días consecutivos, 10 mujeres apretaron sus dientes sobre un transductor de fuerza de mordida por 15 minutos utilizando sólo un 25% de su fuerza de mordida máxima. El desarrollo del dolor, sensibilidad, y molestia en los músculos masticatorios fue evaluado con balanzas análogas visuales (BAV) de 10-cm y el Cuestionario de Dolor de McGill (CDM). Los umbrales de detección de dolor (UDD) y los umbrales de tolerancia al dolor (UTD) a los estímulos de presión percutánea fueron medidos en los músculos masetero y temporal anterior. Se evaluó la fuerza de mordida voluntaria máxima al apretar los dientes brevemente. Los resultados indicaron niveles moderados de dolor (media ± SE; 5,3 ±1,0), sensibilidad (5,2 ± 1,0), molestia (5,8 ± 0,8), y los valores del CDM (16,4 ± 4,9) inmediatamente después de apretar los dientes con una fuerza menor que la máxima el primer día. En los días siguientes, los valores no aumentaron; en contraste, se detectaron disminuciones significativas en el quinto día en cuanto a la intensidad del dolor (–49,8% ±14,6%), sensibilidad (–46,1% ± 14,2%), molestia (–50,4% ± 8,5%), y los valores del CDM (–45.8% ± 13,3%) (P < 0,05) al compararlos con el primer día. La acción de apretar los dientes no logró inducir un aumento progresivo del dolor y la sensibilidad de los músculos masticatorios durante los 5 días. Ninguno de los parámetros evaluados en este estudio pareció ser el comienzo de un ciclo vicioso.

Zusammenfassung

Auswirkungen von wiederholtem submaximalem Pressen während 5 Tage auf die Kaumuskulatur bezüglich Schmerzen und Empfindlichkeit: Eine experimentelle Studie

Diese Studie analysiert, ob wiederholtes Pressen bei einer submaximalen Kraft, eine progressive Steigerung der Schmerzen und der Empfindlichkeit der Kaumuskeln bewirken kann. An 5 aufeinanderfolgenden Tagen haben 10 Frauen auf einem bite force transducer für 15 Minuten mit 25% der maximalen Kraft gepreßt. Die Entwicklung von Schmerzen, Empfindlichkeit und Unwohlsein in den Kaumuskeln wurde durch die Visual analog scale (VAS) und dem McGill Schmerzfragebogen (MPQ) ausgewertet.Die maximale Bisskraft wurde bei kurzem Zusammenbeissen gemessen. Die Schmerzschwelle und die Schmerzerträglichkeitsschwelle auf Druckreize wurden auf dem Masseter und auf dem anterioren Anteil des Temporalis gemessen. Die Ergebnisse zeigten gleich nach dem submaximalen Pressen am ersten Tag mäßige Werte für die Schmerzen (mean ± SE; 5.3 ± 1.0), für die Empfindlichkeit (5.2 ± 1.0), für das Unwohlsein (5.8 ± 0.8) und für den MPQ (16.4 ± 4.9). An den darauffolgenden Tagen stiegen die Werte nach dem Pressen nicht; im Gegenteil konnte man am 5. Tag eine signifikante Abnahme der Schmerzintensität (–49.8% ± 14.6%), der Empfindlichkeit (–46.1% ± 14.2%), des Unwohlseins (–50.4% ± 8.5%) und des MPQ (–45.8% ± 13.3%) ($P < .05$) wahrnehmen. Das wiederholte Pressen hat zu keiner progressiven Steigerung der Schmerzen in der Kaumuskulatur während der 5 Tage geführt. Keiner der untersuchten Parameter läßt auf das Entstehen eines Circulus vitiosus schliessen.