Effect of Tooth Clenching and Jaw Opening on Pain-Pressure Thresholds in the Human Jaw Muscles

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The measurement of the pain-pressure threshold in the human jaw muscles may be affected by variables such as the size of the pressure-transducer recording surface and the rate of applied pressure. The jaw muscles have a complex architecture that results in changes in muscle stiffness and compliance when different motor tasks are performed. Such changes in the jaw muscles are likely to affect the pain-pressure threshold. The central motor program associated with different tasks may also affect the pain-pressure threshold. A pressure algometer was used to measure the pain-pressure threshold in various regions of the masseter and temporalis muscles at different magnitudes of tooth clenching and jaw gape. The pain-pressure threshold increased at all recording sites as muscle contraction associated with tooth clenching increased. The pain-pressure threshold was not affected when the jaw gape changed. There were no apparent regional differences in pain-pressure thresholds in the masseter or temporalis muscles at different amounts of tooth clenching or jaw gapes. Pain-pressure thresholds were consistently higher in the temporalis muscle. When quantitative measures of jaw muscle pain-pressure thresholds are planned, the nature of the motor task should be controlled.

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Pressure algometry is often employed as an adjunct in the diagnosis of musculoskeletal pain in the human jaws and limbs.[1–4] The measurement of the pain-pressure threshold (PPT) is commonly used as a means of evaluating muscle tenderness and has been shown to be sensitive and reliable.[3–7] There is, however, considerable variability in the PPT in the jaw and limb muscles as well as between different regions in individual muscles, which complicates the interpretation of muscle tenderness.[1,4,7] Studies involving PPT measurements are also affected by variations in the experimental technique (the design of the pressure algometer and the rate of pressure application), which affect the magnitude of the measured PPT. The PPT has been shown to decrease as the area of the algometer tip increases, and it increases as the loading rate increases.[6,8]

The internal anatomy of the human jaw elevator muscles is complex, with muscle fibers inserted at different angles into multiple connective tissue tendons that are spread out in a sheetlike arrangement.[9] The disposition of connective tissue tendon varies regionally within the jaw muscles,[9,10] and its inherent stiffness appears to vary when the tension within the muscle is altered as a consequence of tasks such as tooth clenching.[11] Likewise, connective tissue architecture contributes to muscle compliance,[12] which has been cited as a possible source of the variation in the PPT observed in different regions of the masseter muscle.[7] Muscle compliance may be modified by changes in the behavioral set of the muscle, for example, by changes in the position of the jaw,[11,13] but how these affect the PPT in the jaw muscles is unclear.

Motor activity is associated with changes in transmission of somatosensory information in the trigeminal and other segmental systems (reviewed in Feine et al[14]). Both isometric and dynamic motor tasks decrease the size of evoked responses in the somatosensory cortex.[15] In exercising limbs, cutaneous tactile thresholds are modulated in a load-dependent manner, and the threshold may vary depending on the phase and direction of the task.[16,17] The efferent barrage from the somatosensory cortex is considered to play a key role in sensory threshold changes produced as a consequence of isometric exercise.[17] Thus, it seems likely that the motor program associated with the performance of different tasks may affect the muscle PPT.

Variations in muscle contraction levels as a consequence of clenching of the teeth and changes in jaw position are likely to affect PPT measurements in the jaw muscles. Therefore, this study investigated the effect of tooth clenching and jaw gape on the PPT in the masseter and temporalis muscles.

Materials and Methods

Ten male subjects (age range 22 to 30 years) participated in the study. The subjects were undergraduate dental students, had complete natural dentitions, and reported no history of jaw dysfunction.

PPT Recording Procedure

PPT Recording Sites. Each subject was seated in an upright position. The right masseter muscle was palpated to determine its anterior and posterior borders. The central point of recording site M1 was located 10 mm posterior to the anterior border of the muscle and 10 mm inferior to the lowest point on the zygomatic buttress. Site M3 was located 10 mm posterior to the anterior border of the muscle and 10 mm superior to the lower border of the mandible. Site M2 was located 10 mm posterior to the anterior border of the muscle, equidistant from sites M1 and M3.

The right anterior temporalis muscle was palpated to determine its anterior border. Site T2 was located 10 mm posterior to the anterior border of the muscle and 10 mm superior to the highest point on the zygomatic buttress. Site T1 was located 10 mm posterior to the anterior border of the muscle and 20 mm superior to site T2. Site T3 was located 20 mm posterior to T2 and 10 mm superior to the highest point on the zygomatic buttress (Fig 1).

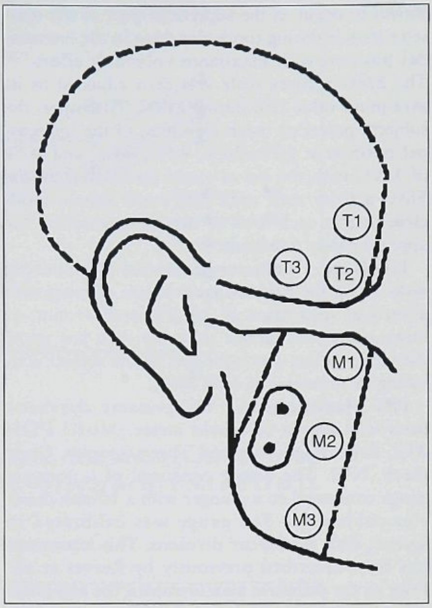

Fig 1 Location of PPT measurement sites in the right masseter (M1 to M3) and temporalis (T1 to T3) muscles. Bipolar surface EMG electrodes are situated over the superficial masseter muscle, posterior to sites M1 to M3.

Tooth Clenching. Bipolar surface electrodes with an interelectrode distance of 20 mm (Myotronics Research, Seattle, WA) were positioned over the body of the superficial fibers of the right masseter muscle at least 5 mm posterior to PPT recording sites M1 to M3 (Fig 1). A surface reference electrode was attached to the nape of the neck. The electromyographic (EMG) signals were amplified, filtered and processed, then displayed digitally (EMG biofeedback monitor, model NB-222, Narco Bio-Systems, Houston, TX). The display consisted of a dial and an activity scale from 0 to 10.

Initially, each subject performed tooth clenching in the intercuspal position and increased the effort until maximum voluntary muscle contraction (MVC) was achieved. Peak EMG activity has been shown to occur in the superficial part of the masseter muscle during tooth clenching in the intercuspal position with maximum voluntary effort.[18,19] The EMG activity scale was then adjusted to its maximum value (10) during MVC. Thereafter, the subjects practiced tooth clenching in the intercuspal position at 10%, 20%, 40%, 60%, and 80% of MVC with the aid of visual feedback from the EMG activity scale until they could sustain tooth clenching at each level of muscle contraction for approximately 6 seconds.

Jaw Gape. Subjects performed jaw opening tasks along the habitual path of jaw opening with a vertical separation of 10, 20, and 40 mm, as measured at the incisor teeth. At each jaw gape, the jaw position was stabilized by the subject activating the masseter to 10% MVC.

PPT Measurement. The pressure algometer used was a pain-threshold meter (Model PTH-AF2, Pain Diagnostics and Thermography, Great Neck, NY). The device consisted of a pressure gauge connected to a plunger with a 10-mm diameter rubber tip. The gauge was calibrated in kg/cm^2, with 0.1 kg/cm^2 divisions. This instrument has been described previously by Reeves et al.[4] Prior to the definitive measurements, the algometer was placed perpendicular to the skin overlying the recording sites and the operator calibrated using a stopwatch to ensure that a controlled rate of pressure (0.5 kg/cm^2/s) was applied.

The PPT has been defined as the point at which pressure applied to the skin changes from a sensation of pressure to pain.[7] Subjects were asked to raise their hands when the pressure applied to the recording site just changed from a sensation of pressure to pain; the algometer was then removed from the recording site. Counterpressure was exerted by the operator's hand located on the left side of the subjects' heads during PPT measurement.

The experiment took place in a "quiet" room, with only the subject and operator present, to minimize extraneous noise and distraction. The subject sat in a chair with his arms resting comfortably on his lap. The biofeedback monitor was located directly in front of the subject for easy visualization. The subject focused attention on the test stimulus (algometer) because changes in attention are known to modulate cutaneous sensitivity and neural responses to somatic stimuli generally.[20]

The order of measurement at the PPT recording sites in the masseter and temporalis muscles was randomized.[7] There was a rest period of at least 30 seconds between each measurement, during which the subjects relaxed their jaws. All recording sites were measured at 10%, 20%, 40%, 60%, and 80% of MVC during tooth clenching, with the order of muscle contraction levels randomized between subjects. It should be noted that some subjects found it difficult to sustain tooth clenching at 60% to 80% MVC. When this occurred, the rest period between measurements was increased so that there was no residual muscle pain prior to subsequent PPT measurements. Thereafter, recordings were made in a random manner at jaw gapes of 10, 20, and 40 mm. Two stimulus trials were made at each recording site for the different tooth clench levels and jaw gapes.

Data Analysis

The mean PPTs from stimulus trials 1 and 2 were used for data analysis.[3] A four-factor analysis of variance (ANOVA) was used to compare PPTs at different tooth clench levels and jaw gapes. A multiple comparisons test with the Bonferroni adjustment was then used to test for differences in PPTs in adjacent tooth clenching levels and jaw gapes. A 5% level of significance was used for each test.

Results

All subjects were able to sustain the tooth clench task at 10% to 40% MVC relatively easily, with no discomfort in the jaw muscles. However, five subjects found it difficult to sustain the tooth clench at 60% MVC consistently, and all subjects had difficulty maintaining 80% MVC during the recording period due to moderate discomfort in the jaw muscles. There was no discernible discomfort associated with the jaw opening task at any time during the experiment.

The mean values of PPTs (kg) measured at six recording sites in the right masseter and temporalis muscles at different muscle contraction levels during tooth clenching and different jaw gapes are shown in Tables 1 and 2. The magnitude of the PPT measured at each recording site increased as the level of tooth clenching increased (Fig 2). There were statistically significant differences between PPTs measured at different tooth clenching levels ($P < .0001$), and between PPTs in adjacent tooth clenching levels ($P < .0004$) at each recording site in both muscles. There was, however, no significant difference between PPTs measured at different magnitudes of jaw gape in either muscle ($P > .18$) (Fig 3).

Pressure pain thresholds were consistently higher in the temporalis muscle compared with the

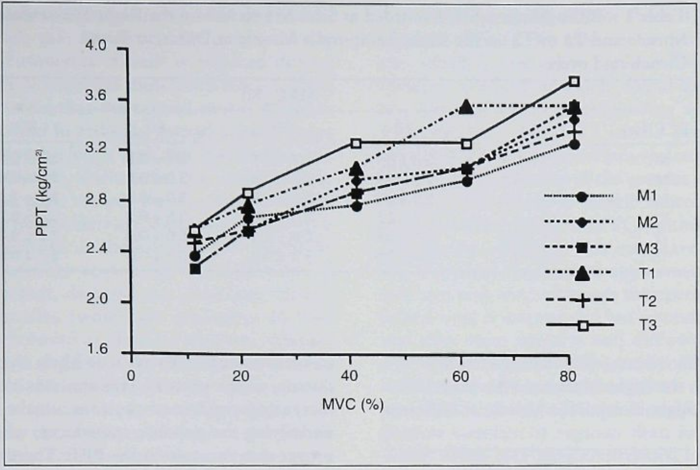

Fig 2 PPTs plotted against tooth clenching level (% MVC) for sites M1 to M3 and T1 to T3.

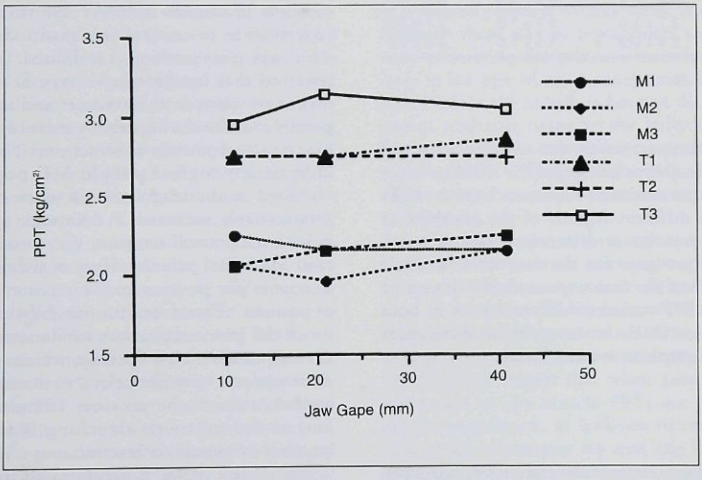

Fig 3 PPTs plotted against jaw gape (mm) for sites M1 to M3 and T1 to T3.

Table 1 PPTs (Mean ± SD) Recorded at Sites M1 to M3 on the Right Masseter Muscle and T1 to T3 on the Right Temporalis Muscle at Different Tooth Clenching Levels

	MVC (%)				
PPT (kg)	10	20	40	60	80
M1	2.3 ± 0.7	2.6 ± 0.7	2.7 ± 0.7	2.9 ± 0.9	3.2 ± 0.9
M2	2.2 ± 0.7	2.5 ± 0.7	2.9 ± 0.8	3.0 ± 0.8	3.4 ± 1.0
M3	2.2 ± 0.6	2.5 ± 0.6	2.8 ± 1.0	3.0 ± 0.9	3.5 ± 1.1
T1	2.5 ± 0.8	2.7 ± 0.6	3.0 ± 0.8	3.5 ± 0.9	3.5 ± 0.7
T2	2.4 ± 0.6	2.5 ± 0.6	2.8 ± 0.8	3.0 ± 0.9	3.3 ± 0.9
T3	2.5 ± 0.7	2.8 ± 0.9	3.2 ± 0.9	3.2 ± 0.6	3.7 ± 0.8

Table 2 PPTs (Mean ± SD) Recorded at Sites M1 to M3 on the Right Masseter Muscle and T1 to T3 on the Right Temporalis Muscle at Different Jaw Gapes

	Jaw gape (mm)		
PPT (kg)	10	20	40
M1	2.2 ± 0.7	2.1 ± 0.7	2.1 ± 0.5
M2	2.0 ± 0.5	1.9 ± 0.5	2.1 ± 0.5
M3	2.0 ± 0.5	2.1 ± 0.5	2.2 ± 0.6
T1	2.7 ± 0.8	2.7 ± 0.8	2.8 ± 0.8
T2	2.7 ± 1.0	2.7 ± 1.0	2.7 ± 0.9
T3	2.9 ± 0.9	3.1 ± 1.0	3.0 ± 1.0

masseter, irrespective of the amount of tooth clenching ($P < .04$) or jaw gape ($P < .0001$).

There was no statistical difference between PPTs measured in different regions of the masseter or temporalis muscles at different levels of tooth clenching or jaw gape for the data set as a whole ($P > .28$). When the data were analyzed subject by subject, the PPT varied at different sites in both muscles ($P < .0001$); however, these differences were not consistent between subjects.

Discussion

A passive muscle is generally compliant, but when it contracts, its stiffness increases due to the formation of cross-bridges between its contractile elements.[21] In the present study, the tooth clench and jaw opening tasks involved sustained isometric contraction of the jaw muscles, and stiffness played an important role in the active muscles.[21] As the degree of tooth clenching increased, PPTs in the masseter and temporalis muscles increased consistently. Due to the associated increase in jaw elevator muscle activity, it is likely that the transduction of the pressure stimulus was altered by the increasing rigidity of the musculoskeletal tissues underlying the pressure transducer, which led to a progressive increase in the PPT. There were, however, no significant changes in PPT in either muscle when the jaw was in different opening positions, as might have been expected due to changes in muscle compliance with changes in jaw position.[7,11] It was, nonetheless, likely that there was an increase in muscle stiffness due to jaw muscle coactivation to control jaw position, as occurs when any joint position is stabilized.[22] It has been observed that low threshold (type S) motor units (MUs) are active in the masseter and anterior temporalis muscles during coactivation of the jaws at low levels of muscle contraction,[23,24] whereas an increasingly high threshold MU population is recruited as the magnitude of tooth clenching is progressively increased.[25] Although type S units only develop small tensions, they produce significant stiffness, which offers resistance to any change in jaw position and is important in control of posture.[21] Therefore, it is possible that the rigidity of the jaw muscles was similar irrespective of the magnitude of jaw opening, which resulted in a more uniform musculoskeletal environment for the transduction of the pressure stimulus than occurred during tooth clenching with different amounts of muscle contraction.

The central motor program associated with the different tasks may also have affected the muscle PPT. During exercise, somatosensory thresholds generally increase in the limbs.[17,26] In this study, the PPT increased as jaw muscle activity associated with the tooth clench task increased. A similar load-dependent threshold elevation has been observed during isometric flexions of the hand and foot.[17] The efferent barrage from motor to sensory structures in the central nervous system is thought to be the basis of changes in sensory thresholds, with the result that somatosensory cortex activity evoked by cutaneous stimuli is reduced during short periods of isometric muscle activity.[15,17] Thus, it seems possible that the central motor program may be involved in reducing somatosensory input during the tooth clench task but not during jaw opening. However, during the jaw opening task, although the gape varied, the amount of muscle activity was likely relatively constant. Therefore, a similar threshold at different gapes might be expected. Another reason for the difference in thresholds is that, during tooth clenching, the jaw elevators muscles (which are analogous to limb extensors[27]) behaved as classical elevators, whereas at different jaw gapes, the muscles behaved as "flexors." McMillan and Moudy[16] have shown that the direction of motor activity affects pain thresholds in the limbs, with higher thresholds occurring more consistently during muscle extension than flexion. Thus, the direction of the jaw muscle activity may have affected the PPT.

Muscle pain and fatigue during the task may also have affected sensory thresholds.[28,29] Diffuse noxious inhibitory controls (DNICs) are involved in the modulation of pain.[23,29,30] The magnitude of inhibition is closely related to the intensity of the painful conditioning stimulus. Pain thresholds appear to increase and subjective pain ratings decrease when noxious conditioning stimuli are applied to human body parts, whereas nonpainful conditioning stimuli do not modulate painful stimuli.[29] In this experiment, when subjects clenched at 60% to 80% MVC, the noxious stimulus (muscle pain) may have inhibited the perception of the second noxious stimulus (algometer) by means of counterirritation, which resulted in an increase in the PPT as the task-induced muscle pain increased. At different jaw gapes there were no noxious muscle stimuli, so thresholds were unlikely to be affected by DNICs.

The temporalis muscle PPT was higher than the masseter muscle PPT regardless of the anatomic location of the PPT recording site, tooth clenching, or jaw gape. This is consistent with previous findings in the jaw muscles[7] and concurs with Fischer's observations[1] that muscles generally have different PPTs. It is presently unclear why the temporalis muscle PPT is higher; however, it is possible that there may be fewer cutaneous and muscle receptors in the temporal region, as the density of sensory receptors is known to vary with the anatomic location.[31] There is also variation in the density of connective tissue tendon in the anterior temporalis region compared with the masseter, which may have contributed to the difference in PPTs.[9]

The present study did not show regional differences in PPTs in the masseter or temporalis muscles, which is contrary to previous findings in these muscles.[7] Ohrbach and Gale[7] found similar PPTs in the temporal region corresponding approximately to locations T2 and T3 in the present study. However, some within-subject regional differences in PPTs were observed in the present study, particularly at high levels of muscle contraction during tooth clenching (>40% MVC), although no specific pattern emerged. This may have been due to the occasional inconsistent application of the pressure stimulus, even although the operator was calibrated with a stopwatch,[8] but a more likely cause was that some subjects had difficulty sustaining high levels of muscle contraction consistently without muscle discomfort during the measurement period. Ohrbach and Gale[7] measured PPTs in a greater number of regions than in the present study, which may have contributed to their observations of regional variability. However, they did not indicate whether the jaw position or level of muscle activity was controlled during the recording procedure, which may have affected their measurements. List et al[32] recorded PPTs with the jaw in a relaxed position without tooth contact. In this situation there may be nonuniform support of tissues underlying the pressure transducer, particularly in the case of the masseter muscle, where the tissue below the muscle is bone at the mandibular ramus and soft tissue in the belly region. This makes the application of a controlled pressure stimulus more difficult to achieve, particularly in a naive subject population such as patients with muscle pain.

Jaw muscle tenderness is a common clinical finding in patients with craniomandibular dysfunction.[7,32] The measurement of the PPT has been used as an aid in the diagnosis of muscle pain and to monitor the effect of treatment modalities such as intramuscular injections and physiotherapy.[2,6] Our findings suggest that when quantitative measurements of jaw muscle PPTs are planned in a patient population, in addition to controlling the size of the algometer tip and the loading rate, the degree of tooth clenching should also be taken into account.

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Resumen

Efecto del rechinamiento dental y la apertura mandibular sobre los umbrales de presión y dolor en los músculos mandibulares humanos.

La medida del umbral de presión – dolor de los músculos mandibulares en los humanos puede ser afectada por variables tales como el tamaño de la superficie registradora del transductor a presión y el valor de la fuerza aplicada. Los músculos mandibulares tienen una arquitectura compleja que trae como resultado cambios en la rigidez muscular y el acatamiento de las diferentes labores motoras cuando es necesario realizarias. Tales cambios en los músculos mandibulares probablemente afecten el umbral de presión – dolor. El programa motor central asociado con las diferentes labores puede afectar también el umbral de presión – dolor. Se utilizó un algómetro para medir el umbral de presión – dolor en varias regiones de los músculos masetero y temporal en diferentes magnitudes de rechinamiento dental y de apertura bucal. El umbral de presión – dolor aumentó en todos los sitios en donde se registró, a medida que la contracción muscular asociada con el rechinamiento dental aumentaba. El umbral no estuvo afectado cuando se cambió la apertura bucal. No se presentaron diferencias regionales aparentes en los umbrales de presión – dolor de los músculos masetero y temporal en diferentes grados de rechinamiento dental o de apertura mandibular. Los umbrales de presión – dolor fueron consistentemente mas altos en el músculo temporal. Cuando se planeen medidas cuantitativas de los umbrales de presión – dolor de los músculos mandibulares, se debe controlar la clase de labor motor.

Zusammenfassung

Auswirkung von Zähnepressen und Kieferöffnen auf die Druckschmerzhaftigkeitsschwelle in menschlichen Kaumuskeln.

Die Messung der Druckschmerzhaftigkeitsschwelle in menschlichen Kaumuskeln kann von Variabeln wie der Fläche der Druckübertragung und dem Mass des ausgeübten Druckes beeinflusst werden. Die Kaumuskeln weisen eine komplizierte Architektur auf, die zu Veränderungen der Muskelsteifigkeit und – konsistenz während der Durchführung verschiedener Aufgaben führt. Solche Veränderungen in den Kaumuskeln können die Druckschmerzhaftigkeitsschwelle beeinflussen. Auch das zu den jeweiligen Aufgaben gehörige zentralmotorische Programm kann seinen Einfluss auf die Druckschmerzhaftigkeitsschwelle ausüben. Um die Druckschmerzhaftigkeitsschwelle an verschiedenen Stellen des M. masseter und des M. temporalis zu messen, wurde ein Druckalgometer eingesetzt; dies bei verschieden starkem Zähnepressen und bei verschiedener Mundöffnung. Die Druckschmerzhaftigkeitsschwelle stieg an allen Stellen an, wenn mit zunehmendem Pressen die Muskelkontraktion zunahm. Die Druckschmerzhaftigkeitsschwelle wurde von der Mundöffnung nicht beeinflusst. Es bestanden keine regionalen Differenzen der Druckschmerzhaftigkeitsschwelle innerhalb der Masseteren oder der Mm. temporales bezüglich Stärke des Zähnepressens oder Grösse der Mundöffnung. Die Druckschmerzhaftigkeitsschwelle der Mm. temporales lagen allerdings generell höher. Wenn also qualitative Messungen der Druckschmerzhaftigkeitsschwelle der Kaumuskulatur vorgenommen werden, sollte die Art der motorischen Tätigkeit berücksichtigt werden.