Joint Tenderness, Jaw Opening, Chewing Velocity, and Bite Force in Patients with Temporomandibular Joint Pain and Matched Healthy Control Subjects

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Aims: *To evaluate the effect of temporomandibular arthralgia on mandibular mobility, chewing, and bite force.* ***Methods:*** *Twenty female patients (ages 19 to 45 years) with unilateral temporomandibular joint (TMJ) pain during chewing (49 ± 27 mm on a 100-mm visual analog scale) and provocation, as well as TMJ tenderness, were studied. The TMJ conditions were classified as disc derangement disorders (n = 9), osteoarthritis (n = 7), and inflammatory disorders (n = 4). The patients were compared with matched healthy volunteers without orofacial pain or tenderness. Exclusion criteria were the presence of fewer than 24 teeth or malocclusion. The methods used were (1) algometric assessment of the pressure pain threshold (PPT) over the TMJ; (2) clinical recordings of maximum jaw opening; (3) computerized kinematic assessment of maximum vertical distance, velocity, and cycle duration during chewing of soft gum; and (4) measurement of unilateral molar bite force.* ***Results:*** *The mean (± SD) PPT in the patients' painful side (69 ± 20 kPa; P = .000001) was significantly lower than in the control subjects (107 ± 22 kPa). Jaw opening was also significantly less (P = .00003) in the patients (42 ± 9 mm) than in the controls (52 ± 4 mm). Chewing cycle duration and maximum closing velocity were significantly different (P ≤ .03) in the patients (948 ± 185 milliseconds and 142 ± 46 mm/s, respectively) versus the controls (765 ± 102 milliseconds and 173 ± 43 mm/s, respectively), and bite force was significantly lower (P = .000003) in the patients (238 ± 99 N) than in the controls (394 ± 80 N). Both bite force and jaw opening in patients were significantly correlated (P ≤ .02) with PPT (r = 0.53 and 0.63, respectively).* ***Conclusion:*** *These systematic findings supplement results from acute pain experiments and confirm indications from unspecified patient groups that the clinical presence of long-standing TMJ pain is associated with marked functional impairment. This impairment might be a result of reflex adaptation and long-term hypoactivity of the jaw muscles.* J OROFAC PAIN 2004;18:108–113.

Key words: bite force, jaw kinematics, mastication, orofacial pain, temporomandibular joint

It is generally agreed that pain affects jaw function, including a tendency to avoid movements or to perform them more slowly, and limits the ability to work against heavy loads.[1] In addition, pain conditions affecting the temporomandibular joint (TMJ) may be associated with a "splinting" reaction, which may serve to limit jaw movements, and with peripheral and central sensitization contributing to the pain.[2] Experimental TMJ pain elicited by pressure has been reported to reduce jaw-elevator activity during chewing,[3] and experimental muscle pain has been shown to reduce bite force.[4] Patients with temporomandibular disorders (TMD) have generally longer duration of chewing cycles and lower bite force.[5,6] In patients

Table 1 Description of the Participants

Group	Age (y, mean ± SD)	Height (cm, mean ± SD)	TMJ pain (mean ± SD)*	Location of painful TMJ	Duration of pain (y, range)
Patients with unilateral TMJ pain (n = 20)	26 ± 5.5	170 ± 5.4	49 ± 27.0	9 right, 11 left	0.5–6
Control subjects (n = 20)	26 ± 5.5	169 ± 7.0	0 ± 0.0	N/A	N/A

*As recorded on a 100-mm visual analog scale.

with TMD, jaw movements during chewing have also been reported to be slower compared to control subjects.[7,8] However, no systematic, controlled patient studies on jaw function have been performed concerning pain specifically from the TMJ.

The main purpose of this study was to evaluate the effect of clinical TMJ pain on jaw function by comparing recordings from patients with painful TMJ conditions with those from matched control subjects. Recognized methods and criteria were employed for inclusion and description of the patients, and commonly available recording methods and devices were used to monitor the jaw function. Only female patients and controls were included in the study, as jaw function and TMJ pain thresholds differ between genders[9–12] and more women than men are affected by facial pain.[13,14]

Materials and Methods

Patients, Diagnostic Classification, and Control Subjects

The study comprised 20 adult patients, female Caucasians 19 to 45 years old, referred to and treated for unilateral TMJ pain at the Section of Clinical Oral Physiology, School of Dentistry, University of Copenhagen, Denmark in the autumn of 2002 (Table 1). To be included in the patient group the TMJ pain had to be: *(1)* unilateral and the only significant symptom from the orofacial region, *(2)* present during chewing in the last couple of days, *(3)* provoked or aggravated clinically by the examiner (RH), and *(4)* associated with moderate to severe TMJ tenderness induced by manual palpation. The chewing pain was indicated on a horizontal, 100-mm visual analog scale (VAS), with the left endpoint of the scale (0 mm) indicating "no pain during chewing" and the right endpoint (100 mm) indicating "the worst imaginable pain during chewing." Positive provocation of the TMJ pain was recorded if the patient experienced a distinct painful sensation in the TMJ during forceful biting on a thick wooden bite stick in the molar region. TMJ tenderness was assessed as reflex responses (ie, blinking or flinching) elicited by unilateral palpation during slight jaw opening with firm finger pressure (1 to 2 kg) on the capsule (corresponding to the lateral pole of the condyle just anterior to the tragus); only weak tenderness (verbal report, no reflex responses) of jaw-elevator muscles needed to be present.

On the basis of patient history, clinical examination, and hard tissue imaging (routine radiographic examination at the Department of Radiology, School of Dentistry, University of Copenhagen, including orthopantomograms and oblique, transcranial, transpharyngeal, and transmaxillary TMJ projections), the TMJ conditions were classified according to the criteria of the Danish Society of Craniomandibular Disorders.[15] The classification of the American Academy of Orofacial Pain (AAOP)[16] was also fulfilled, with the exception that no magnetic resonance imaging (MRI) was performed. The TMJ conditions were articular disc derangement disorders (AAOP 11.7.2; 6 cases of disc displacements with reductions and 3 chronic cases without reduction); osteoarthritis (AAOP 11.7.5; 6 cases of primary osteoarthritis [ie, osteoarthrosis] and 1 case of secondary osteoarthritis); and inflammatory disorders (AAOP 11.7.4; 3 cases of synovitis and capsulitis and 1 case of polyarthritis).

The patients were compared with 20 age- and sex-matched, healthy, Caucasian controls (staff members, clinical nurses, and dental students) without signs and symptoms of TMD and orofacial pain (Table 1).

Exclusion criteria for both patients and controls were the presence of fewer than 24 teeth in both dental arches or significant malocclusion.

Experimental Protocol

The following parameters were assessed in the following sequence in all participants: *(1)* clinical measurement of mandibular mobility, *(2)* clinical measurement of TMJ pressure pain thresholds (PPTs), *(3)* jaw tracking of mandibular opening and chewing movements, and *(4)* recording of bite force. "Method error" in terms of intraexaminer reproducibility and week-to-week variation (s(i)) was assessed by duplicate measurements in 8 of the control subjects (mean interval between measurements, 26 days).

Mandibular Mobility. Maximum unassisted jaw opening (mm) was measured with a ruler at the central incisors as the largest of 3 measurements, taking overbite into account. The method error was 2.0%.

Pressure Algometry. The PPT was measured in kilopascals with an electronic algometer (Somedic; tip 0.5 cm^2, application rate 20 kPa/s) during slight jaw opening on the capsule, applied to the lateral pole of the condyle just anterior to the tragus. The PPT value was determined as the amount of pressure applied at which the sensation of pressure changed to pain.[17] The subjects indicated the threshold by pressing a button that recorded the current pressure. Four measurements were made at each site with 2-minute intervals between trials, and a label fixed on the skin over the TMJs ensured precise relocation of the algometer. The first measurement was discarded, and the PPT was calculated as the mean of 3 successive trials.[18] In the patient group, the values for the painful TMJ and for the contralateral TMJ were averaged separately, whereas values from both TMJs were pooled in controls. The method error was 11.5%.

Kinematic Assessment by Jaw Tracking. A computerized magnetic system (Siemens JT3; Biopak Research) was used to assess opening distance, chewing velocity, and cycle duration. A magnet was fixed with wax (Stomahesive 10 × 10; Convatec) at the mandibular central incisors and gingiva; then the magnet-sensing devices, carried on an array, were placed on the participant's head, and a positioning bar was used to align the sensor array with the magnet. Recordings of maximum vertical opening distance during 10 seconds of unilateral chewing on the right side and on the left side of 2 pieces of soft gum (Caroxin; Ferrosan, 0.8 g/piece) were performed twice, and the values given by the system (on the x-y templates in the sagittal plane) were averaged. Data acquisition did not start until the gum pieces had been chewed together and the rhythm was stabilized. The method error was 2.9% for jaw opening and 14.4% for chewing distance. The maximum 3-dimensional (3-D) chewing velocity (mm/second) during the opening and closing phase was assessed as the mean of the values from the recorded chewing sequences given by the jaw-tracking system. The method error was 15.8% for opening velocity and 18.0% for closing velocity. The duration (in milliseconds) of the chewing cycle was measured from the sweep of the vertical movements as the mean of the time interval from the most cranial jaw position in 1 stroke to the most cranial jaw position in the next stroke, in the first 5 chewing cycles. The method error was 6.8%.

Assessment of Maximum Jaw-Closing Force. Unilateral bite force (N) was recorded with a strain-gauge transducer (miniature bite-force recorder; Kleven)[19] placed on the mandibular first molar. According to our standard procedure,[20] the transducer was covered with polyvinyl chloride tubes for protection, and the force was measured during maximum clenches (2-second duration) as the stored peak values on the digital display (Newport; Mikro Elektronikk). Four measurements were made in each side; the first was discarded, and the molar bite force was assessed as the mean of the successive 3 trials on the right and the left side. The method error was 8.2%.

Statistical Analyses

The data were analyzed with conventional statistical methods (Statistica, version 5.0; StatSoft). The Kolmogorov-Smirnov test showed no deviations from the normal distribution. Data from patients and controls were treated with *t* tests for independent samples and paired *t* tests. Analysis of variance (ANOVA) was used for comparison between diagnostic groups, and the Tukey honestly significant difference test was used for post hoc comparison. The relationship between TMJ tenderness and jaw function was analyzed with Pearson's linear product-moment correlations. Statistical significance was accepted at $P < .05$. Reproducibility and week-to-week variation (method error: s(i)) was assessed as $(s(i)/x_1) \times 100\%$, $s(i) = \sqrt{\Sigma d^2/2n}$, where d defines the differences between duplicate measurements (x_1 and x_2) and n denotes the number of subjects.

Results

Table 2 compares the results of examinations for TMJ tenderness and jaw function in the patient group with TMJ arthralgia with those from the asymptomatic control group. Tenderness, as assessed by PPT values measured over the TMJ capsules, was significantly more severe in the patients than in the controls. In addition, the PPTs in the patients were significantly lower on the painful side than on the contralateral side. The maximum jaw opening was significantly smaller in the patient group as compared to the control group. During chewing of soft gum, the maximum vertical opening (ie, the maximum chewing distance assessed by the jaw-tracking system) did not differ between the 2 groups, but the chewing was

Table 2 TMJ Tenderness and Jaw Function in Patients with Unilateral TMJ Pain and Control Subjects

Parameter (mean ± SD)	Patients with unilateral TMJ pain (n = 20)	Control subjects (n = 20)	*P*
TMJ algometry (PPT, in kPa)			
Ipsilateral TMJ	69 ± 19.9*	107 + 22.3†	.000001
Contralateral TMJ	77 ± 24.7		.0002
Maximum unassisted jaw opening (mm)	42 ± 8.8	52 ± 3.6	.00003
Maximum vertical chewing distance (mm)	23 ± 4.5	23 ± 4.5	NS
Maximum 3-D chewing velocity (mm/s)			
Opening phase	134 ± 41.3	151 ± 36.0	NS
Closing phase	142 ± 46.0	173 ± 43.2	.03
Chewing cycle (ms)	948 ± 184.5	765 ± 102.3	.0004
Molar bite force (N)	238 ± 99.1	394 ± 79.8	.000003

*P = .03 versus contralateral TMJ
†Results were pooled in controls.
NS = not significant.

Figs 1a and 1b *Measurements of TMJ tenderness and jaw function in 20 female patients with unilateral arthralgia.*

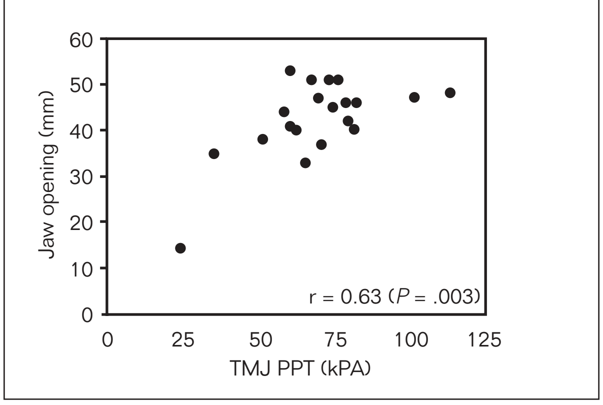

Fig 1a Correlation between maximum unassisted jaw opening capacity and PPTs over the painful TMJ (y = 23.18 + 0.28x).

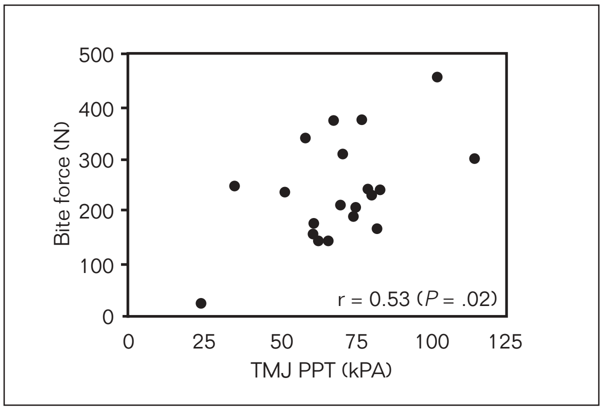

Fig 1b Correlation between maximum unilateral molar bite force and PPTs over the painful TMJ (y = 55.57 + 2.64x).

significantly slower in the patients: the maximum 3-D velocity in the closing phase was slower and the duration of the chewing cycle was longer. Also, the closing force (maximum unilateral molar bite force) was significantly lower in the patients.

Figures 1a and 1b illustrate the relationship between TMJ tenderness and jaw function in the patients. The PPT was significantly and positively correlated with maximum jaw opening as well as bite force: the lower the PPT, the lower the maximum jaw opening and bite force. In addition, Table 3 presents data of TMJ tenderness and jaw function corresponding to the 3 main diagnostic classifications of the 20 patients. Although the results should be interpreted with care because of the low sample size in each classification, the results indicate that the most severe tenderness (ie, lowest PPT) and the most impeded jaw function with respect to maximum jaw opening and bite force coincided in the patients with inflammatory disorders.

Discussion

In the present study, unilateral TMJ arthralgia was diagnosed on the basis of reports of chewing pain from the TMJ, provocation of the pain by forceful biting on a wooden stick, and moderate to severe capsular tenderness induced by manual palpation. Myalgia of the masticatory muscles or other muscle disorder was either not present or insignificant. In all cases, the TMJ pain was long-standing. Such joint pain may be the result of both inflammatory mechanisms and mechanical distortions, and it has

Table 3 TMJ Tenderness and Jaw Function in Patients with Different Diagnostic Classifications

Parameter (mean ± SD)	Disc derangements (n = 9)	Osteoarthritis (n = 7)	Inflammatory disorders (n = 4)	*P*
TMJ algometry (PPT, in kPa)				
Ipsilateral TMJ	80 ± 17.4	68 ± 10.9	46 ± 19.7*	.009
Contralateral TMJ	86 ± 28.4	76 ± 14.2	58 ± 24.3	NS
Maximum unassisted jaw opening (mm)	47 ± 4.5	42 ± 3.1	34 ± 15.9*	.04
Maximum vertical chewing distance (mm)	23 ± 3.6	24 ± 3.8	20 ± 7.3	NS
Maximum 3-D chewing velocity (mm/s)				
Opening phase	124 ± 19.8	159 ± 50.2	111 ± 47.5	NS
Closing phase	136 ± 31.8	160 ± 47.0	122 + 69.8	NS
Chewing cycle (ms)	969 ± 184.6	849 ± 118.8	1,075 ± 225.2	NS
Molar bite force (N)	313 ± 82.2	193 ± 36.6*	147 ± 93.1*	.002

P indicates significance of ANOVA; NS = not significant.
*Significant differences in post hoc comparisons.

been suggested that joint effusions identified by MRI are associated with TMJ pain and inflammation.[21] In the present study, no MRI was performed. However, recent studies have indicated that the diagnostic value of MRI effusions to establish the source of a patient's complaint is inadequate, and that palpation is superior to MRI in identifying the TMJ as the source of pain.[22,23] As judged from the clinical and radiographic examinations, the TMJ pain in our patient group was associated mainly with disorders classified as disc derangement disorders, osteoarthritis, and inflammatory disorders. Such disorders have previously been shown to be associated with TMJ pain.[24,25] In spite of the unilateral pain location in the patients, the PPTs over both the ipsilateral TMJ and the opposite TMJ were lower than in controls. This could be the result of a slight and unnoticed disorder in the opposite joint, but more likely it reflects a combination of so-called peripheral and central sensitization in the nervous system elicited by the inflammatory processes in the involved TMJ.[2]

Jaw opening, bite force, and duration of the chewing cycle in our control group corresponded with measurements in healthy subjects previously studied with identical or similar methods.[9,12] In spite of the large standard deviations due to the biologic variation and the relatively high method errors, including both intraexaminer reproducibility and the variation over time, the recordings in patients with pain differed significantly from the control group. Nonetheless, there was in general an overlap between the results from patients and the results from controls. Thus, even if substantially reduced mandibular mobility is considered an indicator of the presence of TMD and a means to distinguish TMD patients from nonpatients, measurements of maximum jaw mobility do not necessarily distinguish between common TMD subgroups or specific diagnoses.[26,27]

The significant differences between the patient group and control group in the present study indicated that the long-standing, unilateral TMJ pain in the patients limited the maximum jaw opening, slowed chewing, and reduced bite force. These changes could reflect reflex avoidance or reflex adaptation.[28] In addition, the maximum jaw opening and the maximum bite force were positively correlated with the patients' TMJ PPTs. However, the maximum opening may also have been restricted by pathophysiologic intra-articular changes in some of the patients,[29] but such changes could not alone explain the slow chewing pattern, ie, closing velocity and cycle duration, and the low bite force. Also, differences related to gender, age, height, and occlusion[9,11,18] could be ruled out, since the 2 groups were matched in these features. As might be expected from human studies of acute, experimental orofacial pain[3,4] and of unspecificied TMD patient groups,[5–8] the chewing cycle was longer and the bite force was lower in the patients. However, in contrast to reactions to experimental pain, the possible reflex adaptation from chronic TMJ pain could have both acute and prolonged effects on the jaw-elevator muscles. Thus, the lower bite force and the lower velocity in the closing phase during unilateral gum chewing in the patients might on the one hand reflect current TMJ pain and on the other hand a wasting of muscle tissue from long-term hypoactivity of the jaw muscles due to chronic TMJ pain.[30,31] TMJ pain seems to impair jaw-elevator function in the same way as poorly functioning dentures; the differences in bite force and cycle duration observed between patients with TMJ pain and asymptomatic controls are similar to the differences of recordings in denture patients before and after treatment with implant-supported overdentures.[32] Thus, primary afferents other than those carrying nociceptive information might conceivably also be associated with the reflex-adaptation model in the trigeminal system, resulting in a reduction of the agonist motor neuron output and an increase in antagonist firing during movement.[28]

Our systematic findings supplement results from acute pain experiments and confirm indications from unspecified patient groups that the presence of long-standing TMJ pain is associated with marked functional impairment. This impairment is probably a result of sensitization mechanisms, reflex adaptation, and long-term hypoactivity of the jaw muscles.

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