ARTICLE IN PRESS

Available online at www.sciencedirect.com

ScienceDirect

ELSEVIER

Manual Therapy ∎ (∎∎∎∎) ∎∎∎–∎∎∎

MANUAL THERAPY

www.elsevier.com/locate/math

Original article

Masticatory muscle activity during maximum voluntary clench in different research diagnostic criteria for temporomandibular disorders (RDC/TMD) groups

Gianluca M. Tartaglia[a], Marco Antonio Moreira Rodrigues da Silva[b], Stefano Bottini[a], Chiarella Sforza[a,*], Virgilio F. Ferrario[a]

[a]Functional Anatomy Research Center (FARC), Laboratorio di Anatomia Funzionale dell'Apparato Stomatognatico (LAFAS), Dipartimento di Morfologia Umana, Facoltà di Medicina e Chirurgia, Università Degli Studi, Via Mangiagalli 31, I-20133 Milano, Italy

[b]Departamento de Odontologia Restauradora, Faculdade de Odontologia de Ribeirão Preto, Universidade de São Paulo, Brazil

Received 12 October 2006; received in revised form 28 March 2007; accepted 22 May 2007

Abstract

The research diagnostic criteria for temporomandibular disorders (RDC/TMD) are used for the classification of patients with temporomandibular disorders (TMD). Surface electromyography of the right and left masseter and temporalis muscles was performed during maximum teeth clenching in 103 TMD patients subdivided according to the RDC/TMD into 3 non-overlapping groups: (a) 25 myogenous; (b) 61 arthrogenous; and (c) 17 psycogenous patients. Thirty-two control subjects matched for sex and age were also measured. During clenching, standardized total muscle activities (electromyographic potentials over time) significantly differed: 131.7 μV/μV s % in the normal subjects, 117.6 μV/μV s % in the myogenous patients, 105.3 μV/μV s % in the arthrogenous patients, 88.7 μV/μV s % in the psycogenous patients ($p<0.001$, analysis of covariance). Symmetry in the temporalis muscles was larger in normal subjects (86.3%) and in myogenous patients (84.9%) than in arthrogenous (82.7%), and psycogenous patients (80.5%) ($p=0.041$). No differences were found for masseter muscle symmetry and torque coefficient ($p>0.05$). Surface electromyography of the masticatory muscles allowed an objective discrimination among different RDC/TMD subgroups. This evaluation could assist conventional clinical assessments.

Keywords: Electromyography; Man; Temporomandibular disorders; Masseter; Temporalis anterior; Maximum voluntary clench

1. Introduction

Current medical treatments are increasingly evidence-based, allowing a widespread diffusion of diagnostic protocols and of treatment standards that should make scientific-based options available to the largest number of health professionals. Objective and quantitative assessments of function and malfunctioning should also support an evidence-based dentistry (Dworkin and LeResche, 1992). For instance, surface electromyography (EMG) of masticatory muscles is currently a part of the quantitative assessment of patients in dentistry. Diagnosis of the alterations of the stomatognathic apparatus, and assessment of the effects of therapy, will both profit from a quantitative approach, thus reducing the discordance among several clinical examinations (Schmitter et al., 2005; Manfredini et al., 2006). Objective measurements are also needed by insurances and forensic medicine.

EMG can be used for a deeper understanding of the pathologies of several dysfunctional patients, for instance of those with temporomandibular disorders (TMD). TMD is a complex disease, and its nature has not been completely understood yet (Visser et al., 1995;

*Corresponding author. Tel.: +39 02 503 15407; fax: +39 02 503 15387.
E-mail address: Chiarella.Sforza@unimi.it (C. Sforza).

1356-689X/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.math.2007.05.011

Gross et al., 1996; Sato et al., 1998; Liu et al., 1999; Pinho et al., 2000; Alcantara et al., 2002; Ferrario et al., 2002, 2006b; John et al., 2003; Suvinen et al., 2003; Landulpho et al., 2004; Manfredini et al., 2006). A large part of TMD patients report pain in the masticatory muscles, and present symptoms and signs of muscular alteration. EMG assessment of their masticatory function is being used for diagnosis, to monitor the progression of the disease, and to measure the effect of treatment (Visser et al., 1995; Sato et al., 1998; Liu et al., 1999; Pinho et al., 2000; Ferrario et al., 2002, 2006b; John et al., 2003; Suvinen et al., 2003). In particular, when used as a diagnostic test to differentiate between patients with TMD and neck disorders, standardized EMG of the masticatory muscles was found to have a sensitivity of 0.86, with a 0.92 specificity (Ferrario et al., 2006b).

Among the methods developed for the classification of patients with TMD, the research diagnostic criteria for temporomandibular disorders (RDC/TMD) had been proposed to produce reproducible case definitions, to investigate the time course of the disease, and to assess treatment efficacy (Dworkin and LeResche, 1992; Manfredini et al., 2006). The RDC/TMD uses a two-axis system, taking into consideration physical diagnosis, pain-related disability, and psychological status (Dworkin and LeResche, 1992; Schmitter et al., 2005; Manfredini et al., 2006). The physical findings (axis I) can be coordinated with the assessment of psychological distress and psychosocial dysfunctions associated with orofacial disability (axis II). Axis II considers the pain-related disability and the psychological status (depression, anxiety, vegetative symptoms), with subjective reports of pain intensity, activity limitations, and non-specific physical symptoms (Dworkin and LeResche, 1992).

Patient assessment uses a history questionnaire (demographics, general health, specific orofacial pain and symptoms, non-specific health complaints); standard scales are used to estimate pain and orofacial disability. Patient examination comprises both metric (maximum mouth opening, lateral excursion and protrusion) and non-metric (temporomandibular joint (TMJ) sound, spontaneous and provoked orofacial pain and tenderness) items. According to axis I findings, three patient categories are obtained: muscle disorders; disc displacements; and arthralgia, arthritis and arthrosis (Dworkin and LeResche, 1992). Some additional patients do not fall into these groups, and have prevalent axis II findings, where psychological distress mingles with more or less specific somatic symptoms.

A satisfactory between-examiners reliability has been reported for most RDC/TMD measurements, while poor reliability was found for non-metric assessments (Schmitter et al., 2005). Quantitative and objective evaluations are therefore needed also for TMD diagnosis.

In the present study, TMD patients were categorized according to the RDC/TMD, and the quantitative EMG characteristics of their masticatory muscles were analyzed. We wanted to see if patients in the different RDC/TMD groups had some objective differences in the EMG characteristics of their masticatory muscles during standardized teeth clenching. Patient data were also compared to those collected in control subjects without TMJ alterations.

2. Materials and methods

2.1. Patients

One hundred and three patients with a mean age of 43 years, S.D. 16 (90 women, aged 15–74 years, mean 42, S.D. 16; 13 men, aged 19–67 years, mean 41, S.D. 16) were examined. The patients referred to a dental clinic for the treatment of craniofacial pain, reporting subjective symptoms of pain in the orofacial region. In all patients, pain duration was less than 6 months.

The patients were visited by a dentist, their clinical history was gathered according to the RDC/TMD (Dworkin and LeResche, 1992), and they were subdivided into three non-overlapping groups: (a) myogenous patients (25 patients, aged 15–74 years); (b) arthrogenous patients (61 patients, aged 15–68 years); (c) psycogenous patients (17 patients, aged 37–70 years).

Myogenous patients (group I according to the RDC/TMD) reported moderate to severe muscular pain at rest and during mandibular movements; pain was also associated to palpation; no sub groupings (myofascial pain with/ without limited opening) were made.

Arthrogenous patients (groups II and IIII according to the RDC/TMD) lamented pain at palpation in the TMJ area; pain was reported also during functional movements and at rest. Pain was classified grade I–II according to the chronic pain classification scale (low disability with low to high intensity pain). Clicking (in opening/closing) or articular crepitus, together with limitations in opening were found.

Psycogenous patients did not fall into any axis I group, and had prevalent symptoms and signs of RDC/TMD axis II. They had a clinical history of chronic diffuse orofacial pain (grades I–II) that was not provoked by palpation or mandibular movements. They had moderate to severe depression (according to RDC/TMD evaluation), and non-specific physical symptoms. Limitations in daily activities involving TMJ and orofacial function were reported. No clicking or articular crepitus were found. A neurological origin of their disturbances was excluded.

Patients with mixed dysfunctions, and patients with neck disorders, were not considered eligible for the analysis. Only patients which had at least one molar contact for each hemi-arch, either on natural teeth or on fixed prostheses, and without parodontal disorders were included in the study.

A control group of 32 subjects (7 men, 25 women, aged 19–69 years) was also assessed. They were patients attending a private dental practice who received a surface EMG examination either as a part of a global assessment of their stomatognathic function, or at the end of a prosthetic reconstruction. These subjects had no parodontal problems, no craniofacial trauma and surgery, no temporomandibular and craniocervical disorders, and no previous or current orthodontic treatment. Their EMG data (see below) were all within normal reference values (Ferrario et al., 2006a).

All patients gave their informed consent to all the clinical and EMG procedures that were a part of the treatment currently offered. The study protocol was approved by the local ethic committee.

3. Experimental protocol

Surface EMG of the masseter and temporalis anterior muscles were measured in all patients, who were allowed to familiarize with the experimental apparatus and procedures before actual data collection (Ferrario et al., 2006a, b). EMG data collection was made by experimenters who were blind to the patient group, and only numerical sex codes were used (F01 was the first woman entering the study, M01 was the first man, etc.).

The experimental protocol comprised a standardization recording and a maximum voluntary clenching (MVC). The same instrumentation and EMG tests detailed in previous studies were used (Ferrario et al., 2006a, b). In brief, the left and right masseter and temporalis anterior muscles were examined, with disposable pre-gelled silver/silver chloride bipolar surface electrodes (diameter 10 mm, interelectrode distance 21 ± 1 mm) (Duo-Trode; Myo-Tronics Inc., Seattle, WA, USA) positioned on the muscular bellies parallel to muscular fibers (temporalis anterior: vertically along the anterior muscular margin, about on the coronal suture; masseter: parallel to muscular fibers, with the upper pole of the electrode at the intersection between the tragus-labial commissura and the exocanthion-gonion lines). A disposable reference electrode was applied to the forehead.

During all recordings, the patients sat with their head unsupported and were asked to maintain a natural erect position. They were invited to clench as hard as possible.

EMG activity was recorded using a computerized instrument (Freely, De Götzen srl; Legnano, Italy). The analog EMG signal was amplified (gain 150, bandwidth 0–10 kHz, peak-to-peak input range 0–2000 μV) using a differential amplifier with a high common mode rejection ratio (CMRR = 105 dB in the range 0–60 Hz, input impedance 10 GΩ), digitized (12-bit resolution, 2230 Hz A/D sampling frequency), and digitally filtered (high-pass filter set at 30 Hz, low-pass filter set at 400 Hz, band-stop for common 50–60 Hz noise). The signals were averaged over 25 ms, with muscle activity assessed as the root mean square (rms) of the amplitude (unit: μV). EMG signals were recorded for further analysis.

3.1. MVC standardization recording

This recording provides reference EMG values for the subsequent normalization (Ferrario et al., 2006a, b). Two 10-mm-thick cotton rolls were positioned on the mandibular second premolar/first molars of each patient, and a 5-s MVC was recorded. For each of the four analyzed muscles, the mean EMG potential (rms of the amplitude) was set at 100%, and all EMG potentials obtained during MVC directly performed on the occlusal surfaces (see below) were expressed as a percentage of this value (unit: $\mu V/\mu V \times 100$).

3.2. MVC in intercuspal position

The patient was invited to clench as hard as possible with the maxillary and mandibular teeth in maximum contact (intercuspal position), and to maintain the same level of contraction for 5 s. For each patient, the 3 s with the most constant rms EMG signal were then automatically selected by the EMG software, and the EMG potential was normalized as detailed before (EMG amplitude on occlusal surfaces divided by the mean EMG amplitude of the normalization record on the cotton rolls). The test was repeated three times, and the obtained values were averaged. Clenching did not provoke additional muscular/TMJ pain in both conditions (MVC on cotton rolls/ occlusal surfaces).

3.3. EMG variables

All the analyzed variables (standardized muscular activity, POC and TC) had already been found to well discriminate among TMD patients, patients with neck disorders, and control subjects (Ferrario et al., 2006b).

The mean (left and right masseter and temporalis) total muscle activities were computed as the areas of the standardized EMG potentials (normalized rms amplitude) over time (unit: μV/μV s %) (Ferrario et al., 2006a, b).

The EMG waves of paired muscles were compared by computing a percentage overlapping coefficient (POC, unit: %). POC is an index of the symmetric distribution of the muscular activity as determined by occlusion (Ferrario et al., 2006a, b). The index ranges between 0%

(no symmetry) and 100% (perfect symmetry). Masseter and temporalis POCs were obtained for each subject.

Because an unbalanced contractile activity of contralateral masseter and temporalis muscles, for instance, right temporalis and left masseter, might give rise to a potential lateral displacing component, the Torque coefficient (TC, unit %) was calculated by superimposing the right temporalis plus left masseter normalized EMG amplitudes over the left temporalis plus right masseter normalized EMG amplitudes (Ferrario et al., 2006a, b): the area of superimposition was assessed as a percentage of the total EMG amplitudes. TC ranges between 0% (complete presence of lateral displacing force) and 100% (no lateral displacing force).

Reproducibility of surface EMG measurements was tested by repeated analyses of seven subjects chosen at random (Ferrario et al., 2006a). For all EMG variables, the intraclass correlation coefficients were larger than 0.63, showing a good accuracy of the measurements, without random errors (paired Student's *t*-test, $p>0.05$).

3.4. Statistical analysis

Descriptive statistics were computed for all variables within diagnostic group. Mean values were compared by repeated measures analyses of variance, and analyses of covariance, with age used as a covariate; post hoc tests (Tukey's honestly significant difference) were made for significant differences. Categorical variables were compared by Chi-square tests. The level of significance was set at 5% for all statistical analyses.

4. Results

The sex distribution between the four groups (three patient groups and the control group; Table 1) was not significantly different ($\chi^2 = 1.69$, 3 degrees of freedom, $p>0.05$). Age was significantly different among the 4 groups (one-way analysis of variance, $p = 0.003$); the psycogenous patients were significantly older than the myogenous (post hoc test, $p = 0.013$) and arthrogenous ($p<0.001$) patients and control subjects ($p = 0.001$).

Considering the age differences, EMG indices were compared by analysis of covariance with age as covariate. Significant inter-group differences were found for temporalis muscle POC ($p = 0.041$). Overall, the control subjects had a larger symmetry in their temporalis muscles than the TMD patients (Fig. 1). Among the patients, the largest symmetry was found in the myogenous group, followed by the arthrogenous (significantly different from the normal subjects, $p = 0.022$). The lowest value in temporalis symmetry was observed in the psycogenous patients, that were significantly different from both the myogenous patients ($p = 0.049$), and the normal subjects ($p = 0.007$).

The normal subjects had the largest standardized muscular activity during MVC, followed by the myogenous and arthrogenous patients; the lowest value was found in the psycogenous patients (Fig. 1). The differences were statistically significant ($p<0.001$, analysis of covariance); the post hoc tests found significant *p*-values between the psycogenous patients and each of the other three groups ($p = 0.023$ vs. the myogenous patients; $p = 0.047$ vs. the arthrogenous patients;

Table 1
Surface EMG indices in 103 TMD patients and 32 normal controls

	Unit	TMD patients			Normal controls	Comparisons *p*-value
		Myogenous	Arthrogenous	Psycogenous		
Total	N	25	61	17	32	
Men	N	3	8	2	7	NS
Women	N	22	53	15	25	
Age	Y	42.4	39.2	55.1	39.3	0.003
		14.3	15.6	10.6	20.2	
POC masseter	%	83.6	83.3	81.7	82.2	NS
		7.6	8.0	9.3	10.9	
POC temporalis	%	84.9	82.7	80.5	86.3	0.025
		5.8	7.1	12.0	3.8	
TC	%	88.6	89.5	88.5	88.3	NS
		5.3	4.5	5.7	6.9	
Activity standardized	μV/μV s %	117.6	105.3	88.7	131.7	0.002
		35.7	27.7	18.0	64.2	

All values are mean and standard deviation.
POC: percentage overlapping coefficient (index of left-right muscular symmetry). TC: torque coefficient (potential lateral displacing component).
Comparisons were made by analyses of variance (age), covariance (for all other variables, age as covariate), or by Chi-square tests (sex distribution).
NS: not significant ($p>0.05$).

Please cite this article as: Tartaglia GM, et al. Masticatory muscle activity during maximum voluntary clench in different research diagnostic criteria for temporomandibular disorders (RDC/TMD) groups. Manual Therapy (2007), doi:10.1016/j.math.2007.05.011

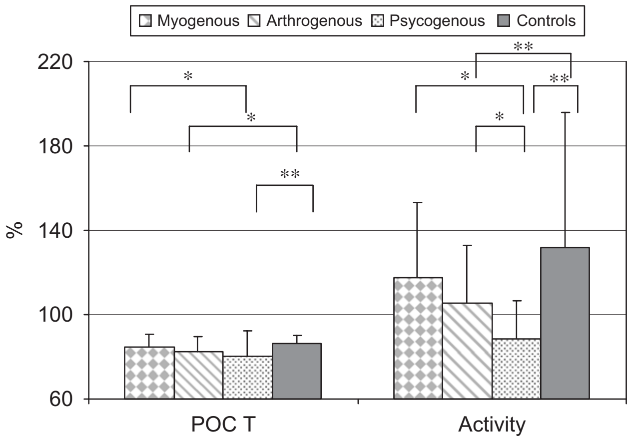

Fig. 1. Activity standardized and temporalis muscle POC indices in myogenous, arthrogenous, and psycogenous TMD patients, and control subjects (mean + 1S.D.). $^{*}p<0.05$; $^{**}p<0.01$ (analysis of covariance, Tukey's HSD).

$p<0.001$ vs. the normal subjects). Furthermore, the arthrogenous patients were significantly different from the normal subjects ($p = 0.003$).

The POC index of the masseter muscle and the torque coefficient did not differ between groups ($p>0.05$ at the analysis of covariance).

5. Discussion

Surface EMG of masticatory muscles is currently a part of patient assessment in dentistry (Ferrario et al., 2006a), providing quantitative data on the function of superficial muscles with minimal discomfort to the patient and without invasive or dangerous procedures.

Indeed, EMG is not universally considered a useful tool for TMD diagnosis (Dworkin and LeResche, 1992; Klasser and Okeson, 2006): if well-standardized methods were not used, the problems in EMG reliability and validity hinder its clinical validity (De Luca, 1997). For instance, technical artifacts (instrumental noise); differences due to facial type, age, sex, thickness of subcutaneous fat (Dworkin and LeResche, 1992; Klasser and Okeson, 2006); cross talk from different muscles. Therefore, a correct EMG assessment should be performed only with standardized (normalized) potentials, thus removing most of biological and technical noise (Castroflorio et al., 2005). In standardization recording, dental contact effect was excluded by making the subjects clench on two cotton rolls positioned on mandibular molars (Ferrario et al., 2006a).

When well-standardized protocols are used, surface EMG of the head muscles has been reported to be an effective method for the functional assessment of the stomatognathic apparatus (Farella et al., 2003; Garcia-Morales et al., 2003; Ciuffolo et al., 2005), with a good repeatability (Kogawa et al., 2006; Ferrario et al., 2006a). Also, standardized EMG indices recorded in MVC had already been used as a diagnostic test to differentiate between patients with TMD and neck disorders (Ferrario et al., 2006b).

In the present study, the quantitative EMG characteristics of the masticatory muscles of TMD patients during standardized teeth clenching were found (1) to differ from those recorded in healthy control subjects without TMJ alterations, and (2) to allow a differentiation among different diagnostic categories defined according to the RDC/TMD.

Three categories of TMD patients without mixed dysfunctions and neck disorders were analyzed; two of them were individualized according to RCD/TMD axis I, while the last one comprised patients who did not fall into any axis I diagnosis but presented prevalent symptoms and signs of RDC/TMD axis II (Dworkin and LeResche, 1992).

The male:female ratio of the current study was approximately 1 man to 6–7 women. Indeed, TMD is more frequently found in women than in men (Ferrario et al., 2002). Nevertheless, the sex distribution between the four groups (three patient groups and the control group) did not significantly differ. Age was significantly different between groups (psycogenous patients significantly older than the single other patient subgroups and control subjects); the effect was statistically controlled using an analysis of covariance. Previous investigations found no significant effects of sex on normalized EMG indices (Ferrario et al., 2006a, b); when the effect of age was ruled out, Ferrario et al. (2006b) found that the differences in EMG indices remained highly significant between TMD patients and patients with neck pain.

Overall, during teeth clenching, normal subjects had the largest standardized muscular activity and the largest symmetry in their temporalis muscles. Myogenous patients were similar to the control subjects in both muscular activity and symmetry, while arthrogenous and psycogenous patients had significantly smaller values. Myogenous and arthrogenous patients were not subdivided into diagnostic subgroups; indeed the EMG indices were somewhat more homogenous in the patient groups than in the control subjects. The only exception was temporalis POC.

The EMG indices were chosen among those that, in a previous study, significantly discriminated between patients with TMD and neck disorders (Ferrario et al., 2006b), but in the current experiment, only two of them gave significant differences. In the previous study, only a mean POC (masseter plus temporalis) was available, while, in the current study, both indices were calculated. Apparently, in differentiating among different diagnostic RDC/TMD categories, the temporalis muscle asymmetry is more useful than the masseter muscle asymmetry. The lack of significant differences in TC

Please cite this article as: Tartaglia GM, et al. Masticatory muscle activity during maximum voluntary clench in different research diagnostic criteria for temporomandibular disorders (RDC/TMD) groups. Manual Therapy (2007), doi:10.1016/j.math.2007.05.011

may arise from its somewhat reduced value in the present reference subjects, who were all dental patients. In contrast, the normal subjects analyzed by Ferrario et al. (2006b) all had healthy occlusal conditions.

Previous investigations found that the masticatory muscles of symptomatic TMD patients were less efficient and become more easily fatigued when compared to those of healthy subjects (Sato et al., 1998; Pinho et al., 2000). Overall, the contraction of masticatory muscles elicited reduced electric potentials (Visser et al., 1995; Sato et al., 1998; Suvinen et al., 2003), the masticatory efficiency was lessened, and the maximum bite force was significantly reduced (Sato et al., 1999; Kogawa et al., 2006). In the current study, bite force was not measured, but EMG activity during MVC may be considered as a useful approximation (van Kampen et al., 2002), pointing to a reduced muscular force in two patient groups of three.

Apparently, in no previous investigation, the objective characteristics of masticatory muscles were compared among subgroups of patients categorized according to the RDC/TMD.

Previous studies based on questionnaires found limited differences among subgroups of TMD patients classified according to RDC/TMD axis I (Kino et al., 2005). The objective and quantitative evaluation of muscle function provided by EMG allows to circumvent some limitations of questionnaires based on self-report (Kino et al., 2005). Also, in the current study both diagnostic axes of RDC/TMD method were used for patient classification (Dworkin and LeResche, 1992). Indeed, the use of physical characteristics only (Schmitter et al., 2005; Manfredini et al., 2006) does not consider the effect that pain produces on the psychological status of the patient (Michelotti et al., 1998; John et al., 2003; Kino et al., 2005).

In both arthrogenous and psycogenous patients, a significant reduction in the standardized muscular activity was found. In particular, in psycogenous patients, MVC on cotton rolls (the standardization recording) was made with significantly larger EMG potentials than MVC in intercuspal position. Therefore, psycogenous patients had a functionally unstable occlusion (Liu et al., 1999). Clenching on the cotton rolls reduced the proprioceptive inputs from this unstable occlusion, and allowed the patients to contract more efficiently their masticatory muscles. Even if the actual role of occlusion in the development of signs and symptoms in patients with TMD is still controversial, in some patients altered occlusal conditions may be a factor in triggering abnormal muscular activity (Ferrario et al., 2002).

EMG indices could not differentiate between normal subjects and myogenous TMD patients. In myogenous patients, the proprioceptive inputs generated when the occlusal surfaces came into contact (MVC in intercuspal position) did not modify the EMG activity of masseter and temporalis muscles relative to the standardization recording (MVC on cotton rolls).

In conclusion, surface EMG of masticatory muscles allowed a fast and simple assessment of the functional and dysfunctional characteristics of the analyzed TMD patients, permitting an objective discrimination among different non-overlapping RDC/TMD subgroups. This evaluation could assist conventional clinical assessments. Nevertheless, the analyzed individuals represent a convenience sample, and the extrapolation of the present results to a wider population, as well as to different TMD diagnostic groups, should be done with caution.

References

Alcantara J, Plaugher G, Klemp DD, Salem C. Chiropractic care of a patient with temporomandibular disorder and atlas subluxation. Journal of Manipulative and Physiological Therapeutics 2002;25:63–70.

Castroflorio T, Farina D, Bottin A, Piancino MG, Bracco P, Merletti R. Surface EMG of jaw elevator muscles: effect of electrode location and inter-electrode distance. Journal of Oral Rehabilitation 2005;32:411–7.

Ciuffolo F, Manzoli L, Ferritto AL, Tecco S, D'Attilio M, Festa F. Surface electromyographic response of the neck muscles to maximal voluntary clenching of the teeth. Journal of Oral Rehabilitation 2005;32:79–84.

De Luca CJ. The use of surface electromyography in biomechanics. Journal of Applied Biomechanics 1997;13:135–63.

Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. Journal of Craniomandibular Disorders: Facial & Oral Pain 1992;6:301–55.

Farella M, Bakke M, Michelotti A, Rapuano A, Martina R. Masseter thickness, endurance and exercise-induced pain in subjects with different vertical craniofacial morphology. European Journal of Oral Sciences 2003;111:183–8.

Ferrario VF, Sforza C, Tartaglia GM, Dellavia C. Immediate effect of a stabilization splint on masticatory muscle activity in temporomandibular disorder patients. Journal of Oral Rehabilitation 2002;29:810–5.

Ferrario VF, Tartaglia GM, Galletta A, Grassi GP, Sforza C. The influence of occlusion on jaw and neck muscle activity: a surface EMG study in healthy young adults. Journal of Oral Rehabilitation 2006a;33:341–8.

Ferrario VF, Tartaglia GM, Luraghi FE, Sforza C. The use of surface electromyography as a tool in differentiating temporomandibular disorders from neck disorders. Manual Therapy 2006b. Available online 12 September 2006b, doi:10.1016/j.math.2006.07.013.

Garcia-Morales P, Buschang PH, Throckmorton GS, English JD. Maximum bite force, muscle efficiency and mechanical advantage in children with vertical growth patterns. European Journal of Orthodontics 2003;25:265–72.

Gross AR, Haines T, Thomson MA, Goldsmith C, McIntosh J. Diagnostic tests for temporomandibular disorders: an assessment of the methodologic quality of research reviews. Manual Therapy 1996;1:250–7.

John MT, Miglioretti DL, LeResche L, Von Korff M, Critchlow CW. Widespread pain as a risk factor for dysfunctional temporomandibular disorder pain. Pain 2003;102:257–63.

Kino K, Sugisaki M, Haketa T, Amemori Y, Ishikawa T, Shibuya T, et al. The comparison between pains, difficulties in function, and associating factors of patients in subtypes of temporomandibular disorders. Journal of Oral Rehabilitation 2005;32:315–25.

Klasser GD, Okeson JP. The clinical usefulness of surface electromyography in the diagnosis and treatment of temporomandibular disorders. Journal of the American Dental Association 2006; 137:763–71.

Kogawa EM, Calderon PS, Lauris JRP, Araujo CRP, Conti PCR. Evaluation of maximal bite force in temporomandibular disorders patients. Journal of Oral Rehabilitation 2006;33:559–65.

Landulpho AB, E Silva WAB, E Silva FA, Vitti M. Electromyographic evaluation of masseter and anterior temporalis muscles in patients with temporomandibular disorders following interocclusal appliance treatment. Journal of Oral Rehabilitation 2004;31:95–8.

Liu ZJ, Yamagata K, Kasahara Y, Ito G. Electromyographic examination of jaw muscles in relation to symptoms and occlusion of patients with temporomandibular joint disorders. Journal of Oral Rehabilitation 1999;26:33–47.

Manfredini D, Chiappe G, Bosco M. Research diagnostic criteria for temporomandibular disorders (RDC/TMD) axis I diagnoses in an Italian patient population. Journal of Oral Rehabilitation 2006; 33:551–8.

Michelotti A, Martina R, Russo M, Romeo R. Personality characteristics of temporomandibular disorder patients using M.M.P.I. Cranio: The Journal of Craniomandibular Practice 1998;16:119–25.

Pinho JC, Caldas FM, Mora MJ, Santana-Penin U. Electromyographic activity in patients with temporomandibular disorders. Journal of Oral Rehabilitation 2000;27:985–90.

Sato S, Ohta M, Goto S, Kawamura H, Motegi K. Electromyography during chewing movement in patients with anterior disc displacement of the temporomandibular joint. International Journal of Oral and Maxillofacial Surgery 1998;27:274–7.

Sato S, Ohta M, Sawatari M, Kawamura H, Motegi K. Occlusal contact area, occlusal pressure, bite force, and masticatory efficiency in patients with anterior disc displacement of the temporomandibular joint. Journal of Oral Rehabilitation 1999; 26:906–11.

Schmitter M, Ohlmann B, John MT, Hirsch C, Rammelsberg P. Research diagnostic criteria for temporomandibular disorders: a calibration and reliability study. Cranio: The Journal of Craniomandibular Practice 2005;23:212–8.

Suvinen TI, Reade PC, Kononen M, Kemppainen P. Vertical jaw separation and masseter muscle electromyographic activity: a comparative study between asymptomatic controls & patients with temporomandibular pain & dysfunction. Journal of Oral Rehabilitation 2003;30:765–72.

van Kampen FMC, van der Bilt A, Cune MS, Bosman F. The influence of various attachment types in mandibular implant-retained overdentures on maximum bite force and EMG. Journal of Dental Research 2002;81:170–3.

Visser A, Kroon GW, Naeije M, Hansson TL. EMG differences between weak and strong myogenous CMD patients and healthy controls. Journal of Oral Rehabilitation 1995;22:429–34.

Please cite this article as: Tartaglia GM, et al. Masticatory muscle activity during maximum voluntary clench in different research diagnostic criteria for temporomandibular disorders (RDC/TMD) groups. Manual Therapy (2007), doi:10.1016/j.math.2007.05.011