Surface electromyography and magnetic resonance imaging of the masticatory muscles in patients with arthrogenous temporomandibular disorders

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Objective. The purpose of this study was to verify the characteristics of surface electromyography (sEMG) of masticatory muscles in patients with temporomandibular disorders (TMDs) with differing pathology.

Study Design. A total of 24 patients with TMDs were categorized according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD); magnetic resonance imaging (MRI) classified the patients as having disk displacement alone (DD) (mean age, 22 years; SD, 5; 3 men, 6 women) or having osteoarthrosis with or without disk displacement (OA) (mean age, 37 years; SD, 10; 4 men, 11 women); sEMG was performed according to a standardized protocol.

Results. The MRI score was significantly correlated to the torque coefficient ($r = 0.57$) and the temporalis ($r = 0.85$) and masseter ($r = 0.46$) muscle standardized symmetry. The discriminating ability of participant age and sEMG scores in separating the 2 groups was assessed by receiver operating characteristic analysis. Each of the sEMG scores showed a significant ability in discriminating between osteoarthrosis and disk displacement.

Conclusions. The recording of the masticatory muscle function through sEMG can be a first diagnostic approach to patients with TMDs, reserving MRI assessment to selected cases. (Oral Surg Oral Med Oral Pathol Oral Radiol 2014;118:248-256)

Temporomandibular disorders (TMDs) are among the most studied chronic orofacial pain conditions. Dwor-kin et al.1,2 and Suvinen et al.3 estimate that 7% of the general population are in need of treatment. In their systematic review, Dahlström and Carlsson1 underline the effect of this pathology on the oral health–related quality of life (OHRQoL). The 12 studies that fulfilled the inclusion criteria of their review found a negative effect on the quality of life in patients diagnosed with a TMD. Despite the epidemiologic prevalence of TMDs in women,5,6 no sex differences in the clinical aspects of the disease were reported. A muscular diagnosis of TMD, arthralgia, or disk displacement without reduction was associated with a more important effect on OHRQoL than was disk displacement with reduction. The studies selected in that review found that OHRQoL is influenced principally by pain and not by functional limitation of the jaw. This aspect accords with the findings reported by Greenspan et al.7 in a large case-control study: patients with TMDs are more sensitive to many experimental noxious stimuli at extracranial body sites than are control persons.

An accurate anamnesis and a clinical examination supplemented with imaging are considered the gold standard for the diagnosis of a pathology not yet completely understood.8-11 To establish uniform assessment criteria, in 1992 Dworkin and LeResche2 introduced the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD). This system has 2 assessment components. Axis I, a clinical and radiographic assessment, is designed to differentiate myofascial pain, disk displacement, and arthralgia, arthritis, and arthrosis. Axis II evaluates psychologic status and pain-related disability.

Statement of Clinical Relevance

The capacity of surface electromyography z score to discriminate between patients with TMDs with different pathologies indicates surface electromyography of the masticatory muscle function and dysfunction as a first diagnostic approach to patients with TMDs. Magnetic resonance imaging assessment could be reserved for selected cases.
Some authors discussed the relation between RDC/TMD and image findings provided by magnetic resonance imaging (MRI). Galhardo et al. reported that the use in clinical practice of RDC/TMD is limited because of the high rate of false-positive results. Robinson de Senna et al. assert that the type of dysfunction and the severity of alterations on the imaging examinations were not related to the severity of pain or the mandibular range of motion assessed with RDC/TMD. In a recent review, Koh et al. reported that there is no evidence of correlation between clinical findings and MRI. Park et al. suggested the use of MRI when clinical examinations cannot predict the true position of the disk. Other investigators state that the presence of skeletal changes is a sign of progression of disease, because it occurs in the joints with advanced internal derangement and it is associated with the duration of the symptoms.

MRI provides information concerning joint morphology and inflammation that cannot be discerned through clinical examination, but it has major limitations because of the high operating costs. MRI requires highly qualified technical staff, long times of image acquisition, and expensive medical equipment. Different protocols have been developed to objectively record the dysfunction present and to supplement the diagnosis of TMD, such as surface electromyography (sEMG). sEMG analyses the masticatory muscle activity through an objective and quantitative record. Tartaglia et al. used the quantitative sEMG characteristics of the masticatory muscles of patients with TMDs to allow a differentiation among different diagnostic categories defined according to the RDC/TMD. In particular, it was possible to differentiate between healthy control participants and patients with impairments of arthrogenous and psychogenic origin, in whom a significant reduction in the standardized muscular activity was found. More recently, De Felício et al. found significant correlations among sEMG findings, orofacial myofunctional status, and TMD severity, showing that the larger deviations from sEMG reference values were found in the patients with the worse clinical findings.

Apparently, in no previous investigations were the objective characteristics of masticatory muscles compared among subgroups of patients categorized according to the MRI interpretation. In the present study, a group of patients with TMDs were categorized according to both RDC/TMD and MRI as patients with disk displacement or those with osteoarthrosis with or without disk displacement. The quantitative sEMG characteristics of their masticatory muscles were analyzed. We wanted to see if patients in the different groups had some objective differences in the sEMG characteristics of their masticatory muscles during standardized teeth clenching. Patient data were also compared with those collected in 2 control groups without muscular or temporomandibular joint (TMJ) alterations.

**MATERIALS AND METHODS**

**Patients**

In 2010, a total of 100 patients with pain in the preauricular area, movement limitation, and joint sounds during the functional excursions of the jaw were referred to the Dental Clinic of the University of Brescia for TMJ treatment. All participants were visited by a dentist, and their clinical history was gathered according to the Research Diagnostic Criteria for TMD (RDC/TMD). Among the patients, those who presented arthrogenous TMD according to the RDC/TMD, axis I, groups II and III, were selected to undergo bilateral high-resolution MRI scans of the TMJs and an sEMG analysis of their masticatory muscles. All patients had a long-lasting TMD (duration of symptoms longer than 6 months).

Additional inclusion criteria were pain to one or both joints during mastication (greater than 4 on a visual analog scale in which 1 = no pain and 10 = the greatest possible pain), limitation during opening (maximal nonforced opening <30 mm) or during left and right excursion or protrusion (<7 mm), and at least 1 molar maxillary-mandibular contact per dental hemiarch. Exclusion criteria were the presence of congenital craniofacial anomalies, systemic disease, or both; dental pain; periodontal problems; craniofacial and cervical trauma and therapy; unilateral or bilateral posterior edentulism; and current orthodontic treatment.

According to the inclusion and exclusion criteria, 24 patients were selected (17 women and 7 men; age range, 14-60 years; mean age, 31 years; SD, 11). According to the MRI examination protocol (described later), the patients were subdivided into group A (15 patients, 11 women and 4 men; age range, 26-60 years; mean age, 37; SD, 10), patients with osteoarthrosis (Figure 1), and group B (9 patients, 6 women and 3 men; age range, 14-29 years; mean age, 22; SD, 5), patients with damage limited to the soft tissues (unilateral or bilateral disk dislocation) (Figure 2).

Group A was significantly older than group B, so we recruited 2 different control groups: a “young” control group (CB) (19 participants, 9 men and 10 women; age range, 20-35 years; mean age, 23 years; SD, 2) and an “old” control group (CA) (19 participants, 5 men and 14 women; age range, 26-71 years; mean age, 37 years; SD, 12). All control participants were submitted to clinical evaluation according to the RDC/TMD and to sEMG examination. They were all healthy, with no
history of any musculoskeletal problems, and were selected for the study according to the following inclusion criteria: no multiple-teeth prostheses; up to 3 single-tooth prostheses on natural teeth; a minimum of 14 occluding pairs of teeth; bilateral molar and canine Angle Class I occlusion; no periodontal problems; no craniofacial or cervical trauma or surgery; no TMDs; and no current orthodontic treatment.

All participants gave their informed consent to all the clinical, MRI, and EMG procedures that were a part of the treatment offered. Consent was also obtained from the parents or legal guardians of the patients younger than 18 years. The study protocol was approved by the local ethics committee. All procedures were noninvasive, were not dangerous, and did not provoke pain or discomfort in the participants, who were free to stop their examinations at any moment. All procedures were conducted according to the Helsinki Declaration.

**Experimental protocol**

For all patients, MRI and sEMG analyses were performed on the same day.

*Magnetic resonance imaging.* MRI scans were performed on a 1.5-T MR unit (Magnetom SP 4000; Siemens, Erlangen, Germany). Parasagittal (perpendicular to the long axis of the mandibular condyles) and coronal 3-mm slice views, with the mouth held in the closed, partially open, and open positions with a mouth prop, were obtained. For all patients, the scanning parameters were as follows: 2D-Flash Sequence, 35°; time of repetition, 400 milliseconds; time of echo, 12 milliseconds; matrix, 256 × 256; and number of excitations, 4.

The MRI images were independently assessed by 2 radiologists for condylar-fossa morphology, disk displacement, and presence of joint effusion. If their evaluations differed, the images were rechecked by the 2 radiologists together, and only those findings on which both radiologists concurred were recorded.
Condylar bone changes were categorized as osteophyte formation and bone marrow edema; soft tissue morphology allowed for categorization of the joints as having normal disk position, anterior disk displacement with reduction, anterior disk displacement without reduction, and thinning, cracking, or warping disk.\textsuperscript{16,18}

For each patient, MRI scores were calculated for both joints; 1 point was given for anterior disk displacement with reduction, 1 other point for fluid joint effusion, 2 points for anterior disk displacement without reduction, 3 points for osteophyte formation, and 5 points for thinning, cracking, or warping disk. The values were doubled in the presence of bone marrow edema.\textsuperscript{16,18,25}

No information from the MRI interpretation was available to the dentist who performed the EMG assessment.

\textit{EMG recordings.} In all patients and control participants, sEMG of the right and left masseter and anterior temporal muscles was performed during maximum voluntary teeth clenching (MVC).\textsuperscript{21,26} Two sets of tests were performed in all participants: a standardization recording (clench on cotton rolls) and a test recording (clench in intercuspal position).\textsuperscript{27} sEMG was performed by an operator who was blind to the TMJ diagnosis. Numerical codes were used, and group assessment was made only at the end of data collection.

To standardize the EMG potentials of the analyzed muscles with tooth contact, two 10-mm-thick cotton rolls were positioned on the mandibular second premolars and first molars of each participant, and a 5-second MVC was recorded. The EMG activity was subsequently recorded during an MVC in intercuspal position. For both recordings, the participant was invited to clench as hard as possible, and to maintain the same level of contraction for 5 seconds; during test performance, the participants were verbally encouraged to perform at their best. All participants repeated the MVC test 3 times. The tests were explained and shown to the participants, who practiced before the data acquisition occurred. For all tests, the participants sat with the head unsupported and were asked to maintain a natural erect position. To avoid any effect from fatigue, a rest period of at least 3 minutes was allowed between each test. In all patients, clenching did not provoke additional muscular/articular pain in both conditions (MVC on cotton rolls or on occlusal surfaces).

Disposable, pre-gelled, silver/silver chloride bipolar surface electrodes (diameter, 10 mm; interelectrode distance, 21 \pm 1 mm) were positioned according to the recommendations of SENIAM (Surface EMG for Non-Invasive Assessment of Muscles).\textsuperscript{28} In brief, the electrodes were fixed on the skin in positions corresponding to the muscular bellies parallel to muscular fibers: for the anterior temporal muscle, vertically along the anterior margin of the muscle (about on the coronal suture); for the masseter, parallel to the muscular fibers, with the upper pole of the electrode at the intersection between the tragus-labial commissure and the ectocanthion-gonion lines. A disposable reference electrode was applied to the forehead.

EMG activity was recorded using a computerized instrument (Freely, de Götzen sr; Legnano, Milano, Italy). The analog EMG signal was amplified (gain 150, peak-to-peak input range from 0 to 2000 \( \mu \text{V} \)) using a differential amplifier with a high common mode rejection ratio (105 dB in the range of 0-60 Hz; input impedance, 10 G\( \Omega \)), digitized (12-b 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). Using the EMA software (de Götzen sr), the signals were averaged over 25 milliseconds, with muscle activity assessed as the root mean square (RMS) of the amplitude (unit, \( \mu \text{V} \)). EMG signals were recorded for further analysis.

\textit{EMG data analysis.} For all tests, the 3-second period with the most constant RMS EMG signal was automatically selected by the software and used for all subsequent analyses, which were automatically performed by the software. For each participant, the EMG potentials of the analyzed muscles recorded during the MVC tests were expressed as a percentage of the mean potential recorded during the standardization test (MVC on the cotton rolls)\textsuperscript{29} (unit, \( \mu \text{V}/\mu \text{V} \times 100 \)). All subsequent calculations were made with the standardized potentials. For each participant, the values obtained in the 3 MVC tests were averaged.

A set of standardized EMG indices were computed.\textsuperscript{29} To assess muscle symmetry, within each participant the EMG waves of paired muscles (right and left, masseter and temporalis) were compared by computing a percentage overlapping coefficient (POC) (unit, \%). POC is an index of the symmetric distribution of muscular activity as determined by occlusion; it ranges between 0% and 100%: when 2 paired muscles contract with perfect symmetry, a POC of 100% is obtained.

Because an unbalanced contractile activity of contralateral temporalis and masseter muscles (for instance, left masseter and right temporalis) might give rise to a potential lateral displacing component, the torque coefficient (TC) (unit, \%) was calculated. This index ranges between 0% (complete presence of lateral displacing force) and 100% (no lateral displacing force).\textsuperscript{29}

To individuate the most prevalent pair of masticatory muscles, the activity index (Ac) (unit, \%) was computed as the percentage ratio of the difference between the mean temporalis and masseter standardized potentials and the sum of the same standardized potentials.\textsuperscript{21,26} Ac is positive (up to 100%) when the
masseter muscle standardized potentials are greater than those of the temporalis muscles, negative (up to –100%) when the temporalis muscle potentials are larger, and null when they are equal. The mean (masseter and temporalis) total standardized muscle activities (unit, μV/μV·s × 100 [%]) were computed as the integrated areas of the EMG potentials over time.29 Reproducibility of sEMG measurements was tested both within the same session and after 6 months, finding no systematic differences and limited random errors.20

Statistical analysis. Descriptive statistics (mean and SD) of all variables (gender, age, EMG indices, and MRI score) were computed for each group (A, patients with osteoarthrosis; B, patients with damage limited to the soft tissues; CA and CB, control participants). Differences in the distributions of gender were assessed by the χ² test. A value of P < .05 was considered as statistically significant.

Each EMG variable was standardized against the values obtained in the healthy control participants by calculating absolute (signless) Z scores (patient value minus mean reference value divided by the SD of the reference group).27 The association of the standardized EMG variables with the MRI score was evaluated through scatter plots and correlation coefficients, namely, the Pearson linear correlation coefficient r and the Spearman monotone correlation coefficient ρ. Because no substantial deviation from linearity emerged, only Pearson coefficients were reported.

The discriminating ability of participant age and Z scores in separating group A and group B was assessed by receiver operating characteristic (ROC) analysis for both single and multiple variables. For the latter case, diagnostic indices (one for each EMG variable) were obtained by multiple logistic regression models in which age and Z scores were included as independent variables. The area under the ROC curve (AUROC) and its 95% CI were calculated by the DeLong method.30

A further aim was to evaluate the discriminating ability of EMG variables accounting for age. To this end, the differences between the AUROC of age and AUROCs of the aforementioned diagnostic indices were assessed by Z tests and by CIs obtained through bootstrap resampling methods (nonparametric, with 2000 bootstrap samples for each estimate).30 All analyses were carried out with R software (R Core Team).31

RESULTS
Table I shows the distribution of gender, age, sEMG, and MRI data of the analyzed patients and control participants. The distribution of gender among the 4 groups (2 patient groups and 2 control groups) was not significantly different (χ² = 2.378; df = 3; P = .498).

EMG data in the patient groups were standardized using the control group data, and Z scores were calculated. Concerning the association of age and Z scores of the EMG indices with the MRI score, the correlation coefficient was quite high for POC temporalis (r = 0.85; 95% CI, 0.69-0.93) and moderately high for TC (r = 0.57; 95% CI, 0.21-0.79) and POC masseter (r = 0.46; 95% CI, 0.07-0.73), whereas for age and the other Z scores the coefficient was not significant at the level of 5% (Table II and Figure 3).

Each of the Z scores showed a significant, moderately high ability in discriminating between osteoarthrosis (group A) and damaged soft tissues (group B), with AUROCs ranging from 0.73 to 0.79 (Table III, part A). Participant age showed a high discriminating ability with an AUROC of 0.91. However, according to the CIs of the estimated AUROC values, there is no evidence to state that the discriminating ability of age is different with respect to EMG variables.

The subsequent analyses yielded better AUROC values for the diagnostic indices including age and each EMG variable (see Table III, part A). Therefore, the additional diagnostic contribution of EMG variables accounting for the effect of age was assessed by a statistical testing procedure. In a first step the difference was assessed by asymptotic Z tests, which yielded no statistical evidence of an increment of discriminating performance. Given the limitations due to the sample size, a less formal assessment was also performed through the bootstrap estimation approach. The results reported in Table III, part B, show that standardized TC may have a significant contribution to the diagnosis after accounting for age: its CI does not include 0.

DISCUSSION
The diagnosis of a TMD is usually performed by clinical investigation combined with imaging techniques. MRI of the TMJ has been indicated as the gold standard in diagnosis because it offers accurate information about joint morphology and alterations. The need for imaging (MRI and computed tomography) is still controversial because of high operating costs, thus leaving a key role to clinical assessments and history taking.15 Conversely, some authors12,33 reported that TMJ abnormalities cannot be reliably assessed by clinical examination only. The current scientific guidelines suggest that practitioners should image only if there is a reasonable expectation that additional information will influence a patient’s treatment approach.34

To support the clinical findings with some quantitative functional data, different protocols have been developed to objectively record the dysfunction. In particular, sEMG analysis of the masticatory muscles is currently a part of patient assessment in dentistry.29
This method provides quantitative data on the function of superficial muscles without invasive or dangerous procedures and without discomfort to the patient. As a matter of fact, sEMG is not universally considered a useful tool for TMD diagnosis; if well-standardized methods were not used, the problems in EMG reliability and validity hinder its clinical validity. Among the major problems are technical artifacts (instrumental noise) and differences due to facial type, age, sex, thickness of subcutaneous fat, and cross talk from different muscles. Therefore, a correct EMG assessment should be performed only with standardized (normalized) potentials, thus removing most biologic and technical noise.

When well-standardized protocols are used, sEMG of the head (masticatory) muscles has been reported to be an effective method for the functional assessment of the stomatognathic system, with a good repeatability to unravel some aspects of jaw elevator muscle functioning. In the present study, the standardization recording was obtained without dental contact by making the participants clench on 2 cotton rolls positioned on mandibular molars. Standardized EMG indices recorded in MVC had already been used as a diagnostic test to differentiate between patients with TMDs and those with neck disorders, among different nonoverlapping RDC/TMD subgroups, and between patients with long-lasting TMDs and healthy participants.

De Felício et al. discriminated patients with TMDs from healthy women through clinical and instrumental examinations. The authors found that the Orofacial Myofunctional Evaluation using Scores protocol, together with a sEMG assessment of masticatory muscles, provides information about the components and functions of the stomatognathic system.

The detection of the relationships between the various diagnostic tools is one of the fundamental steps for the assessment of their validity and clinical performance. For this reason, we investigated the relationship between MRI assessment and sEMG analysis, which has been apparently neglected in the scientific literature so far. In the present study, healthy participants and patients with TMDs (with the latter categorized as patients with osteoarthrosis and those with damage limited to the soft tissues) were submitted to sEMG, and the quantitative characteristics of their masticatory muscles were analyzed.

MRI characteristics allowed a clear differentiation between the 2 groups, which also had significant differences in their sEMG alterations relative to healthy control participants matched for age and sex. Additionally, sEMG variables allowed discrimination between the 2 patient groups as defined by MRI examination. For this reason, the objective recording of the masticatory muscle function and dysfunction through sEMG can be a first diagnostic approach to patients with TMDs. Standardized sEMG is noninvasive, is low-cost, and can be performed in the dental office, without the necessity of sending the patient to a specialized diagnostic center.

The male-to-female ratio of the present study was approximately 1 man to 2 or 3 women. Indeed, TMDs are more frequently found in women than in men. Nevertheless, the sex distribution did not significantly differ between the 2 patient groups. Previous studies have suggested that TMDs are more frequent in women than in men. The male-to-female ratio of the present study was 1:2 or 1:3, which is in agreement with this observation.

Table I. Descriptive statistics of the analyzed patients and control participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group A</th>
<th>Mean ± SD</th>
<th>Group B</th>
<th>Mean ± SD</th>
<th>Group CB</th>
<th>Mean ± SD</th>
<th>Group CA</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>15</td>
<td>N</td>
<td>9</td>
<td>N</td>
<td>19</td>
<td>N</td>
<td>19</td>
<td>N</td>
</tr>
<tr>
<td>Men</td>
<td>4</td>
<td>N</td>
<td>3</td>
<td>N</td>
<td>9</td>
<td>N</td>
<td>5</td>
<td>N</td>
</tr>
<tr>
<td>Women</td>
<td>11</td>
<td>N</td>
<td>6</td>
<td>N</td>
<td>10</td>
<td>N</td>
<td>14</td>
<td>N</td>
</tr>
<tr>
<td>Age (y)</td>
<td>37</td>
<td>10</td>
<td>22</td>
<td>5</td>
<td>23</td>
<td>2</td>
<td>37</td>
<td>12.0</td>
</tr>
<tr>
<td>POC masseter (%)</td>
<td>79.5</td>
<td>12.0</td>
<td>85.8</td>
<td>4.3</td>
<td>84.3</td>
<td>3.8</td>
<td>86.7</td>
<td>1.9</td>
</tr>
<tr>
<td>POC temporalis (%)</td>
<td>73.5</td>
<td>14.9</td>
<td>86.4</td>
<td>5.9</td>
<td>85.0</td>
<td>2.8</td>
<td>86.7</td>
<td>2.2</td>
</tr>
<tr>
<td>TC</td>
<td>87.4</td>
<td>5.4</td>
<td>90.5</td>
<td>3.3</td>
<td>89.2</td>
<td>1.9</td>
<td>90.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Activity index (%)</td>
<td>1.3</td>
<td>23.4</td>
<td>–2.6</td>
<td>9.5</td>
<td>–6.3</td>
<td>12.6</td>
<td>–3.2</td>
<td>4.7</td>
</tr>
<tr>
<td>Activity standardized μV/μV·s, %</td>
<td>112.9</td>
<td>58.2</td>
<td>103.2</td>
<td>11.9</td>
<td>109.5</td>
<td>36</td>
<td>104.1</td>
<td>29.6</td>
</tr>
<tr>
<td>MRI score N</td>
<td>8.53</td>
<td>4.20</td>
<td>2.22</td>
<td>0.97</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

MRI, magnetic resonance imaging; POC, percentage overlapping coefficient; TC, torque coefficient.

Table II. Correlation with MRI score

<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation coefficient: r</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.37</td>
<td>–0.04, 0.67</td>
<td>0.7374</td>
</tr>
<tr>
<td>POC masseter</td>
<td>0.46</td>
<td>0.07, 0.73</td>
<td>0.02483</td>
</tr>
<tr>
<td>POC temporalis</td>
<td>0.85</td>
<td>0.69, 0.93</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>TC</td>
<td>0.57</td>
<td>0.21, 0.79</td>
<td>0.003729</td>
</tr>
<tr>
<td>Activity index</td>
<td>0.04</td>
<td>–0.37, 0.43</td>
<td>.8615</td>
</tr>
<tr>
<td>Activity standardized μV/μV·s</td>
<td>0.03</td>
<td>–0.38, 0.43</td>
<td>.8849</td>
</tr>
</tbody>
</table>

MRI, magnetic resonance imaging; POC, percentage overlapping coefficient; TC, torque coefficient.
investigations found no significant effects of sex on normalized EMG indices\textsuperscript{29} when the effect of age was ruled out. Age was significantly different between groups (patients with osteoarthrosis were significantly older than patients with damage limited to the soft tissues and control participants); the effect was statistically controlled using $z$ scores computed from control groups of comparable age. The age differences between patients with osteoarthrosis and patients with damage limited to the soft tissues can be explained with the clinical findings of TMDs. Condylar and eminence bone changes may reflect the details of the progression of TMJ osteoarthrosis, which occurs predominantly in joints with advanced internal derangement.\textsuperscript{17}

The present study had some limitations. First, the small sample of patients with TMDs reflected the difficulty in finding participants with chronic TMJ degeneration who met the inclusion and exclusion

Fig. 3. Receiver operating characteristic curves for differentiating patients with osteoarthrosis and patients with disk dislocation. The reported curves correspond to the variables: participant age (A); $z$ scores combined with age; percentage overlapping coefficient for masseter (B); percentage overlapping coefficient for temporalis (C); torque coefficient (D); activity (E); and impact (F). \textit{(AUROC}, area under the receiver operating characteristic curve.)

Table III. ROC analysis of age and standardized EMG variables ($z$ scores)

<table>
<thead>
<tr>
<th></th>
<th>Part A</th>
<th>Part B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Discriminant performance</td>
<td>Difference between AUROC of composite diagnostic scores</td>
</tr>
<tr>
<td></td>
<td>$z$ scores combined with age, AUROC (95% CI)</td>
<td>$z$ test</td>
</tr>
<tr>
<td>Age</td>
<td>0.91 (0.81, 1.00)</td>
<td>-0.03</td>
</tr>
<tr>
<td>POC masseter</td>
<td>0.73 (0.52, 0.95)</td>
<td>-0.04</td>
</tr>
<tr>
<td>POC temporalis</td>
<td>0.79 (0.60, 0.98)</td>
<td>-0.07</td>
</tr>
<tr>
<td>TC</td>
<td>0.78 (0.58, 0.97)</td>
<td>-0.01</td>
</tr>
<tr>
<td>Activity index</td>
<td>0.75 (0.55, 0.95)</td>
<td>-0.03</td>
</tr>
<tr>
<td>Activity standardized</td>
<td>0.73 (0.54, 0.92)</td>
<td>-0.03</td>
</tr>
</tbody>
</table>

\textit{ROC}, receiver operating characteristic; \textit{EMG}, electromyography; \textit{AUROC}, area under the receiver operating characteristic curve; \textit{POC}, percentage overlapping coefficient; \textit{TC}, torque coefficient.
criteria. Second, MRI was not performed in the participants of the control groups; we recruited the healthy participants following standardized clinical protocols. Indeed, Tasaki et al.34 reported a range of asymptomatic internal derangements in up to 33% of TMJs, but these numbers are probably connected with an incorrect interpretation of MRI.34 On the other hand, we believe that it is not ethically acceptable to expend resources on expensive instrumental examinations if it is not strictly necessary.34

The present data suggest that sEMG in controlled protocols can be an important diagnostic tool in patients with TMDs, providing additional information that cannot be obtained by clinical assessment and history. Indeed, notwithstanding a significant mean age difference between the 2 groups, there is some overlap between them. For instance, 4 patients of group A (27% of the analyzed patients) had an age (20, 26, 26, and 27 years) well included in the range of group B. A diagnostic classification based only on age would not include these participants in the arthrosis group, and this is ethically not acceptable. In perspective, TMJ arthrosis in a young person is a pathology with high costs in terms of both OHRQoL and money.45,46 An early diagnosis could reduce the gravity of the problems, providing a more conservative therapy with generally a good patient response.47 An anterior disk displacement is in fact an intracapsular dysfunction that leads to degenerative changes in the disk and joint surfaces.25,48 The exclusive use of clinical criteria to detect these participants is also problematic, because pain in the TMJ and mandibular area is better tolerated by younger than by older patients,6 and it could indicate different types of diseases.12

The EMG assessment enabled classification of the gravity of the pathology, guiding the clinician on the opportunity to prescribe new diagnostic examinations or different therapeutic approaches.

CONCLUSION
The results of the present investigation support the importance of clinical and instrumental examinations of the stomatognathic system; all of them provide useful information for diagnosis. The use of sEMG may be proposed for a first screening of patients with TMDs, submitting to MRI only those who have the largest discrepancies from the reference values. Furthermore, understanding how evaluation methods are related is an important step toward a better diagnosis and more effective treatment planning.

REFERENCES


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