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Normalizing surface electromyographic measures of the masticatory muscles: Comparison of two different methods for clinical purpose

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ABSTRACT

Purpose: To compare a new normalization technique (wax pad, WAX) with the currently utilized cotton roll (COT) method in surface electromyography (sEMG) of the masticatory muscles.
Methods: sEMG of the masseter and anterior temporalis muscles of 23 subjects was recorded while performing two repetitions of 5 s maximum voluntary clenches (MVC) on COT and WAX. For each task, the mean value of sEMG amplitude and its coefficient of variation were calculated, and the differences between the two repetitions computed. The standard error of measurement (SEM) was calculated. For each subject and muscle, the COT-to-WAX maximum activity increment was computed. Participant preference between tasks was also recorded.
Results: WAX MVC tasks had larger maximum EMG amplitude than COT MVC tasks ($P < 0.001$), with COT-to-WAX maximum amplitude increments of 61% (temporalis) and 94% (masseter) ($P = 0.006$). WAX MVC had better test-retest repeatability than COT. For both MVC modalities, the mean amplitude ($P > 0.391$) and its coefficient of variation were unchanged ($P > 0.180$). The WAX task was the more comfortable for 18/23 subjects ($P = 0.007$).
Conclusion: WAX normalization ensures the same stability level of maximum EMG amplitude as COT normalization, but it is more repeatable, elicits larger maximum muscular contraction, and is felt to be more comfortable by subjects.

1. Introduction

Surface electromyographic (EMG) analysis of the masticatory muscles has been introduced in dentistry for both research and clinical practice. Its clinical usefulness has encountered both positive (Aldana et al., 2011; Hugger et al., 2012; Santana-Mora et al., 2014) and negative findings (Al-Saleh et al., 2012; Klasser and Okeson, 2006; Manfredini et al., 2013; Suvinen et al., 2009). In particular, to investigate the relationship between dental occlusion and neuromuscular balance of the stomatognathic system, several protocols have been proposed and used, without obtaining a shared consensus between researchers and clinicians. Nevertheless, we believe that EMG, when correctly used, represents a unique technique to investigate the neuromuscular function of the stomatognathic system in a non-invasive, low-cost and easy-to-use way. However, this simplicity hides well-known problems inherent in the clinical interpretation of the instrumental results (Manfredini et al., 2013), that can be open to excessive and inadequate clinical speculations and lead to inaccurate conclusions (De Luca, 1997). For instance, raw EMG potentials are vulnerable to several muscular and extra-muscular factors that may alter and distort the actual myoelectric signal. Electrode placement, skin impedance, subcutaneous fat distribution, muscle-fiber type and size, and muscular cross-talk can all influence the measured EMG activity amplitude (Castroflorio et al., 2005; Lehman, 2002). The non-homogeneity of these factors between both homologous (contralateral) and ipsilateral muscles makes the clinical speculations on activity level and asymmetry/asynergy unreliable when the raw potentials are used.

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Therefore, to reduce the "extra-myoelectric noise", and allow for more reliable comparisons between intra-individual EMG amplitude and inter-subject muscular activation pattern, the raw EMG potentials have to be standardized (normalized) (Ferrario et al., 2000). In the past years, several research groups, including the authors, have performed masticatory muscle EMG analysis by normalizing EMG amplitude values to those recorded during maximum voluntary teeth clench (MVC) while two cotton rolls (COT) are bilaterally interposed between the second mandibular premolars and first molars (Botelho et al., 2011; Ferrario et al., 2006). This standardization task eliminates the influence of dental contacts on the muscular contraction, especially the anterior contacts, and enables maximum and steady temporalis and masseter muscle contractions.

Currently, the COT normalization protocol is the most used and has been recently adopted by several research groups to assess function and coordination of masticatory muscles in various investigation fields: temporomandibular disorders (TMD) (De Felício et al., 2013; Manfredini et al., 2013; Tartaglia et al., 2011), sleep bruxism (Lucas Bde et al., 2014), oral rehabilitation (Tartaglia et al., 2008), maxillofacial surgery (Dellavia et al., 2007; Ko et al., 2013). However, the clinical authors' experience shows that the patient's perceptions while performing this task are not always completely comfortable, mainly due to the texture of the industrial cotton and patient intolerance. Besides, although the rolls prevent ordinary dental contact influences, they cause the occlusal pressure to be constrained to the teeth where they are inserted. In this case it is possible to activate a proprioceptive inhibition of muscular contraction (from teeth, periodontium, TMJ, etc.) that would cause a misinterpretation of the EMG analysis. It has to be mentioned that the level of muscle recruitment also depends on the distance of the cotton rolls from the joint fulcrum, which varies the lever arm and torque. Moreover, in patients who lack any teeth in the region where the cotton rolls are placed, it is impossible to apply the standardization protocol correctly. These drawbacks are a critical problem for this normalization technique, since any uncertainty of the validity of the reference values of a patient's EMG amplitude can lead to inaccuracy and unreliability of the subsequent calculations of his/her functional standardized parameters.

For these reasons, we tested a new device to be used in substitution of the cotton rolls for the EMG standardization task: an arch-shaped wax pad. We hypothesized that its texture and shape would overcome the drawbacks of cotton rolls, leading to better MVC performances. The participants' subjective comfort perception and the quantitative EMG parameters of maximum activity, stability and repeatability of the masticatory muscles contraction were measured as performance factors and compared between the two normalization techniques.

2. Material and methods

2.1. Participants selection

Twenty-three Caucasian volunteers (12 men, 11 women; mean age 37.6 years, SD 10.8, age range 15–61) were selected from the staff (5 subjects) and the patients (18 subjects) attending the TMD and Orofacial Pain unit at SST Dental Clinic (Segrate, Italy). The subjects underwent a complete non-invasive EMG protocol test (Forrester et al., 2010, 2011) to record their neuromuscular balance status. Study Inclusion Criteria were moderate-good general health status without severe signs and symptoms of TMD, myalgia and arthralgia (Diagnostic Criteria for Temporomandibular Disorders, DC/TMD) (Schiffman et al., 2014).

The participants were also in good oral health and presented:

1. At least 26 teeth or implant-supported single teeth (excluding the third molars)
2. DMFT index $\leqslant 50$
3. Tooth mobility Modified Miller index $\leqslant 1$
4. No dental treatment during the preceding two months period
5. No history of bruxism
6. No history of TMD treatments within a year.

A clinical functional evaluation of occlusion was performed. Any Angle class or malocclusion were allowed; in particular, 11 participants had Angle II or III class occlusion relationships, 4 patients showed one or two dental losses (except the third molars), 5 patients had accentuated over-bite or over-jet, 1 had cross-bite.

The participants (and the parents of the underage participants) were informed about the procedures, and agreed to take part in the investigation by signing a written informed consent. The principles were in accordance with Helsinki declaration and Italian law. The Institutional Review Board (IRB02-2015 Doc. MQ 03 AL 02 AGM) approved all the procedures.

2.2. EMG recordings and instrumentation

The masseter and anterior temporalis muscles of both sides (left and right) were examined. EMG activity was recorded using a wireless EMG system (FreeEMG, BTS SpA, Garbagnate Milanese, Italy), with light probes (weight, 5 g) clipped to the electrodes. Disposable bipolar Ag/AgCl surface pre-gelled electrodes (10 mm diameter; inter-electrode distance, 21 ± 1 mm; Myo-tronics Inc., Seattle, USA) were placed on the skin along the main direction of the muscular fibers, detected by palpation during subject's MVC, according to a standardized protocol (Ferrario et al., 2000). Before electrode placement, the skin was scrubbed with an alcohol soaked gauze pad; men had to be clean-shaven. Each participant was comfortably sitting on a dental chair with a 15°-extended backrest and with his/her head in a natural erect position. The electrodes were positioned at the beginning of the experimental session, and all tasks were performed without any modification of the electrodes or of their position.

Using manufacturer's software, the analog EMG signal was amplified and digitized (gain 150, resolution 16 bit, sensitivity 1 μV, temporal resolution 1 ms) using a differential amplifier with a high common mode rejection ratio (CMRR > 110 dB in the range 0–50 Hz, input impedance > 10 GΩ). All the recorded EMG signals were digitally band-pass filtered (range, 30–400 Hz) with a 2nd order Butterworth filter, cleaned from power line interferences, and rectified by calculating the root mean square (RMS) in adjacent temporal windows of 25 ms.

To the complete EMG protocol routinely used in our clinic, composed of two repetitions of MVC in intercuspal position and two repetitions of MVC on cotton rolls (COT), two repetitions of MVC on wax pad (WAX) were added. Then, for the purpose of this investigation, only COT and WAX tasks were taken into account.

- COT task: 5 s-MVC while two 10 mm-thick cylindrical cotton rolls (Roeko Luna #2, Coltene, Whaledent, Germany) were positioned on the mandibular second premolars/first molars of each subject.
- WAX task: 5 s-MVC while an arch-shaped 2 mm-thick wax pad (Pre-shaped pink wax, Henry Schein-Krugg, Buccinasco, Italy) was inserted between the two dental arches (Fig. 1).

The order of the tests was randomly planned among the investigated subjects, who were not aware of the actual aim of the