Effect of tens on the activation pattern of the masticatory muscles in TMD patients

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Abstract
Temporomandibular disorder (TMD) is characterized by several signs and symptoms, such as pain and changes in the activation pattern of the masticatory muscles. Thus, the objective of this study was to evaluate the effect of transcutaneous electrical nerve stimulation (TENS) of the electromyographic pattern of the masticatory muscles in individuals with myogenic TMD. This study evaluated 40 female volunteers: 20 with myogenic TMD (x=23.04 ± 3.5) and 20 normal individuals (x=23.3 ± 3). TENS (conventional mode, 150Hz) was applied once to each group for 45 minutes. The electromyographic (EMG) signal (gain of 100 times and 1KHz sampling frequency) and visual analogue scale (VAS) were applied before and immediately after TENS application. The VAS data were analyzed using paired t-test. The EMG signals were analyzed using the normalized linear envelopes. The results showed that individuals with TMD have an alteration in the activation pattern of the masticatory muscles, when compared to the control group, and the TENS reversed this pattern. TENS reduced the pain intensity in the TDM group. We conclude that a single TENS application is effective in pain reduction and promotes betterments in the activation pattern of the masticatory muscles in individuals with TMD.

Key Words:
temporomandibular disorders, electromyography, masticatory muscles, transcutaneous electrical nerve stimulation, pain.

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Introduction
It seems to be well defined in the literature that individuals with temporomandibular disorder (TMD) may present alterations in the electromyographic (EMG) activity. When compared the values of asymptomatic individuals, the patients’ myoelectric activation is increased even when they keep their jaw in a resting position\(^{1,2}\), whereas a lower level of activation was found during the clenching\(^{3,4}\). Moller et al.\(^5\) and Stohler et al.\(^6\) also report that, in mastication, individuals with TMD present activity in jaw-closing muscles (masseter and temporal muscles) during the opening phase, when they should be relaxed.

The alteration in the muscular activity and the consequences for the movements are frequently signs found in individuals with TMD and it is believed that such condition is related to pain, which is the most frequent symptom reported by these patients.

The application of different therapeutic procedures, such as the occlusal splint, the orthodontic treatment, biofeedback sessions\(^7\), the classic massage\(^8\), and the application of the transcutaneous electrical stimulation\(^2\) proved to be able to modify the electromyographical activity of the masticatory muscles.

Frequently used in the clinical physiotherapeutic practice for the relief of chronic and acute pains, the transcutaneous electrical nerve stimulation (TENS) application was attributed to the promotion of analgesia, the reduction of the electromyographic activity during rest\(^2\), and the increase of the electromyographical activity during the clenching\(^3\) in individuals with TMD. However, the effect of TENS on the activation pattern of masticatory muscles has still not been reported. Thus, the objective of the present study was to evaluate the effect of TENS in the pattern of masticatory muscles activation in individuals with TMD in its myogenic form.

Material and Methods
Forty female volunteers participated in this study: twenty myogenic TMD individuals, aged 19 to 33, (23.04 ± 3.5 years) and twenty clinically normal individuals aged 19 to 31 (23.3 ± 3 years). In the TMD group the volunteers presented: 1. temporal and masseter muscles pain during functional activities for at least one year and at most five years; 2. occlusal parafunction (clenching and/or grinding) for at least one year; 3. pain and/or muscular fatigue at waking up; 4. no functional limitation.

The control group included individuals with no occlusal parafunction, no joint trauma, no joint and/or muscular pain during functional activities, no muscular fatigue and/or pain at waking up. Patients with dental loss, systemic disease which could affect TMJ or cervical joints, e. g. rheumatoid arthritis, osteoarthritis, osteoporosis, diabetes, and those taking analgesic, myorelaxants, or anti-inflammatory drugs were excluded because such drugs could influence the results.

The volunteers were selected following a functional evaluation (personal data, anamnesis, background facts, visual inspection, muscular palpation, and functional exam), and dental evaluation, considering oral and dental conditions. All volunteers signed the formal participation term submitted to and approved by the Human Research Ethics Committee at the Dentistry School of Piracicaba - FOP/UNICAMP.

Surface EMG was recorded from the anterior temporal and masseter muscles using surface differential electrodes of silver bars 10mm apart, 10mm long, 2mm wide, gain of 100 times, input impedance of 10GΩ and common mode of rejection ratio - CMRR of 130dB (Lynx Electronics Ltd., São Paulo, SP, Brazil). The EMG signals were analogically amplified with gain of 100 times, filtered (10-509Hz band-pass Butterworth, second order filter) and sampled by 12 bits A/D covert board (model CAD 12/46 - Lynx Electronics Ltd., São Paulo, SP, Brazil) with a 1KHz frequency. The signals were digitally band-pass filtered (10-500Hz).

The differential electrodes were placed over both masseter and anterior temporal muscles; the position was determined by muscle palpation. A rectangular stainless steel electrode (3x4cm) was also used as a reference electrode to reduce noise acquisition, fixed on the right wrist of the volunteer. The volunteers remained comfortably seated on a chair with their bodies lined up and their backs at rest (Frankfurt plan parallel to the ground) eyes open, and arms resting on inferior limbs.

The EMG signal was captured before and after the electrostimulation during non-habitual masticatory activity controlled by a metronome, having placed Parafilm “M” (Chicago, IL) between occlusal face of the premolar teeth, the first and the second upper and lower molar, bilaterally. Before taking the electromyographic data recordings, training was given to volunteers. An adequate verbal command instructed individuals to touch the teeth for 5 seconds every time they heard the sound of the metronome. The same command was given for the masticatory signal for 15 seconds. Before the removal of surface EMG electrodes, marks were drawn on the volunteers’ skin to indicate where to replace them after the electrical stimulation.

TENS was delivery by transcutaneous electrical stimulator (model Dualpex 961 - Quark Medical Products, Piracicaba, SP, Brazil) of the two channels and four circular self-adhesive percutaneous electrodes measuring 42mm (ValuTrode Fallbrook, Califôrnia, U.S.A.). TENS was applied using: frequency of 150Hz; pulse width of 20µs; intensity (mA) exclusively set at subject sensorial threshold; modulation up to 50% of variation frequency; quadratic biphasic symmetrical pulse, and length of application 45 minutes.

The volunteers were stimulated in dorsal decubitus,
adequately positioned with a roll under the knees. The percutaneous electrodes of electrical stimulation were placed on the masseter and on the anterior portion of the temporal muscle bilaterally. The channels were distributed so that one channel would stimulate the masseter and the other, the temporal, due to their morphological differences and distinct intensity quantities for a given limit of the electrical excitability. After the period of application of the electrical stimulation, recording electrodes were repositioned and the EMG signal was recorded as described in the previous protocol. Pain evaluation was done using a visual analogue scale (VAS), which was applied before and immediately after electrical stimulation in both studied groups through different recording forms so that individuals could not observe what they had written before the application. The intensity of pain was reported to values in centimeters, measured from the beginning of the scale (no pain) to the point established by the volunteer. These data showed regular distribution and were compared using paired t-test, at 5% significance level for the values before and after the electrical stimulation application only for TMD group. The value obtained in the scale for the control group was zero, that is, they did not present pain before or after the application.

Data analysis:
The intensity of pain was assessed using the visual analogue scale in centimeters, measured from the beginning of the scale (no pain) to the point established by the volunteer. These data showed regular distribution and were compared by paired t-test, with a 5% significance level for the values before and after the electrical stimulation application only for the TMD group. The value obtained from the control was zero, i.e., they did not present pain before or after the application.

The muscular activation pattern of three masticatory cycles recorded between the fifth and the ninth recording seconds was obtained through the straightening and smoothing of the rough electromyographic signal with movable 250-ms windows and normalization by the electromyographic amplitude average of the straightened line. The construction of normalized linear envelopes was done by the MATLAB - The language of technical computing (Version 5.0 by The MathWorks Inc.) program, which was adapted for the analysis of the obtained recordings. The program presents a continuous black curve which represents the average line of the volunteers, curves above and below this line represent the pattern deviation.

Results

Pain intensity
The obtained results of the analog visual scale applied before and immediately after the TENS application (Table 1), showed that the applied resource promoted a significant (p=0.001) pain relief in the TMD group. Pain in the region of muscles temporal and masseter.

<table>
<thead>
<tr>
<th></th>
<th>Before TENS</th>
<th>After TENS</th>
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<tbody>
<tr>
<td>Pain intensity</td>
<td>5.75±1.41</td>
<td>1.32±1.05 *</td>
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Table 1. Mean values and standard deviation of the VAS in TMD group (n=20) before and after TENS application. Values in cm.

Normalized linear envelope and activation pattern
Observing the normalized linear envelope of the right masseter and right temporal muscles of the control group (Fig.1,2), we can notice that there is no EMG activity of the jaw-closing muscles during the opening phase of the jaw – interval indicated by the arrow – when the jaw-opening muscles are active. The same pattern was observed for the left masseter and the left temporal muscle of the control group before the application of TENS. In the TMD group, before the application of TENS, we can observe that the right masseter and right temporal muscles present EMG activity during the opening phase of the jaw – interval indicated by the arrow (Fig.3,4). The same pattern is observed for all the muscles evaluated in this group before TENS. After the application of electrical stimulation, we can observe that the jaw-closing muscles presented an activation pattern similar to the one presented by the control group (Fig. 5 and 6), i.e., there is no EMG activity in the jaw-closing muscles when the jaw is opening – interval indicated by the arrow. This was observed in all the muscles studied.

Fig. 1: Linear envelope normalized by average of the rectified EMG signal, recorded at the right masseter of the control group before the application of TENS (n=20).
Fig. 2: Linear envelope normalized by average of the rectified EMG signal, recorded at the right temporal muscles of the control group before the application of TENS (n=20).

Fig. 3: Linear envelope normalized by average of the rectified EMG signal, recorded at the right masseter muscles of the TMD group before the application of TENS (n=20).

Fig. 4: Linear envelope normalized by average of the rectified EMG signal, recorded at the right temporal muscles of the TMD group before the application of TENS (n=20).

Fig. 5: Linear envelope normalized by average of the rectified EMG signal, recorded at the right masseter muscles of the TMD group after the application of TENS (n=20).

Fig. 6: Linear envelope normalized by average of the rectified EMG signal, recorded at the right temporal muscles of the TMD group after the application of TENS (n=20).

Discussion
The results of this study show that in TMD individual the right and left masseter muscles and temporal muscles present EMG activity in the opening phase of the jaw. This myoelectric disorders was previously described by Moller et al.5 and Stohler et al.6.

After TENS application the experimental group the reported significant pain reduction. Furthermore, reduction in the electrical activity was detected in the jaw-closing muscles during the opening phase.

Other authors have also demonstrated that the electromyographic record of the masticatory muscles of TMD patients show alterations, such as high electromyographic activity in the jaw at resting position1-2,8, slow masticatory pace9 and decrease in the activity of elevator muscles in their isometric contraction1-4.
These changes were described by quantitative analyses of the electromyography and two theories are employed to justify them. The first is based on the hypothesis of the existence of a vicious cycle in which the pain results in a protective muscular spasm, observed in the electromyogram as a hyperactivity of the masticatory muscles, which, in turn, causes pain to increase, maintaining the cycle of events. The presence of a protective muscular spasm would justify the reported findings by Berzin, Rodrigues, and Kamysek of activity at a resting position as well as the presence of activity in the jaw-closing muscles in the opening phase of the masticatory cycle that was found in the present study. However, the reduction of the electromyographic activity in the clenching reported by Cram and Engström and Dahlström could not be directly related to this theory once, at maximum contraction, pain should increase the electromyographic activity recorded.

The other theory makes an attempt at explaining these alterations of the muscular activity due to chronic musculoskeletal pain and was proposed by Lund et al. A theory called “pain adaptation model” says that pain in the TMJ, masticatory muscles, and teeth should be able to influence the activation of agonist and antagonist muscles of a determined movement of the jaw.

Thus, pain would modulate the response of excitatory and inhibitory neurons of the motor activity. This influence would result in an activation of antagonist muscles through the stimulation of excitatory neurons, and of agonist muscles through inhibitory neurons. In short, during opening of the jaw, the suprathyoid and the lateral pterygoid muscles would have their activation reduced, whereas the jaw-closing muscles (temporal, masseter, and medial pterygoid muscles) would be active and working antagonically to movement.

This hypothesis would also explain the reduction in the activity of the jaw-closing muscles in the clenching observed in TMD patients. The activity of the jaw-opening muscles still remains to be further investigated in order to corroborate with the “pain adaptation model” proposed by Lund et al.

In the same way, to test this model and to consolidate the results obtained in the present study, the recordings of the jaw-opening muscles must be done in experimental protocols of future studies.

The change in the motor pattern, present in TMD patients is believed to be related to a sensorial-motor integration involving central and peripheral aspects of the nervous system. It is known that motor neuron alpha (α) of the masticatory muscles is situated at the motor nucleus of the trigeminal nerve and receives 10,000 synaptic terminations, both excitatory and inhibitory. These synapses are the end to paths from several structures of the central nervous system, such as the reticular formation.

Reticular formation is a especially interesting structure in this consideration because it can be influenced by chemical stimuli, central commands, and sensorial afference among which are fibers A-delta and C, which are conductors of nociceptive pulses from peripheral areas. Thus, a nociceptive stimulation from the masticatory muscles and/or TMJ could, through the reticular formation, influence the motor neuron a activity by inhibiting or exciting them.

As to the primary effects of TENS, we can state that it was efficient in the pain relief of TMD patients, as stated by other authors for different painful musculoskeletal conditions. For the parameters chosen, high frequency and low intensity characteristics of stimulation are those which allow us to call this kind of application “conventional”. The mechanisms of pain relief with conventional TENS are known and are associated with a hyper-stimulation of primary mechanoreceptive afferent fibers of large diameter and fast conduction. They are capable of suppressing the responses of nociceptive primary afferents of small diameter in the reticular formation of the brain stem, according to the gate control theory described by Melzack and Wall.

In our experimental conditions it is not possible to state that pain relief and its consequent effects on muscular activity reported herein, have been obtained by pre-synaptic inhibition of the small-diameter afferent fibers. Salar et al. observed an increase of endorphin in the cerebrospinal fluid of painless patients who received high-frequency and low-intensity TENS, suggesting that conventional TENS can evoke pain inhibitory system mediated by the opioid system.

There must be other studies to investigate the muscular activity in the jaw-opening muscles, the length of pain relief, and the reduction of the antagonist activity of the jaw-closing muscles in the opening phase of the masticatory cycle, because TENS must not be considered the only resource of the treatment of these disorders.

The causes of TMD and its resulting pain can be due to different mechanical factors, such as adaptation shortnings provoked by occlusal alterations, postural deviations, dental loss, or yet chemicals, through the inflammatory conditions, and thorough evaluation is necessary in order to determine the resources which will make the therapy successful.

According to the results obtained in this study, we can conclude that the application of a single TENS session is effective in the relief of pain and in the reduction of the myoelectric activity of the jaw-closing muscles during the opening phase of the jaw in TMD patients. More studies should be done to observe the effects of this therapy in the jaw-opening muscles and the duration of its benefits.

References

1. Bérzin F. Estudo eletromiográfico da hiperatividade de músculos mastigatórios, em pacientes portadores de desordem crânio-


