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Surface electromyography in orthodontics – a literature review

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Electromyography is the most objective and reliable technique for evaluating muscle function and efficiency by detecting their electrical potentials. It makes it possible to assess the extent and duration of muscle activity. The main aim of surface electromyography is to detect signals from many muscle fibers in the area of the detecting surface electrodes. These signals consist of a weighted summation of the spatial and temporal activity of many motor units. Hence, the analysis of the recordings is restricted to an assessment of general muscle activity, the cooperation of different muscles, and the variability of their activity over time.

This study presents the main assumptions in the assessment of electrical muscle activity through the use of surface electromyography, along with its limitations and possibilities for further use in many areas of orthodontics. The main clinical uses of sEMG include the diagnostics and therapy of temporomandibular joint disorders, an assessment of the extent of stomatognathic system dysfunctions in subjects with malocclusion, and the monitoring of orthodontic therapies.

Key words: surface electromyography • sEMG • masticatory muscles • muscle activity

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Background

Electromyography (EMG) is the most objective and reliable technique for evaluating muscle function and efficiency by detecting their electrical potentials [1]. It makes it possible to assess the extent and duration of muscle activity. One type of EMG uses intramuscular electromyography in which a needle and fine-wire electrodes are inserted through the skin into the muscle tissue. This technique detects single motor unit potential (motor unit action potential – MUAP). Another type of EMG is surface electromyography (sEMG), which uses surface electrodes and detects superimposed motor unit action potentials from many fibers, as opposed to the single ones recorded by the intramuscular type [2]. In recent years the value of the high-density surface electromyography (HD-sEMG) has been extensively proven. In this new technique, signals are detected by the use of specially designed surface electrodes. The sensitivity and selectivity of sEMG are almost the same as those provided by the intramuscular type. It also allows for single motor unit analysis and gives information about muscle fiber conduction velocity (MFCV) [3,4].

The aim of this study was to present the main assumptions in the assessment of electrical muscle activity through the use of surface electromyography. Moreover, it is hoped that this paper will clarify the limitations and possibilities of the application of sEMG in orthodontics.

Main Assumptions in the Assessment of Electrical Muscle Activity

The main aim of surface EMG is to detect signals from many muscle fibers in the area of the detecting electrode. These signals consist of a weighted summation of the spatial and temporal activity of many MUs. Hence, the analysis of the recordings is restricted to general muscle activity, the cooperation of different muscles, and the variability of their activity over time [1]. This non-invasive and painless way of registering the results through the use of surface electrodes compensates for the aforementioned limitations, and its non-invasiveness is one of the most important advantages of this method [2].

Apart from the fact that these electrodes are not very selective, using them is limited to detecting the signals only from the muscles located close to the skin, thus masseter and anterior temporalis muscles are the most frequently evaluated. To register the activity of medial and posterior fibers of the temporalis muscles, removal of the hair is necessary, which is normally disliked by patients, and anatomical difficulties exist in the case of the pterygoid muscles.

An additional disadvantage of surface electromyography is its sensitivity to imbalances in impedance [2]. Inconsistency in impedance is the main reason for the low accuracy and precision of EMG measurements, resulting in low reproducibility.

This reproducibility is also questioned because of the different inter-electrode distances and their various locations over the muscles. Thus, the inter-electrode distance should be fixed and templates should be used to eliminate variability in electrode placement [5–7].

The most common solution to the inconsistency in impedance, which affects the reliability of sEMG, is an adequate quantitative electromyographic analysis with normalization procedures. The normalization of sEMG results consists of converting them into quotient indices. Thus, electrical activity is presented as a percentage of another high-reproducible activity of this muscle recorded under the same conditions (recordings are performed by using the same electrodes). Maximum voluntary contraction (MVC) seems to be a highly reproducible activity. The recorded electrical activities are therefore presented as a percentage of their activity in the MVC (%MVC). The main assumption of the normalization procedure is the constancy and good reproducibility of the forces generated during maximum voluntary clench [8,9].

The other possibility of the quantitative analysis is to relate the electrical activity of the muscles to the reference values obtained from the recordings performed in the submaximal voluntary contraction (subMVC). A high correlation coefficient was found between the electrical activity of the muscles and the forces generated by them in the subMVC [8].

Castroflorio et al. [6] verified these assumptions by analyzing the electrical activity of the masseter and temporalis muscles in 3 experimental sessions separated by 1 week. The subjects performed voluntary contractions at 80% MVC and occlusal forces were measured by compressive-force sensors. The reproducibility of these measurements was estimated at 71.9%. Moreover, the influence of the inter-electrode distance on the reproducibility of the EMG variables was observed. The high data reproducibility of the sEMG indices computed for 75% of the healthy subjects, estimated at a 6-month interval, was revealed by De Felicio et al. [10]. Visser et al. [11] also did not observe any statistically significant discrepancies between the activity and the asymmetry indices of both masseter and temporalis muscles estimated in healthy patients in the next 2 days (for activity index $p>0.20$, for asymmetry index $p>0.10$).

The studies described above confirm that quantitative electromyographic analysis permits a reliable and accurate assessment of the electrical activity of muscles.

Many of the most important issues related to the methodology of sEMG recordings were recently unified by a multi-national

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consensus initiative called SENIAM (Surface Electromyography for Non-Invasive Assessment of Muscles) and ISEK (The International Society of Electromyography and Kinesiology). Both of these organizations give recommendations for electrode placement, sEMG signal processing, and modelling.

The electrical activity of the masticatory muscles can be recorded and assessed during static tests (rest, maximal, or submaximal voluntary clenching) or during active tests (opening or closing the mouth, protrusion, retrusion, or lateral deviation of the mandible, mastication, swallowing, or speaking). From a biomechanical point of view, the most important are dynamic activities such as mastication and 2 ambivalent static activities such as rest and the maximal isometric contraction of the muscles.

Rest activity is usually performed at the clinical rest position, the so-called postural position. There is no isoelectric line observed in the sEMG recordings in this position determined by freeway space (2–4 mm). Moreover, the muscles are active [12]. These conclusions are supported by Suvinien et al. [13], who observed minimum muscle activity with an average opening of 15.4 mm, while postural position was determined by a 2–4 mm range of opening. Similar results, based on observations in a group of 40 subjects aged 22–34 years, were reported by Michelotti et al. [14]. The clinical rest position was determined with an average opening of 1.4 mm, and the lowest electrical activity was observed with a 7.7 mm average opening of the mouth.

The analysis of the electrical muscle activity during isometric contraction, without any shortening of the muscle's fibers, can be performed during 3 to 5 seconds of clenching the teeth with maximum force, usually in intercuspal position, or during clenching of the teeth with controls (cotton rolls positioned on the mandibular second pre-molar and molars) (subMVC) [15,16].

Ferrario et al. [15], in a study in which 30 healthy subjects with Angle class I and overbite and overjet ranging from 2 to 5 mm were examined, observed larger standardized potentials in MVC in the temporalis anterior muscle (91.1 µV/µV%) than in the masseter muscle (85.45 µV/µV%). It was noted that the potentials were standardized against the MVC carried out with cotton rolls positioned on the posterior teeth, and in this condition the temporalis anterior normally contracted with a lower intensity, which is why the standardized potential of these muscle resulted in a higher value.

It is also very important to assess the electrical activity of the muscles in the fatigue test – a continuous 10-second submaximal or maximal isometric muscle contraction. This makes it possible to evaluate the muscle fatigue that occurs because of the biomechanical processes, which determine muscles achieving the required or exerted forces. The most objective sEMG parameters used to evaluate muscle fatigue are median power frequency (MPF) and time-frequency distributions.

Lodetti et al. [17], in a study of 29 healthy patients aged 20–35 years, observed higher values of MPF in the masseter, temporalis anterior, and trapezius muscles recorded during maximal clenching of the teeth in the intercuspal position, than during clenching the teeth with controls (cotton rolls). The highest values for the mean power frequency was achieved by the temporalis muscle (157 Hz), then the masseter (140 Hz), with the lowest being the trapezius muscles (68 Hz). This was explained by greater forces exerted during clenching of the teeth by the masseter and temporalis muscles than by the trapezius muscles.

Among the dynamic activities, mastication is the one that is the most frequently analyzed. It is defined as the most important physiologic activity of the stomatognathic system. Because of the high variability of the movements that contribute to this activity, an assessment of mastication is very difficult and includes parameters such as the duration of the masticatory act, the number of cycles, and its effectiveness depending on the generated forces and the consistency of the food [18,19].

The mean values for the number of masticatory cycles recorded in healthy subjects for 15 seconds were greater for hard bolus such as paraffin wax (11.60) or an apple (11.60) compared to soft bolus such as a banana (10.60). The same was true for the mean values of the duration of the masticatory act involving the same substances. This was estimated for paraffin (498.67 ms), apple (457.33 ms), and banana (436.33 ms) [18].

To widen the quantitative electromyographic analysis to include all static and dynamic activities, electromyographic indices such as the activity index (Ac), symmetry (percentage overlapping coefficient – POC), and torque coefficient (To, Tc) should be evaluated. They make it possible to assess the activity, coordination, and symmetry of the homologous, synergistic, and antagonistic muscles. Common estimates of these indices confirm their high clinical value.

Ferrario et al. [15] confirmed symmetric muscular patterns in MVC for masseter and temporalis muscles by using recordings performed in healthy patients with no temporomandibular disorder. The percentage overlapping coefficient (POC) in MVC for the masseter and temporalis anterior was estimated at 88.06% and 89.34%, respectively. Moreover, in MVC, the torque coefficient (TC) was low – 6.36% – which indicated no laterodeviating effect on the mandible caused by unbalanced temporalis and masseter muscles of either right or left sides. This is in accordance with the results presented by De Felicio et al. [10]. In MVC, POC masseter was 87.11% and

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POC temporalis was 88.11%. TC was estimated at 8.79%. The symmetrical muscular pattern for the masseter, temporalis, and sternocleidonomastoid muscles in subjects without temporomandibular disorders was also corroborated by the EMG recordings performed in a group of 27 males and 35 females. POC in MVC for all the muscles ranged from 80.7% to 87.9%, and there were no significant differences between the groups.

Precise analysis of the electrical activity in muscles through the use of surface electromyography performed in different tests simplifies the quantitative analysis of the stomatognathic system and permits an objective assessment of the muscles.

Factors Affecting the Electrical Activity of the Masticatory Muscles

Current knowledge does not permit an explicit evaluation of the influence of sex on masticatory muscle activity. Ferrario et al. [20] did not observe any differences between the rest activity of the masseter and temporalis muscles in males and females according to the recordings obtained from 92 healthy subjects. However, differences were recorded for the maximal voluntary contraction (MVC) in the intercuspal position. The mean MVC potentials for the masseter and temporalis muscles were higher in males (181.9 µV, 216.2 µV) than in females (161.7 µV i 156.8 µV). This does not correspond with the results presented by Pinho et al. [21]. Overall, the resting activities of the masseter and temporalis muscles were higher in women (2.64 µV) than in men (1.37 µV). Just as in the previous study, for MVC, higher muscle activity was observed in females. This was estimated at 65.17 µV in females and 51.24 µV in males. Rilo et al. [22], on the basis of an assessment of 40 subjects without any signs or symptoms of temporomandibular joint dysfunctions, noticed similar activities for the masticatory muscles in both sexes during clenching and maximum opening of the mouth.

Age is a very important sociomedical factor, which should *a priori* be taken into consideration during any assessment of the activity of muscles. The 24-hour recordings of sEMG described by Ueda et al. [23] indicated a longer duration for the activity of the temporalis muscles in children and the masseter muscles in adults. The authors attributed this to the incomplete development of dentition and temporomandibular joints, as well as the immaturity of the muscles in children.

The next factor that modifies the electrical activity of muscles is the difference in the activation of the motor units during the day and night. Tabe et al. [24] and Hiyama et al. [25] confirmed the decrease in the activity of the masticatory muscles at night. This is supported by the results presented by Saifuddin et al. [26], who compared the resting activities of the muscles assessed during the day and night with the activities of the muscles during mastication in 2 registration sessions. The lowest activity for both the masseter and temporalis muscles was recorded at night.

sEMG in the Diagnosis and Treatment of TMD Patients

Temporomandibular dysfunction (TMD) is a widely comprehended term that includes disorders of the masticatory muscles and temporomandibular joints. Many theories have been presented relating to the etiology of these disorders. Some clinicians indicate occlusal disturbances, while others cite psycho-emotional factors as being the main etiological factors for TMD.

Li et al. [27] investigated the short-term impact of occlusal disturbances such as an occlusal 0.5 mm high spot that was placed on the right lower first molar. On the 3rd day following placement of these high spots, all the patients complained of headaches in the right temporal region and the activity of the right anterior temporalis muscle significantly increased at rest. Moreover, on the 3rd and 6th day with the high spot, the EMG activity of the tested muscles significantly decreased in the maximum voluntary contraction (MVC) and the asymmetry index of bilateral anterior temporalis significantly increased.

The high diagnostic value of the sEMG recordings in the diagnosis of TMD was also reaffirmed by Pinho et al. [21]. The results of their study indicated a satisfactory sensitivity in the discrimination of TMD patients on the basis of EMG muscle analysis in both static activities. The overall mean resting activity of the masticatory muscles was lower in the healthy subjects (1.92–1.20 µV) than in the TMD patients (2.52±1.25 µV). Conversely, the recordings obtained in the maximal voluntary contraction (MVC) were higher in the healthy subjects. Overall mean activity in MVC was 110.30±82.97 µV in the healthy group and 66.77±35.22 µV in the group consisting of TMD patients. Similar conclusions were presented by Tartaglia et al. [16]. Surface electromyography of the masseter and temporalis muscles was performed during maximum teeth clenching in 103 TMD patients and compared to 32 control subjects. The standardized total muscle activity was significantly higher in healthy subjects (131.7 µV/µV%) than in TMD subjects (88.7–117.6 µV/µV%). Moreover, symmetry in the temporalis muscles was larger in the control group (86.3%) than in TMD patients (80.5–84.9%).

The importance of a parameter such as muscular symmetry was also mentioned by Liu et al. [28]. EMG recordings were performed in 24 TMD symptomatic (mean age 26.7 years) and 20 normal (mean age 27.1 years) subjects. The results indicated that asymmetry of the masseter during maximal clenching (MVC) was significantly pronounced in TMD patients (30.5%)

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compared to normal subjects (19.1%). The asymmetry index of the posterior temporalis in MVC was also larger in symptomatic (30.1%) compared to healthy patients (17.4%). The asymmetry of the anterior temporalis was more pronounced in TMD patients during 70% MVC and was estimated at 28.6%, and in normal subjects it was 19.6%. The asymmetry of anterior digastricus in the mandibular rest position was also higher in the symptomatic (17.2%) compared to the asymptomatic (8.8%) group.

The validity and objectivity of the sEMG studies in distinguishing normal and TMD patients was also confirmed by Woźniak [29]. The most important in this respect were the recordings of the temporalis muscles in MVC (AUC=0.918) and changes in the mean power frequency (MPF%) of the masseter during a 10-second maximal voluntary contraction in intercuspal position (AUC=0.911).

The results of the sEMG studies presented above help identify TMD patients. Moreover, the sEMG analysis can be useful in assessing the effectiveness of treatments for these dysfunctions. Such a study was presented by Ferrario et al. [30]. sEMG recordings, which were performed to assess neuromuscular equilibrium, confirmed the immediate effect of a stabilization splint on muscle activity in TMD patients. The 2 mm-thick splint reduced the electrical activity of the masseter and temporalis muscles at rest and made the muscles more equilibrated both between the left and right side (larger symmetry in the masseter muscle, $p<0.05$) and between the temporal and masseter muscles (activity index, $p<0.01$). A similar influence of the splint was reported by Botelho et al. [31]. The sEMG recordings of 15 TMD patients after installing a splint confirmed a higher symmetry between the temporalis and masseter muscles during MVC; the symmetry index values were similar to those in the control group.

The importance of sEMG is that it is used as biofeedback as part of a safe and adverse effects-free therapy. Such a therapeutic procedure, which uses EMG instruments to measure, process, and give reinforcing information as feedback, helps patients learn how to control muscle tension levels previously under automatic control. By monitoring sEMG recordings, patients attempt to relax those muscles that are tense in TMD subjects. The importance of biofeedback was supported by Turk et al. [32]. Two studies were conducted to assess the differential efficiency of 2 commonly used TMD therapies – intraoral appliances and biofeedback (BF)—separately and in combination. Improvements to the benefits of treatment observed in the follow-up to BF therapy supported the importance of performing dental and psychological treatments for successfully helping patients with TMD.

EMG should be used for a deeper understanding of the pathologies of dysfunctional patients. It complements standard clinical assessments, providing quantitative data on the function of the stomatognathic system, with minimal discomfort to the patients and without invasive procedures. It is also a useful tool that helps to create algorithms of treatment procedures and makes it possible to monitor them.

EMG Recordings in Patients with Malocclusions

It is very difficult to accurately define the relationships between facial morphology and the function of the stomatognathic system because of the many etiological factors for malocclusions, large inter-individual variability, and the plurality of the predictors that describe dentoalveolar and morphological disorders. Hence, the main aim of the studies based on EMG recordings is to find such an association.

The influence of vertical malocclusions on the electrical activity of the muscles was described by Yousefzadeh et al. [33]. EMG recordings of the temporalis, masseter, orbicularis oris, and digastric muscles were performed in patients aged 10.1–13.2 years with an anterior open bite. The patients with malocclusions exhibited lower activity in the muscles during clenching and higher activity in the muscles of the balancing side during chewing compared with healthy subjects. Studies by Ciccone de Faria et al. [34] paid attention to the different activities of the muscles in patients with either a skeletal or dentoalveolar malocclusion. Healthy patients presented the highest electrical activity in the temporalis and masseter muscles during MVC (85.27%). Significantly lower activity was detected in subjects with a dentoalveolar anterior open bite (61.52%), and the lowest in patients with a skeletal open bite (42.13%). Moreover, patients with a skeletal malocclusion showed the lowest electrical activity in the muscles during chewing.

The aim of the study by Moreno et al. [35] was to determine the influence of sagittal malocclusion on the electrical activity of the masticatory muscles. The results obtained indicated that patients with Angle class II showed higher activity than other classes for the temporalis muscles in deglutition and chewing; subjects with class III achieved the highest activity for the temporalis and masseter muscles during MVC. The values of temporalis activity in MVC for patients with I, II, and III Angle classes were significantly different: 185.40 μV, 123.46 μV, and 226.80 μV, respectively.

A very interesting study that investigated the electrical activity of the anterior temporal (TMA) and masseter muscles (MMA) in different facial skeletal types described by the angles as ANB and SN-GoMe was presented by Cha et al. [36]. There were no significant differences in resting MMA among all groups; resting TMA was significantly higher in patients

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with class III and SN-GoMe >36°. As when at rest, TMA during MVC was also higher in the latter group.

Many studies have also determined the influence of the transversal malocclusions on the function of the masticatory muscles. Moreno et al. [35] observed that the posterior crossbite resulted in a large decrease of ipsilateral masseter activity during a maximum effort test, thus most of the force was generated by the anterior temporalis muscle. Another study showed that this malocclusion also affected mastication [37]. The percentage of reverse cycles when chewing was 59.0% (soft bolus) and 69.7% (hard bolus) for the affected side, and 16.7% (soft bolus) and 16.7% (hard bolus) for the non-affected one. Moreover, it was once more proved that masseter activity was reduced on the crossbite side and unaltered or increased on the non-affected side [37].

Slightly divergent results were presented by Tecco et al. [38]. The sEMG activity for the masseter muscles between patients with crossbite and the control group was similar, suggesting that the occlusal alteration being investigated had no predictable effect on the activity pattern of these muscles. Nevertheless, they observed a significant difference in sEMG activity for the anterior temporal muscle, which was higher at rest on the crossbite side. They also observed significantly lower activity in the sternocleidomastoid muscles during MVC in the control group compared to the group with transverse malocclusion.

Analysis of the studies presented above confirms that craniofacial morphology has a considerable influence on the electrical activity of the masticatory muscles. These studies also clarify the anatomical and physiological coincidence in the stomatognathic system. Therefore, sEMG extends the number of tools that are useful in the clinical diagnosis of sagittal, transversal, and vertical malocclusions.

sEMG in Monitoring of Orthodontic Therapies

Because of the inextricable association between function and morphology, one of the possibilities for orthodontic treatment is functional therapy. The objective of this kind of treatment is to enhance the equilibrium of the muscles and correctly balance the forces inducing the growth and the development of craniofacial skeletal features [39,40]. This justifies EMG recordings of the masticatory muscles before, during, and after orthodontic therapies in order to monitor or assess their effectiveness.

The main example of a functional removable appliance is the activator, invented by Andresen. Erdem et al. [40] evaluated the activities of the masticatory muscles in children with class II division 1 malocclusion treated with this appliance and compared to untreated control patients at the start of the therapy and 12 months later, to check the effectiveness of this functional appliance. The activity of the temporalis and masseter muscles during clenching, chewing, and swallowing increased in both groups, particularly in the treatment group. The activity of the orbicularis oris during whistling increased significantly only in the treatment group.

sEMG recordings performed in a study by Saccucci et al. [39] confirmed that the functional device employed (Occlus-o-GuideOrtho-Tain Inc., Toa Alta, Puerto Rico) also achieved the aim of this orthodontic functional therapy. The study sample consisted of thirteen 9-year-old children with class II, deep bite, and labial incompetence, and 15 children of the same age with normal occlusion. The electrical potentials of the orbicularis oris (OO) were investigated before therapy, as well as after 3 and 6 months of treatment during many functional tests. The treatment group showed significantly lower values in the muscle tone of the lower OO at rest (1.7 $mV \cdot s^{-1}$) and during protrusion of the mandible (31.9 $mV \cdot s^{-1}$) with respect to the control group (at rest 3.1 $mV \cdot s^{-1}$; protrusion of the mandible 52.1 $mV \cdot s^{-1}$). In the treated group there was a significant increase in the muscle tone of the lower OO at rest after 3 months of therapy (from 1.7 $mV \cdot s^{-1}$ to 3.5 $mV \cdot s^{-1}$). The upper OO showed a significant increase from 9.3 $mV \cdot s^{-1}$ to 28.5 $mV \cdot s^{-1}$ during protrusion of the mandible recorded between the 3rd and 6th months of treatment. Patients after treatment reached a muscular activity similar to that in the control group, where no changes in muscle tone were observed.

The EMG studies were also helpful in defining the requirements for the application time of the functional appliances. To estimate this, the activities of the muscles at different times of day and night were compared. The results of the study by Tabe et al. [24] confirmed the low effectiveness of functional therapy during the night. The activity of the masseter, temporalis, and digastric muscles with the appliance in the mouth significantly decreased at night compared to daytime. The authors recommended use of functional appliances mostly during the day in combination with voluntary biting to achieve adaptation by the masticatory muscles, due to the high electrical activity during MVC and the higher activity of the muscles during the day than the night. Similar conclusions were presented by Hiyama et al. [25]. They analyzed the nocturnal activity of the masseter and suprahyoid muscles during therapy with a functional appliance such as the bionator. There were no significant changes in the maximal EMG activities of the muscles recorded during the first 3 hours without the appliance inserted and after 3 hours with the bionator in the mouth. This supports findings of the previous study, that it is not advisable to use functional appliances during sleep to obtain the desired treatment effects.

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EMG studies were also used to monitor therapy with fixed functional appliances, such as the Herbst appliance [41,42] or its modification, the Forsus Fatigue Resistant Device (FFRD) [43].

Studies by Leung and Hägg [41] permitted an analysis of the activity of the masseter and the temporalis muscles during treatment with the Herbst appliance, and determined the optimal time for such a therapy was 6 months. Similar changes in the activity of the same masticatory muscles during gradual advancement of the mandible with the Herbst appliance were described by Du and Hägg [42]. The electrical activity increased, especially in the masseter muscles. Moreover, the stability of the treatment's effects was assessed by monitoring muscle activities in the follow-up period after treatment. Further studies by Sood et al. [43] that described the muscle response during treatment with the Forsus Fatigue Resistant Device demonstrated that the appropriate neuromuscular adaptations occurred at the end of the 6th month of the therapy provided by this kind of fixed appliance. After 1 month of treatment there was a decrease in masticatory muscle activity during the swallowing of saliva and maximal voluntary clenching as a result of the instability of the occlusion due to the protrusion of the mandible.

Electromyographic recordings also permit an assessment of interdisciplinary orthodontic-surgical treatments, whose aim is to improve not only facial features but also the function of the stomatognathic system. Trawitzki et al. [44] found an increase in the EMG activities of the masseter and temporalis muscles during MVC and mastication in patients who underwent surgical correction of class III. Despite such an improvement, the activities of the muscles were still lower than those recorded in patients without malocclusion. Van den Braber et al. [45], in a sample of retrognathic patients, did not report any changes in either chewing efficiency or MVC activity in the masticatory muscles after surgical correction of this deformity. Moreover, all the recorded values were lower than those obtained from healthy controls.

Conclusions

This systematic review of the above studies confirms the high value of surface electromyography as a non-invasive, objective, and precise tool that expands our knowledge about the anatomy, physiology, and pathology of the stomatognathic system.

References:

1. Witkowska A: An outline of the history of electromyography. The significance of surface electromyography in neurophysiological diagnosis. Nowiny Lekarskie, 2008; 77(3): 227–30
2. Woźniak K, Lipski M, Lichota D, Buczkowska-Radlińska J: Surface electromyography in dentistry: EMG 8 – Bluetooth. Implantoprotetyka, 2008; 3(32): 52–55
3. Lapatki BG, van Dijk JP, Jonas IE et al: A thin, flexible multielectrode grid for high-density surface EMG. J App Physiol, 2004; 96(1): 327–36
4. Drost G, Stegeman D, Engelen B, Zwarts M: Clinical applications of high-density surface EMG: A systematic review. J Electromyogr Kinesiol, 2006; 16(6): 589–602
5. Castroflorio T, Farina D, Bottin A et al: Surface EMG of jaw elevator muscles: effect of electrode location and inter-electrode distance. J Oral Rehabil, 2005; 32: 411–17
6. Castroflorio T, Icardi K, Becchino B et al: Reproducibility of surface EMG variables in isometric sub-maximal contractions of jaw elevator muscles. J Electromyogr Kinesiol, 2006; 16(5): 498–505
7. Castroflorio T, Icardi K, Torsello F et al: Reproducibility of surface EMG in the human masseter and anterior temporalis muscle areas. Cranio, 2005; 23(2): 130–37
8. Ferrario VF, Sforza C, Zanotti G, Tartaglia GM: Maximal bite forces in healthy young adults as predicted by surface electromyography. J Dent, 2004; 32(6): 451–57
9. Glaros AG, Waghela R: Psychophysiological definitions of clenching. Cranio, 2006; 24(4): 252–57
10. De Felicio CM, Sidequersky FV, Tartaglia GM, Sfoza C: Electromyographic standardized indices in healthy Brazilian young adults and data reproducibility. J Oral Rehabil, 2009; 36(8): 577–83
11. Visser A, McCarroll Rs, Naeije M: Masticatory Muscle Activity in Different Jaw Relations During Submaximal Clenching Efforts. J Dent Res, 1992; 71(2): 372–79
12. Suvinen TI, Kemppainen P: Review of clinical EMG studies related to muscle and occlusal factors in healthy and TMD subjects. J Oral Rehabil, 2007; 34(9): 631–44
13. Suvinen TI, Reade PC, Könönen M, Kemppainen P: Vertical jaw separation and masseter muscle electromyographic activity: a comparative study between asymptomatic controls & patients with temporomandibular pain & dysfunction. J Oral Rehabil, 2003; 30(8): 765–72
14. Michelotti A, Farella M, Vollaro S, Martina R: Mandibular rest position and electrical activity of the masticatory muscles. J Prosthet Dent, 1997; 78(1): 48–53
15. Ferrario VF, Sforza C, Colombo A, Ciusa V: An electromyographic investigation of masticatory muscles symmetry in normo-occlusion subjects. J Oral Rehabil, 2000; 27(1): 33–40
16. Tartaglia GM, Moriera Rodrigues da Silva MA, Bottini S et al: Masticatory muscle activity during maximum voluntary clench in different research diagnostic criteria for temporomandibular disorders (RDC/TMD) groups. Man Ther, 2000; 13(5): 434–40
17. Lodetti G, Mapelli A, Musto F et al: EMG spectral characteristics of masticatory muscles and upper trapezius during maximum voluntary teeth clenching. J Electromyogr Kinesiol, 2012; 22(1): 103–9
18. Berretin-Felix G, Genaro KF, Trindade IEK, Trindade Júnior AS: Masticatory function in temporomandibular dysfunction patients: electromyographic evaluation. J App Oral Sci, 2005; 13(4): 360–65
19. Shimanda A, Yamabe Y, Torisu T et al: Measurements od dynamic bote force during mastication. J Oral Rehabil, 2012; 39: 349–56
20. Ferrario VF, Sforza C, Miani A et al: Electromyographic activity of human masticatory muscles in normal young people. Statistical evaluation of reference values for clinical applications. J Oral Rehabil, 1993; 20(3): 271–80
21. Pinho JC, Caldas FM, Mora MJ, Santana-Penin U: Electromyographic activity in patients with temporomandibular disorders. J Oral Rehabil, 2000; 27(11): 985–90
22. Rilo B, Santana U, Mora MJ, Cadarso CM: Myoelectrical activity of clinical rest position and jaw muscle activity in young adults. J Oral Rehabil, 1997; 24(10): 735–40
23. Ueda HM, Miyamoto K, Saifuddin M et al: Masticatory muscle activity in children and adults with different facial types. Am J Orthod Dentofacial Orthop, 2000; 118(1): 63–68
24. Tabe H, Ueda HM, Kato M et al: Influence of functional appliances on masticatory muscle activity. Angle Orthod, 2005; 75(4): 616–24
25. Hiyama S, Kuribayashi G, Ono T et al: Nocturnal Masseter and Suprahyoid Muscle Activity Induced by Wearing a Bionator. Angle Orthod, 2002; 72(1): 48–54

26. Saifudin M, Miyamoto K, Ueda HM et al: A quantative electromyographic analysis of masticatory muscle activity in usual daily life. Oral Dis, 2001: 7(2): 94–100
27. Li J, Jiang T, Feng H, Wang K et al: The electromyographic activity of masseter and anterior temporalis during orofacial symptoms induced by experimental occlusal highspot. J Oral Rehabil, 2008; 35(2): 79–87
28. 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. J Oral Rehabil, 1999; 26(1): 33–47
29. Woźniak K: Temporomandibular dysfunction in the light of some instrumental diagnostic methods. 1st ed. Szczecin, Hogben, 2009
30. Ferrario VF, Sforza G, Tartaglia GM, Dellavia C: Immediate effect of a stabilization splint on masticatory muscle activity in temporomandibular disorders patients. J Oral Rehabil, 2002; 29: 810–15
31. Botelho AL, Silva BC, Gentil FH et al: Immediate effect of the resilient splint evaluated using surface electromyography in patients with TMD. Cranio, 2010; 28(4): 266–73
32. Turk DC, Zaki HS, Rudy TE: Effects of intraoral appliance and biofeedback/stress management alone and in combination in treating pain and depression in patients with temporomandibular disorders. J Prosthet Dent, 1993; 70(2): 158–64
33. Yousefzadeh F, Shcherbatyy V, King GJ et al: Cephalometric and electromyographic study of patients of East African ethnicity with and without anterior open bite. Am J Orthod Dentofacial Orthop, 2010; 137(2): 236–46
34. Ciccone de Faria Tdos S, Hallak regalo SC, Thomazinho A et al: Masticatory muscle activity in children with a skeletal or dentoalveolar open bite. Eur J Orthod, 2010; 32(4): 453–58
35. Moreno I, Sanchez T, Ardizone I et al: Electromyographic comparison between clenching, swallowing and chewing in jaw muscles with varying occlusal parameters. Med Oral Patol Oral Cir Bucal, 2008; 13(3): 207–13
36. Cha BK, Kim CH, Baek SH: Skeletal sagittal and vertical facial types and Electromyographic activity of the masticatory nuscle. Angle Orthod, 2007; 77(3): 463–70
37. Piancino MG, Farina D, Talpone F et al: Muscular activation during reverse and non-reverse chewing cycles in unilateral posterior crossbite. Eur J Oral Sci, 2009; 117(2): 122–28
38. Tecco S, Tetè S, Festa F: Electromyographic evaluation of masticatory, neck, and trunk muscle activity in patients with posterior crossbites. Eur J Orthod, 2010; 32(6): 747–52
39. Saccucci M, Tecco S, Ierardoa G et al: Effects of interceptive orthodontics on orbicular muscle activity: a surface electromyographic study in children. J Electromyogr Kinesiol, 2011; 21(4): 665–71
40. Erdem A, Kilic N, Eröz B: Changes in soft tissue profile and electromyographic activity after activator treatment. Aust Orthod J, 2009; 25(2): 116–22
41. Leung DK, Hägg U: An electromyographic investigation of the first six months of progressive mandibular advancement of the Herbst appliance in adolescents. Angle Orthod, 2001; 71(3): 177–84
42. Du X, Hägg U: Muscular adaptation to gradual advancement of the mandible. Angle Orthod, 2003; 73(5): 525–31
43. Sood S, Kharbanda OP, Duggal R et al: Muscle response during treatment of Class II Division 1 malocclusion with Forsus Fatigue Resistant Device. J Clin Pediatr Dent, 2011; 35(3): 331–38
44. Trawitzki LV, Dantas RO, Mello-Filho FV, Marques W Jr: Effect of treatment of dentofacial deformities on the electromyographic activity of masticatory muscles. Int J Oral Maxillofac Surg, 2006; 35(2): 170–73
45. Van den Braber W, van der Glas H, van der Bilt A, Bosman F: Masticatory function in retrognathic patients, before and after mandibular advancement surgery. J Oral Maxillofac Surg, 2004; 62(5): 549–54

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