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Review Article

Masticatory Muscles Activity Associated with Occlusal Factors: An EMG Review

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Abstract: The aim of the study was to conduct a review of electromyographic studies, in order to assess the relationship between various occlusal features and masticatory muscles' activity. An exhaustive MEDLINE computer search was performed to identify all experimental studies present in the English literature describing the relationship between the electromyographyc evaluation of patients and their occlusal morphology. The search methodology provided a total of 102 abstracts and from these 11 full reports were selected as full text. Of the 11 articles selected, 8 studied the variation of the muscular activity as a consequence of the experimental introduction of occlusal disturbances whereas the remaining three studies estimated the electrical muscular characteristics without any artificial alteration of the occlusal morphology. The results obtained seem to suggest that occlusal features can affect the electrical signals recordings of masticatory muscles. Further researches are strongly requested to realize if this altered muscular activity can turns in the occurrence of TMDs.
Keywords: electromyography, masticatory muscles, temporomandibular disorders, occlusion.

INTRODUCTION

The temporomandibular disorders (TMDs) includes a heterogeneous group of clinical conditions affecting the stomatognathic system and its related structures [1]. At present, the aetiology of TMDs has not been fully understood but it's thought that a large number of factors may affect the adaptive capacity of the masticatory system, resulting in the occurrence and/or maintenance of TMDs [2-8] Many authors reported that a condition of muscular unbalance could be related with the development of TMD signs and symptoms [9, 10]. Muscular unbalance can originate from any deviation from normal contacts of opposing dentitions, such as, for example, premature contacts, balancing side or working side interferences, loss of posterior teeth [11-20]. Surface electromyography (EMGs) of masticatory muscles allows an approach of quantitative type, and it could be useful in order to clarify the relationship between occlusal morphology and masticatory muscles activity levels. For example significant correlations between the electromyographic characteristics of masticatory muscles (amplitude of the electric potentials, duration of contractile activity) and the number of dental contacts have been found [21-24]. Considering these preliminary remarks, the aim of the present paper was to discuss the available electromyographic studies on the risk to develop an altered pattern of contraction of the masticatory muscles as a function of various occlusal features. To get a maximum amount of statistical information without worrying about the imprecision of results, a study of metanalysis should have been performed [25], however the outcomes of the studies collected were not univocal, the studies used small-size samples or they were little reliable: in view of these concerns, the chance to carry out a meta-analysis was prevented.

MATERIALS AND METHODS

An exhaustive MEDLINE computer search was performed to identify all experimental studies present in the English literature, describing the relationship between the electromyographic evaluation of patients and their occlusal morphology. Key words used in the search included "electromyography", "masticatory muscles", "temporomandibular disorders", "occlusion". The main outcome of interest was the alteration in the activity of anterior temporalis muscle and masseter muscle in presence of any occlusal deviation. Inclusion in this review was restricted to trials carried out on people that did not undergo prosthetic rehabilitation, orthodontic treatment or surgery in the maxillo-facial region, and that did not exhibit serious pathological conditions to the musculoskeletal apparatus or other rheumatic or neurological diseases. The abstracts and titles achieved from this research were screened according to the inclusion criteria for possible admittance in the review: all studies that appeared to meet the above mentioned criteria were then achieved as complete articles.

RESULTS

The search methodologies provided a total of 102 abstracts and from these 11 full reports were required as full text. Screening of abstracts led to the exclusion of the remaining articles because they were considered clearly irrelevant or they were rejected because they didn't met inclusion criteria. Of the 11 articles selected, 8 studied the variation of the muscular activity as a consequence of experimental alterations. The methods employed to introduce occlusal disturbances were different: in detail 4 studies applied occlusal devices to the mandibular arch [16, 26-28] to the maxillary arch, [14, 20] and 2 to both [13, 15]. Three studies estimated the electrical muscular characteristics without any artificial alteration: Nishigawa *et al.* [18], who recorded the masticatory muscles activity levels in presence and absence of balancing contacts, Cardenas and Ogalde [29] that studied the relationship between occlusion and electromyographyc activity in prognathics and controls, and Liu *et al.* [19] that analyzed the EMG activity in relation to various mandibular movements in subjects with different occlusal patterns. Between the all studies only two utilized randomization methods and were performed in double blinding [27, 28].

DISCUSSION

Some authors studied the variation of muscular activity as a function of the type and the amount of dental contacts recorded in maximal intercuspidation and when the mandible moves to laterality and protrusion. In theory, these data could provide an objective index representative of an alteration, allowing the interception, through an opportune analysis of the electromyographic signal, of a risk factor for the occurrence of some muscle diseases [30]. Bakke and Moller [13] evaluated the changes in the muscular activity during maximal clenching in presence of premature unilateral contacts created by means of celluloid strips of various thickness. The results obtained showed a significant asymmetry in all muscles, with stronger activity on the same side of the premature contacts. With increasing the thickness of the strip, the mean voltage decreased in the same way on both sides, so the authors suggested that the asymmetry was caused by larger spindle afferent activity on the ipsilateral side, and the decrease of the muscle activity was due to the reduced activation of periodontal pressoceptors. Ferrario *et al.* [20] utilized shim-stocks strips to assess the relationship between EMG activity and number of dental contacts. The recordings were performed in maximum voluntary clenching (MVC) and the subjects were divided into two groups, respectively with many occlusal contacts (with at least ten occlusal contatcs) and few occlusal contacts (less than ten occlusal contacts); data showed notable differences in the activity of the masseter and the temporalis anterior muscles (the last averagely greater) between groups: EMG activity was smaller in the subjects with a lower number of occlusal contacts. The study of Cardenas and Ogalde [29] evaluated the relationship between occlusion and EMG activity in a group of prognathics and in healthy controls. Their findings suggest that the EMG activity recorded is not proportional to the total amount of contacts as reported by Bakke *et al.* [21], and Naeije *et al.* [31]: the average EMG voltage in the masseter muscle was similar in both groups, whereas the mean total number of contact points in tooth arches, recorded in maximum intercuspal position, was greater in the control group than in the patient group, with a greater number of contact points between premolar and molar areas. Moreover, analyzing the premolar and molar contacts, both groups presented a balanced occlusion. The finding of a similar EMG activity in the two groups induced the authors to sustain the importance of a balanced occlusion in the posterior areas. Baba *et al.* [15] utilized three types of artificial devices to clarify the influence on jaw elevators muscles of some occlusal interference [32] during various clenching efforts performed in eccentric mandibular positions. The authors obtained *the IP ratio* (IP) [33] to assess the level of muscle activity and *the asymmetry index* (AI) [31] which estimates the activity balance for each muscle pair. With the introduction of the canine guidance, a reduction of the IP ratio was recorded bilaterally in the masseter and in the anterior and posterior temporalis, in accordance with how reported by Belser and Hannam [24]; also the working side interferences determined an alteration of the IP ratio, but the relationship between right and left responses of muscles remained unchanged; neither the introduction of nonworking side interferences altered this ratio. Subsequently the same investigators [16] analyzed deeper the effect of nonworking side occlusal contacts on jaw elevator muscle activity. The authors found a dominance of posterior and anterior temporalis muscle on the working side under natural conditions, while adding a non working side occlusal contact the dominance of temporalis muscle decreased. This dominance was strongly reduced after introducing a non working side occlusal interference. In agreement with other studies [15, 34] no variation of activity of the masseter muscle was found as a result of the occlusal alterations induced. On the base of these results it can be hypothesized that some occlusal features can affect the activity of the masticatory muscles, but not in univocal way (the effects were seen in temporalis muscle activity but not in the masseter one) and this can change the nature of the forces applied at both the teeth and the TMJs, providing support during parafunction and reducing joint loading. In agreement with these reports, Ferrario *et al.* [14] investigated the muscular changes induced with the introduction of artificial interferences. They analyzed the so called *percentage overlapping coefficient* (POC) (used to assess the distribution of the muscular activity of paired muscles determined by the occlusion) and the *torque coefficient* (TC) (used to estimate the direction of the resultant forces of masseter and temporalis muscles) with the purpose of recognize possible adverse effects of these interferences on the temporomandibular joint structures

(TMJ). They found that the TC increased following the introduction of the interferences (it meant that the interferences lead the occurrence of a laterodeviating couple of forces on the mandible). Nevertheless this finding does not imply the presence of macroscopically observable mandibular movements because the activity of others muscles could contrast the TC induced from masseter and temporalis muscles. The POC analysis showed that following the introduction of the interferences the main effect occurred in the temporalis muscle, while in the masseter muscle the variation was less appreciable. These findings are in contrast with how sustained by Humsi *et al.* [35] and by McCarroll *et al.* [36] who recorded some effects only in the masseter muscle, and with the data reported by Ingervall and Carlsson [37] who did not find any variation of the electrical activity of the muscles studied. In the literature there are many other studies that tried to clarify, by means of the electromyography, the relationship between the presence of interferences and TMJ biomechanics [26, 17]. Okano *et al.* [26] studied the influence of occlusal patterns on the EMG activity and mandibular displacement during maximum clenching. Four patterns were simulated: canine to second molar contact on the working side and second molar balancing contact (GF+BC); canine to second molar contact (GF); canine to second premolar contact (semi-GF); canine contact (CP). The data collected showed that the introduction of BC was associated to a greater muscular activity, while CP caused the lowest electrical recording. Furthermore the CP, semi-GF and GF were associated with a condilar shift (upward and forward), with a larger displacement on the non working-side. It was observed a linear increase in the amplitude of the non working side condyle displacement across CP, semi-GF and GF, while this was not recorded for the working side; so the GF was associated with the largest elevation of the non-working side condyle and the CP with the smallest. The introduction of the BC to GF also caused a significant reduction in the condylar elevation, becoming similar to CP. In agreement with the study Minagi *et al.* [38], it is possible to hypothesize that the BC has a protective role and that it acts as a supporting tool for the same side.

Unlike the greater part of the analyzed studies Nishigawa *et al.* [18] analyzed a sample of subjects with natural balancing side molar contacts. The results showed a positive value of the asymmetry index for all muscles, particularly for the masseter muscle: higher activity levels were observed in chewing side masticatory muscles. Moreover the asymmetry index was larger when chewing on a side with balancing molar contacts. Nevertheless even if the EMG showed a clear difference between the two groups, the jaw movements traced during unilateral chewing did not show significant difference between them, perhaps for the influence of other muscles, not considered in this paper, that can affect the chewing pathway; another possibility could be that the EMG signals derived from the isometric contraction which is not responsible of mandibular movements. The authors concluded that different occlusal interfaces result in different masticatory muscle activity patterns during unilateral chewing and this can affects the articular load by the loss of the muscular coordination. Liu *et al.* [19] in order to demonstrate functional differences of jaw muscles between symptomatic and asymptomatic TMD patients, performed a comprehensive EMG analysis of 20 subjects with TMD signs and symptoms and 12 controls. All subjects received a clinical examination which covered the following variables of tooth alignment, tooth loss, tooth attrition, occlusal interference and premature contact. It was concluded that a functional occlusion dominated by occlusal interference might be related to the low functional efficiency of muscle activities in symptomatic subjects as these variables showed a significantly positive association with electromyographic activity at 70% level of maximal voluntary clenching, but no association with the corresponding bite force. Finally, there seemed to be a tendency in normal subjects that, for most of the common occlusal variables such as protruding and lateral interference and premature contact; the more normal these variables are, the shorter is the silent period duration and the longer is its latency; such associations became weaker or attenuated in symptomatic subjects. Among the studies considered, only the investigation realized by Michelotti *et al.* [27] was performed with blinding and randomization methods. The investigators recorded (by portable recorders) during a six-week observation period the effects induced by four different occlusal conditions: before interference application, with dummy and active interference, and after interference remotion. The active interference influenced the electromyographic activity of the masseter muscle leading to a decrease in the number of activity periods in the first two days and in an increase gradually later. The increase of the number of the activity periods proceeds parallel with the decrease of occlusal discomfort; this could be related to the subjects' adaptation to the disturbance perceived, or to the decrease of the height of interference. It can be assumed that the lower electromyographyc activity level observed immediately after the applications of gold strips represents the expression of the activation of alternative mandibular pathways, to avoid the interferences and alleviate the perceived discomfort. Some others authors in the past hypothesized that the activation of those ways could lead to muscular hyperactivity, with loss of muscular coordination [39]. The study of Michelotti *et al.* [27] estimated also the long-term effects of these interferences on the stomatognatic system and none of the subjects of the study sample referred signs or symptoms of TMD until the end of the study and only three subjects reported headache assessed by the visual analog scales (VAS). Electromyography showed variation of muscular activity without any clinical symptoms; therefore it was concluded that EMG is deceptive as predictive test.

Subsequently the same authors [28] analyzed the possible appearance of symptoms due to the presence of interferences by pressure algometry (PPT): they used the same types of interferences applied for 8 days; the results indicated that the introduction of an acute active occlusal interference disturbing the centric occlusion did not alter the PPT of masseter and temporalis bilaterally. It is generally accepted that the aetiology of TMDs is multifactorial but there is no consensus on the association between occlusion and temporomandibular disorders. On the base of these premises, the aim of the above reported studies was to assess the relationship between various alterations of the occlusal morphology and EMG recordings of masticatory muscle activity, such for example muscle spasms, fatigue and muscle imbalance. Literature data seem to suggest that the occlusal features may influence these recordings, even if the results reported by different authors are often contrasting. This concern could be due to several biological and technical factors that influence the reliability, validity, sensitivity and specificity for the use of EMG [40, 41]. Ferrario obtained that the electrical activity is lower if there are few occlusal contact. In the presence of interferences, the major effects occur in the temporalis muscle, while in the masseter muscle the variations are less appreciable. These conclusion are in contrast with the findings of Humsi *et al.* [35] and McCarroll *et al.* [36] who recorded some effects only in the masseter muscle, and with the data reported by Ingervall and Carlsson [37] who did not find any variation of the electrical activity. Cardenas and Ogalde [29] suggested that the EMG activity recorded is not proportional to the total amount of contacts as reported by Bakke *et al.* [21], and Naeije *et al.* [31] Michelotti *et al.* [27] studied the long-term effects of the interferences on the stomatognatic system and concluded that the EMG is deceptive as predictive test.

CONCLUSION

An evaluation of literature data on this issue is complicated for many reasons, the first of which is the difficulty in comparing different studies for the notable variety of methodology employed, not only to create interferences (different for site, geometry, material and magnitude) but also in the different masticatory tasks purposed to record their effects. Another concern is the lack of long-term studies so that it is not possible to evince if the effects recorded represent a permanent disruption of the homeostatic equilibrium between the various components of the masticatory system instead of an immediate and transitory adaptation to the alteration introduced. Moreover it is possible to conduct perspective long-term studies in subjects with natural interferences, while with the application of experimental interferences is possible to appraise only changes in short or middle term. Occlusal interferences alter the normal mandibular excursion from and to maximum intercuspidation. It was hypothesized that these contacts can change the pattern of muscular activity, hesitating in hyperactivity and then in muscular overload which can trigger signs and symptoms of TMD [10]. The variation of muscular activity in presence of interferences could be due to alterations in the proprioceptive and periodontal inputs to the central nervous system, so altering the number of motor units, the sequence of activation and its duration in order to avoid the interference [21]. It is conceivable that these alternative pathways, probably finalized to the diminution of the perceived discomfort, can disrupt the stability of the stomatognatic system with the occurrence of dysfunction. This occlusal schemes were considered as risk factors for TMD, however there is not still enough evidence supporting their contributing role in the occurrences of masticatory muscles disease, and what occlusal guidance is beneficial to the muscle function seems to remain unclear. Finally, as suggested by Liu *et al.* [19] it could be that TMD signs and symptoms may alter the functional balance or adaptation of the occlusal factors and the activity of jaw muscles to some extent. In conclusion further investigations are needed to explore the relationship between occlusal features and muscular activity, designed following specific criteria (randomization, inclusion and exclusion criteria, similarity between groups at baseline, detailed description of the protocols to facilitate replication, blinding methods) in order to establish if a causal association between these variables really exist, thus avoiding spurious associations. Longitudinal studies with the purpose to appraise the long-lasting effects of occlusal disturbance on the activity of masticatory muscles are strongly requested. Finally, a greater accuracy of the electromyography would be desirable to confer to the results obtained an absolute reliability [40, 41].

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