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Relationship between bite force and electromyographic activity of the temporal and masseter muscles

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Abstract

Introduction: Maximal bite force and surface EMG (sEMG) are important determinants of the masticatory function and their recording is essential for the estimation of the dental status.

Aim: The aim of the study was to investigate the relationship between the bite force and electromyographic activity of the masticatory muscles and to estimate the possibility of using sEMG for the evaluation of the masticatory force.

Material and Methods: The study included 68 individuals of mean age 18.4 ± 6.1years: 33 male and 35 female. The bite force and the sEMG were measured to all subjects simultaneously, consecutively on the right and the left side during maximal and submaximal clenching. Statistical analysis was performed by IBM SPSS Statistics, version 23.0.

Results: Both EMG and maximal bite force values did not show significant difference on the left and right side. A strong positive correlation was found between the bite force and the EMG activity of the temporal and masseter muscles on the right and left. The correlation was stronger during submaximal bite (2/3) compared to maximal clenching both for the temporal and the masseter muscles on both sides.

Conclusion: The strong positive correlation between the bite force and the EMG values of the masticatory muscles makes the EMG a good alternative method for the estimation of the masticatory function.

Keywords: maximal bite force, surface electromyography, correlation, masticatory muscles

Introduction

Research and clinical studies are devoted to the masticatory function and the relationship between the bite force (BF) and the electromyographic (EMG) activity of the masticatory muscles. Early studies show, that in patients with normal occlusion at rest and during exertion of an increasing biting force the electromyographic activity increases proportionally in all parts of the temporalis muscle. At rest and during movement of the mandible backwards prevails the function of the posterior part of the muscle (2).
Examination of the BF and the EMG activity of the temporalis and the masseter muscles in healthy subjects and in subjects with symptoms and signs of functional abnormalities in the maxillofacial region showed that the maximal bite force of the healthy subjects is higher than in the symptomatic patients. No significant differences of the muscle activity on the left and the right side, and between men and women were found (2). A strong linear relationship existed between the EMG and biting force when the force is increasing. During isometric contraction was found correlation between the biting force and the electromyographic activity, significant when measured unilaterally, but not during bilateral measurement. The gradual increase of the force of contraction up to 10-15 sec, shows a similar relationship with the muscle activity on the same side (2). The direct measurement of the BF by a gnathodynamometer (GDM) is good for measurement of submaximal forces, but for the maximal BF there are risks as tooth fracture, pain, discomfort and fear, that hinders the maximal bite, or technical restrictions of the instrument like inaccuracy during great loading. The EMG examination eliminates these disadvantages, and can be used when planning prosthetic constructions, that could bear the occlusal burden.
An EMG examination of the masticatory muscles showed higher values of the front part of the temporalis muscle than those of the masseter muscle (3). The authors did not find gender differences of the EMG values. The finding, that in healthy subjects the values of the EMG activity of the temporalis muscle is higher than of the temporalis muscle is supported by other researchers as well (4).
Studies on the BF and the EMG activity of the masticatory muscles showed that during bilateral measurement of the BF, the correlation with the EMG is weaker, compared with the unilateral recording. This allows to conclude, that the unilateral recording of the biting force reflects more precisely the muscle force of the chewing muscles, moreover that both on the left and the right side was found high correlation between the two variables, when measured separately (5).
The possibility to evaluate the biting force by recording only the EMG potentials, taking into consideration the relationship EMG/biting force during various submaximal efforts, when measured simultaneously bilaterally was examined by Ferrario V., et al. (2004). The authors conclude that the simultaneous registration of EMG and the BF shows linear correlation and reproducibility of the results within a two weeks interval. Other studies report near to linear relationship between the EMG potentials and the BF, especially concerning the submaximal biting forces (2, 7, 8, 9). When measuring the maximal bite force (MBF) the vertical distance between the teeth is increased, and studies show that the increase more than 10 mm leads to a decrease of the maximal electrical activity of the masticatory muscles. Moreover, during great increase of the BF the relationship between BF/EMG deviates from a linear relationship (6).

It can be concluded that the maximal bite force, evaluated by the afore mentioned methods can be used in clinical practice as an indicator of the force of the masticatory muscles, and is a reliable clinical method for the estimation of the changes of the force during the development of the maxillofacial region during treatment or as a result of teeth loss (2).

Taking into consideration the importance of the masticatory function and the reliability and the disadvantages of the methods used for its evaluation, the aim of this study was to investigate the relationship

between the BF and the EMG activity of the masticatory muscles during maximal and submaximal clenching in healthy young adults.

Material And Methods

The study included 68 individuals of mean age 18.4 ± 6.1years: 33 of them were male and 35 female. The bite force and the surface EMG were measured to all subjects simultaneously, consecutively on the right and on the left side. The inclusion criteria were: no temporo-mandibular disorders; no pain during clenching the teeth; no missing teeth in the lateral areas and no evidence of an acute inflammatory process. The study did not include individuals who underwent or are undergoing orthodontic treatment or have evidence of bruxism.

Assessment of bite force

The bite force was measured by a strain-gauge transducer – a gnatodynamometric system GD500.1, with a test range of 0-700 Newtons (N). The subjects sat on the dental chair with the head upright in natural position and unsupported. The horizontal planes of the gnathodynamometer were positioned in the area of the first permanent molars. Maximal voluntary clench was performed on the fork of the strain-gauge transducer. After recording of the maximal value, the subject was asked to bite with 2/3 and 1/3 of the maximal bite force for a second and third record. The subject observed the display and applied the necessary strain for 3 seconds. The measurement was performed bilaterally, sequentially to the left and right side with interval of one minute, simultaneously with the recording of the EMG potentials of m. masseter and m. temporalis.

Assessment of the EMG Activity of the Masticatory Muscles

The surface EMG recording was performed using a two-channel electromyograph (Neuro-EMG-Micro-2) with “Neuro-MEP-Ω” software. The The electrical potentials of temporalis anterior (TA) and the masseter muscle (MM) were measured. Before placing the surface electrodes (Ag/AgCl), the skin was cleaned with 90% ethyl alcohol over the most prominent part of the muscle palpated in contraction, parallel to the fibers according to the Surface EMG for Non-Invasive Assessment of Muscles (SENIAM) program guidelines. Before sEMG measurement, all the subjects were instructed about the procedure. Maximal and mean EMG activity values of every contraction of the right and the left masseter and the anterior temporalis were recorded during maximal (1), 2/3 and 1/2 of the maximal bite force during a 3-seconds period. The EMG potentials were recorded in microvolts (μV). All participants signed an informed consent.The simultaneous measurement of BF and EMG activity is shown on Fig.1.

Fig. 1 Simultaneous measurement of bite force and EMG activity.

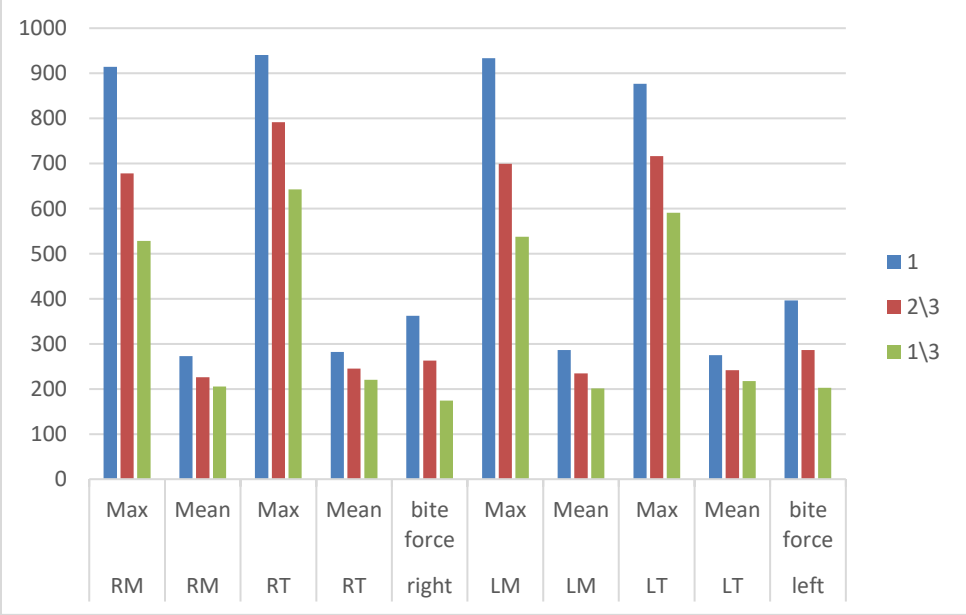
Statistical Analysis.

The statistical analysis was performed using IBM SPSS Statistics version 23.0. The test of Kolmogorov - Smirnov was used to check the normality of distribution.
Statistical analysis used Spearman's correlation coefficient to verify significant association between the study variables. Nonparametric tests were applied to the variables that did not present normal distribution. All statistical tests were done at a level of 5% for significance $p<0.05$.

Results

The values of the BF and the EMG activity during maximal and submaximal clenching on the left and the right side are shown on figures 2. No significant difference was found for the bite force and the EMG potentials of the masticatory muscles between the right and the left side.

Fig 2. Bite force and EMG activity of masseter and temporalis muscles on the *right* and the *left* side



The correlation analysis revealed that on the right there is a significant positive correlation between both the maximal and the mean EMG values of the masseter and the temporalis muscle with the bite force during maximal and submaximal clenching. During maximal clenching the correlation is moderate for the right m. masseter, and moderate to strong for the right m. temporalis. For bite force 2/3 of the maximal, the correlation is moderate for the masseter and strong for the temporalis muscle. During clenching 1/3 of the maximal clench (1) the correlation varies from weak and moderate for the masseter muscle, and strong for the right temporalis. (Table 1).

Table 1: Correlation between EMG and BF values of the masseter and temporal muscles on the *right*

Bite force	Muscles	Correlation coefficient (r)
1	Right m. masseter Max	0,328**
	Right m. masseter Mean	0,357**
	Right m. temporalis Max	0,484***
	Right m. temporalis Mean	0,541***
2/3	Right m. masseter Max	0,354**
	Right m. masseter Mean	0,431***
	Right m. temporalis Max	0,640***
	Right m. temporalis Mean	0,694***
1/3	Right m. masseter Max	0,244*
	Right m. masseter Mean	0,328**
	Right m. temporalis Max	0,595***
	Right m. temporalis Mean	0,699***

* - p<0,05, ** - p<0,01, *** - p<0,001

The simultaneous measurement of the bite force and the EMG on the left showed similar results. There was a significant positive correlation between the bite force and the EMG activity of the chewing muscles during maximal voluntary clench and 2/3 and 1/3 of the maximal voluntary clench. On the left the correlation was moderate to strong for the masseter muscle and strong for the temporalis muscle.

Table 2: Correlation between EMG and BF values of the masseter and temporal muscles on the left

Bite force	Muscles	Correlation coefficient (r)
1	**Left m. masseter Max**	**0,392****
	Left m. masseter Mean	**0,428*****
	Left m. temporalis Max	**0,575*****
	Left m. temporalis Mean	**0,618*****
2/3	**Left m. masseter Max**	**0,379****
	Left m. masseter Mean	**0,436*****
	Left m. temporalis Max	**0,616*****
	Left m. temporalis Mean	**0,712*****
1/3	**Left m. masseter Max**	**0,211**
	Left m. masseter Mean	**0,364****
	Left m. temporalis Max	**0,519*****
	Left m. temporalis Mean	**0,566*****

*** - p<0,05, ** - p<0,01, *** - p<0,001**

The results show that there is a statistically significant positive correlation between the muscle force and the electromyographic activity of the masticatory muscles on both the left and the right side. It is significant during maximal, and submaximal clenching. The results also show that the correlation between BF and EMG values is stronger expressed for the temporal muscle, compared with the masseter muscle, which is valid for both left and right side.

Discussion

The present study evaluates the bite force and the EMG activity of the masticatory muscles in young healthy adults who were not subjected previously to orthodontic treatment. Furthermore, it provides values of the bite force and EMG during maximal and submaximal clenching of 2/3 and 1/3 of the maximal clench.

The masseter and anterior temporalis muscles are the most frequently studied masticatory muscles using EMG because of their easy accessibility by the surface electrodes both in physiological and pathological conditions (2, 3, 6, 10). Previous studies on the EMG and BF report near to linear relationship between the electromyographic potentials and the biting force, especially concerning submaximal biting forces (2, 7, 8). Pita M. et al., (2011) recorded the EMG activity of the temporalis and masseter muscles and found greater activity of the masseter muscle in both men and women. In the present study both the maximal and the mean EMG values were higher in the temporalis muscle than in the masseter muscle during maximal and submaximal clenching, but the difference was statistically insignificant. Another study (12) observed a significant direct correlation between the bite force in the right premolars and the surface EMG of the left temporalis, left masseter and right masseter muscles. The authors suggested, that the greater the biting force, the higher the values of the sEMG in the mentioned muscles. A reliable association was found between the EMG activity of the masseter and temporalis muscles and the bite force measured in the incisors and molars (12). Our data support the finding that with the increase of the biting force the EMG potentials of the temporal and masseter muscles also increased.

De Melo et al., (2016) found correlation between BF and sEMG of the masticatory muscles only during bite on the right side. Analysis of the data showed, that the greater the force exerted, the higher the electrical activity in the left temporal, right masseter and left masseter muscles. These data suggest that the impact of the electrical activity in the temporal muscles is more closely related to the contralateral side, whereas it maintains bilateral influence on the masseter muscles (12). In the present study with the increase of the biting force were recorded higher EMG values both of the masseter and the temporalis muscle on right and left. It is of interest to note, that we observed higher, although insignificant values of the bite force on the left side, and higher EMG activity of the temporalis muscle on the contralateral side.

Gonzalez et al., (2011) found a linear relationship between the electromyographic activity and bite force, but data on the reliability of this relationship are limited. The contribution of the study is that the authors used 2 devices concurrently, thus increasing the accuracy of the measurement. The bilateral activity of the temporalis and the masseter muscles and the bite force were examined during maximal voluntary clenching in young healthy adults of both genders (14). The authors found a positive correlation between the BF and the EMG potentials, and higher EMG activity of the masseter than of the temporalis muscles. The correlation coefficient for the temporalis was higher than for the masseter muscle (0.512 vs 0.360). Similar results were found in our study with a significant positive correlation for m. temporalis of 0.484 vs 0.328 for the m. masseter during maximum clench. In the present study we also used simultaneous monitoring of the EMG and the bite force during all tests to achieve higher reliability of the results.

The combined evaluation of BF and EMG measurement allows to explore a possible asymmetry of the masticatory muscles and the masticatory function in healthy individuals, in TMD patients (15), and in subjects with different facial types (10, 12, 16). Data show that a significant relationship exists between occlusal forces and facial morphology, dental conditions, and the presence of temporomandibular disorders (2, 6). Crawford S. et al.,(2015) studied the relationship of the jaw closing muscle the EMG activity with incremental submaximal and maximal bite force levels and found a linear relationship between the muscle activity and bite force levels in pooled male and female data. These findings are similar to the results of Ferrario V. et al., (2004) who reported a correlation of 0.964 for the bite force and the submaximal EMG in healthy young adults. It is of interest to note, that the results of the present study also show stronger

correlation between BF and EMG during submaximal clench, compared to maximal clench. Because of the limitations of the direct force assessment by maximal BF measurement like pain, discomfort, dental fractures, an alternative method of indirect estimation of the bite forces is more preferable. A possible alternative is sEMG of the masticatory muscles as a non-invasive way. So determining a relationship between the BF and EMG potentials could make EMG a good alternative for the evaluation of the masticatory forces.

Conclusion

Considering the results of this study, it can be concluded that the EMG activity of the temporalis and masseter muscles and the bite force during maximal and submaximal clenching did not differ significantly on the left and the right side. A strong significant positive correlation between the EMG values of the temporalis and the masseter muscles and the bite force during maximal and submaximal clenching was found. Therefore, the EMG measurement may be a method of choice for the estimation of the bite force and an alternative for the indirect evaluation of the masticatory forces, noninvasive and safe.

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