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## Electromyographic Activity of Masticatory Muscles in Asymptomatic Young Adults

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**ORIGINAL ARTICLE**

## **Electromyographic Activity of Masticatory Muscles in Asymptomatic Young Adults**

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### **ABSTRACT**

**Introduction:** The masseter and the anterior part of the temporalis are the muscles mainly responsible for the clenching function. Clenching patterns and the activity of these muscles are not expected to differ between male and females, nor between different occlusal classes. **Objective:** The aim of this study was to determine whether the activity index of the masseter and temporalis muscles is related to occlusal class and gender. **Methods:** This study involved 145 eighteen-year-old Caucasian volunteers who underwent surface electromyography. The sEMG was analyzed at the moment of 100% occlusal contact. Occlusal classes were determined using plaster casts. **Results:** The Class I group contained 34 males and 63 females, while Class II had 11 males and 25 females. Comparison of the ACI data showed an insignificant relation between the genders in the activity indices of Classes I and II. Significant relation between male gender and predominance of the masseter muscles, as well as between female gender and an almost equal balance between the muscles, though with a tendency towards a predominance of the temporalis anterior. **Conclusion:** The activity of masseter muscles during clenching the teeth is bigger in the male than in the female group. Activity index is related to gender.

**Key words:** activity index, Angle's classification, electromyography, mastication muscles, young adult

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### **INTRODUCTION**

The masseter and the anterior part of the temporalis are the adductor muscles responsible for the clenching function.<sup>1</sup> The thickness, fiber size, and distribution of the mastication muscles affect the bite force, which should thus differ between males and females.<sup>2</sup> The quality of occlusal contact is also expected to affect bite force—for example, lost teeth and ongoing pain may result in decreased muscle activity. It is interesting to ask whether occlusal class can also affect the electromyographic potential of masticatory muscles.<sup>2</sup> According to the *Glossary of Prosthodontic Terms*, Angle's classification of occlusion (occlusal class) is based on the intercuspatation of the first molar teeth, originally described by Angle in four major groups, depending on the anteroposterior jaw alveolar ridge. Angle's classification contains the following categories: Class I: normal anteroposterior relationship of the jaws, as indicated by intercuspal position of maxillary and mandibular molars, but with crowding and rotation of

teeth elsewhere; Class II: the mandibular dental arch is posterior to the maxillary dental arch in one or both lateral segments; the mandibular first molar is distal to the maxillary first molar. Class III: the mandibular arch is anterior to the maxillary arch in one or both lateral segments; the mandibular first molar is mesial to the maxillary first molar; the mandibular incisors are usually in anterior reverse articulation. Class IV is no longer in use.<sup>3</sup> Electromyographic potential can be investigated using electromyography, a noninvasive method that objectively records muscle activity.<sup>4</sup> This method is vulnerable to extramuscular factors, such as motion artifacts and physiological noise, which can alter and distort the true electrical signal, but with well-standardized protocols its results do not statistically significantly differ from intramuscular recordings.<sup>5</sup> A T-scan III device allows the distribution of contact between the teeth to be recorded at any moment from first contact to disclusion—including the moment at

which 100% occlusal contact is reached. We could not find any correlation reported in the literature between masticatory muscle activity at the point of 100% possible occlusal contact, occlusal class, and gender. Using these two methods, and also by determining occlusal classes, we sought a relationship between the activity indices of the masseter and temporalis anterior muscles and the occlusal classes of asymptomatic young adults. The numbers of participants in previous study groups have been small,<sup>5,6</sup> the groups have been inhomogeneous in age,<sup>6</sup> and differences in muscle activity have been investigated in relation to artificial occlusal trauma.<sup>7</sup> It would be interesting to determine whether these findings also hold true in a homogeneous, asymptomatic group of eighteen-year-olds, using the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) protocol. We chose eighteen-year-old volunteers because, craniofacial development would have completed by this age and any pathological effects on the craniofacial complex could be expected to be minimal. We would expect the clenching pattern and muscle activity not to differ between males and females, or between occlusal classes.

## OBJECTIVE

The aim of the study was to determine whether in fact there exists any significant relation between the activity index for the masticatory muscles, gender, and occlusal class in healthy young adults.

## METHODS

### Study material

The volunteers were all eighteen-year-old Caucasians recruited from two high schools. They were asked to take part in a project aimed at evaluating the status of the stomatognathic system in healthy young individuals (project no. N N403 589138). In the screening phase, 268 (198 female and 70 male) of 1000 individuals willing to participate in the project underwent clinical examination by the same trained dentist and filled out the Polish version of the RDC/TMD temporomandibular disorder questionnaire.<sup>8-10</sup> Subjects passed to the next phase of the study if they possessed complete permanent dentition up to the second molars and showed no symptoms of temporomandibular dysfunction or psychological disorders (based on the RDC/TMD). The exclusion criteria were transversal malocclusion, any periodontal disease, caries, damaged dental tissue, any prosthetic restorations, bruxism (on the basis of clinical examination, or as indicated by excessive wear or a questionnaire for detecting bruxism), a history of parafunctional tooth clenching or grinding, neuropathic conditions, systemic or localized maxillofacial disease, Botox therapy, mandibular torus, or pregnancy.<sup>3-5,7</sup> In addition, it was necessary for the

subjects to be unfamiliar with all the investigators and the devices used in the protocol, in order to eliminate any potential bias that might affect their attitude to the study protocol, which might affect the results.

Finally, 145 of the 268 (98 female and 47 male) prescreened subjects underwent the study.

This was performed after the protocol had been approved by the ethics committee of our institution and all subjects had signed informed consent forms in accordance with the Declaration of Helsinki and the ICH Guideline for Good Clinical Practice. Participants were allowed to withdraw from the study at any time, for any reason, without prejudice.

### Procedures

We made every effort to inform the subjects of the aim of the study in order to enhance their cooperation. All examinations were performed between 8 am and 10 am, just before school classes. Prior to the examination, the volunteers sat for five minutes in a quiet environment with relaxing music playing. During the examination, they were instructed to sit upright in a chair with their head unsupported. The skin was cleaned with 95% alcohol and rubbed with abrasive paper; a recording was then made using bipolar surface pregelled rectangular bipolar Ag/AgCl electrodes with an interelectrode distance of  $19 \pm 1$  mm and a measurement surface of about 680 mm<sup>2</sup> (40 mm × 17 mm) (BioFLEX, BioResearch Associates, Brown Deer, WI, USA), which were placed bilaterally on the skin overlying the anterior temporalis—that is, vertically along the anterior muscular margin and approximately over the coronal suture.<sup>13</sup> For the masseter, the electrodes were placed parallel to the muscle fibers with the upper pole of the electrode at the intersection between the tragus–labial commissure and the exocanthion–gonion lines, perpendicular to the skin surface. A plate ground electrode was secured to the forehead.<sup>3-6,8,14</sup> To minimize any interference from the activity of other muscles, the subjects were asked to refrain from making additional movements involving the facial muscles. The next step was to select the correct size (large or small) of T-scan sensor for the subject, depending on the size of the dental arch. The T-scan III hardware consisted of a recording handle to hold the recording sensor connected to a computer through a USB port. Held securely within the recording handle was a “sensor support” that keeps the 100- $\mu$ m-thick recording sensor properly extended flat within the mouth during the intraoral recording procedures. The T-scan sensor was placed in the subject’s mouth with its support pointer between the upper central incisors. The volunteers were then asked to close their jaws as firmly as possible. When a force is exerted on the sensor, a voltage drop occurs across its conduction paths; this is immediately recorded by the software upon each tooth contact and is displayed for clinical

analysis.<sup>11</sup> The T-scan and EMG recordings were begun simultaneously. While the recording was in progress, the real-time results of both the T-scan and the sEMG were shown on the same computer screen.<sup>11</sup> During the examination, the subject was asked to clench three times for three seconds, with three seconds of relaxation between each clench.<sup>4-7</sup> All registrations were repeated three times. The sEMG examination involved recording the occlusion using a T-scan III device. All the sEMG and T-scan measurements were carried out by the same investigator, who possesses expertise in using such devices. The details of this protocol are described by Wieczorek et al.<sup>15-17</sup>

The unique time at which occlusal contact reached 100% was selected to analyze the voltage of the masseter (MM) and the temporalis anterior (TA) muscles. The T-scan III software was used to identify this moment by automatically selecting the still image with maximal occlusal contact. The software automatically calculated the distribution of occlusal contact at the point of maximum clench at the moment when 100% of possible contact was reached. The study protocol involved analyzing the sEMG values during this moment of maximum occlusal contact. The T-scan III/BioEMG III integration software displayed the maximum voltage of the muscles at that moment and extracted the data from the still of the T-scan.<sup>18</sup> Before beginning the protocol with the volunteers, we tested measurement variability through repeated sEMG analyses of two randomly chosen subjects. A trained dentist carried out three sessions on subsequent days at the same hour each day, using the same protocol. A recording lasting 2000 ms was made during each test, lasting from the first to the third second.

Accuracy and precision were calculated which involves intraclass correlation coefficients (ICC).

To describe the relative contributions of the masseter and temporalis anterior muscles to the clenching effort, the following formula was used:

$$\text{Activity index (AcI)} = \frac{(\text{RMS}_{\text{masseter}} - \text{RMS}_{\text{temporalis}})}{(\text{RMS}_{\text{masseter}} + \text{RMS}_{\text{temporalis}})} \times 100.$$

The AcI can vary from +100 to -100. An activity index of +100 indicates activity of the masseter muscles (MM) only; an index of -100 indicates activity of the temporalis anterior muscles (TA) only; an index of 0 indicates equal activity of both muscle groups. This index has previously been described by Naeije *et al.*<sup>19</sup> Occlusal classes were determined using plaster study models taken during the examination in the form of alginate impressions of the volunteers' maxillae and mandibles. The Angle occlusal classes were analyzed

by an experienced professional. The plaster models were examined in habitual occlusion.

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### Statistical analysis

All data were analyzed using SPSS (Statistical Package for the Social Sciences) Statistics 17.0 (2008) for Windows. The normal distribution was tested for with the Kolmogorov–Smirnov test (with the Lilliefors correction) and with the Shapiro–Wilk test. In the case of normally distributed variables, the differences between the three occlusal classes were tested by one-way ANOVA, and differences between occlusal classes and gender were tested by two-way ANOVA. The Intraclass Correlation Coefficient (ICC) was tested using the *F*-test. Statistical significance was set at 5% ( $p < 0.05$ ).

## RESULTS

### Accuracy and precision of the study

The ICC of measurement variability was calculated as 0.765.

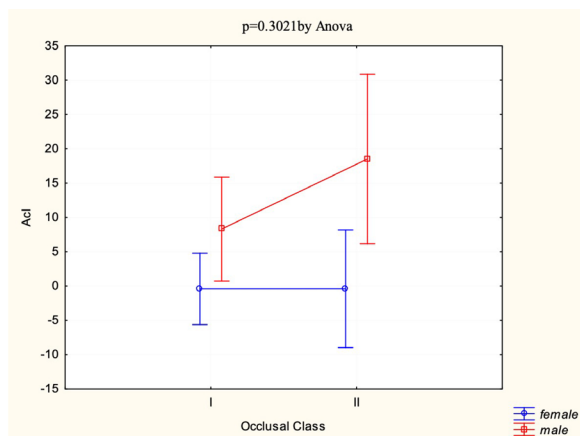
### Division into groups by occlusal class

One hundred and forty-five volunteers were included in the study. The entire group was organized by occlusal class based on examination of the plaster models created during the examinations.

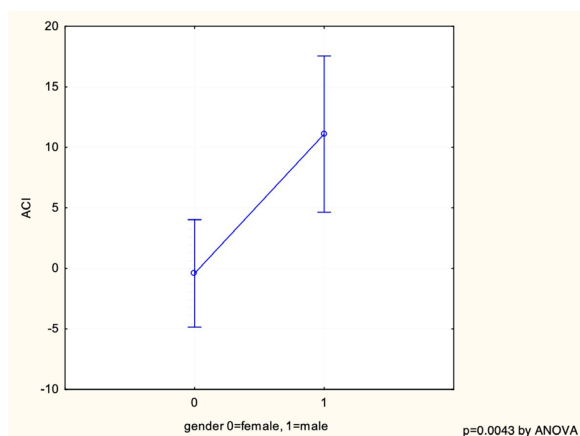
Ninety-seven of the volunteers displayed occlusal Class I, thirty-six were in Class II, and twelve were in Class III. No significant relation existed across the occlusion class groups (see Table 1). For this reason, we decided to combine the data from all 145 subjects and to consider them by occlusal class and gender. On account of the small number of cases, we excluded Class III individuals from further analysis.

**Table 1.** Activity index (AcI) by occlusal class; ANOVA  $p < 0.05$  indicates a significant difference.

	Occlusal class	n	Mean	SD	p < 0.05
<b>Activity index</b>	Class I	97	2.386	23.2354	0.312
	Class II	36	5.496	20.1875	
	Class III	12	-5.697	14.1708	



**Figure 1.** Association between occlusal class, gender, and activity index (ACI);  $p = 0.3021$ , indicates a insignificant difference.



**Figure 2.** Association between gender (0 = female, 1 = male) and activity index (ACI).  $p = 0.0043$ ; indicates a significant difference.

### Division by occlusal class and gender

The Class I group contained 34 males and 63 females, while Class II had 11 males and 25 females.

Comparison of the ACI data showed an insignificant relation between the genders in the activity indices of Classes I and II (Figure 1), while the F value was 1.864682 for the occlusal effect and 1.364424 for the gender effect. However, by considering only the association between gender and activity index, we found a significant relation between male gender and predominance of the masseter muscles, as well as between female gender and an almost equal balance between the muscles, though with a tendency towards a predominance of the temporalis anterior (Figure 2).

## DISCUSSION

Comparison of the data showed a significant relation between gender and activity indices, with a predominance of masseter muscles in the male group

and an almost equal activity index in the female group, though with a slight tendency towards predominance of the temporalis anterior.

Although we did not find any significant difference between gender and activity index in occlusal Class I or II, we did observe dominance of the masseter muscle in the male group, especially in Class II, while in female group the ACI was equal in both classes. The ACI results for both genders show that there was predominance of the masseter muscle over the anterior part of the temporalis muscle in the male group. Masseter muscles are stronger in Class II in the male group; this is in contrast with the female group, which exhibited a slight prevalence of the temporalis anterior. These results could be affected by various characteristics of the model of chewing in men and women, and well as by variations in the facial skeleton.

It is also interesting that the various Angle classes of occlusive contact in women were not significantly related to the balance between the temporalis anterior and the masseter. On the other hand, greater domination of the masseter over the temporalis anterior was seen in the males in Angle Class II; this might be explained by difference in facial skeletal structure between males and females. One additional value of our study is that it is the first of its kind to involve a large group that is homogeneous in age. To the best of our knowledge, most previous study groups contained no more than 20–30 subjects, and the few that were close in size to ours had much wider age ranges.<sup>6</sup> Additionally, previous authors did not examine the electromyography of mastication muscles or occlusal class. In considering the sEMG results, we should be aware of the results of Conceicao et al.,<sup>20</sup> who showed that significant differences can be seen in the sEMG of masseter muscles when recording the distribution of occlusal contacts with the T-scan and without. This clearly has an effect on the absolute value.

In our study, we analyzed the EMG data at the moment of 100% occlusal contact in young adult volunteers who lacked signs of temporomandibular or psychological disorders (according to the RDC/TMD). The age group was chosen to guarantee that the development of the stomatognathic system would most have finished, and that the effects of wear on the masticatory organs would be minimal. We wished to determine whether there existed any correlation between the activity index and the occlusal classes and gender.

One interesting finding arose as a result of dividing the occlusal class groups by gender: significant differences were observed between the activity index and gender, showing the predominance of masseter muscles in the male group and an equal balance in the female group, with a tendency towards the predominance of the temporalis anterior. It might be asked whether the activity index is correlated with chewing efficiency.



This question should be pursued in further studies. It seems, however, that the domination of a particular group of masseter muscles is mainly associated with type of facial skeleton structure.

A literature search regarding the relationship between the distribution of occlusal contact and sEMGs of the masseter and anterior temporal muscles revealed few studies involving comparable age groups. The studies that we did find looked at the effects of artificial interference on the voltage of the temporalis anterior and masseter muscles.<sup>19</sup>

On the basis of our results, we can conclude that, in asymptomatic patients, the activity index may also differ between genders. This can be explained by gender sEMG differences, such as electrode location, subcutaneous fat, facial morphology, and skin impedance, as well as the individual properties of electrodes. Using the BioEMG system, we were able to determine the voltage of the temporalis anterior, masseter, sternocleidomastoid, and anterior digastric muscles. The muscles mainly responsible for the closing movement of the mandible are the masseter and the temporalis anterior. Using this tool, we were unable to analyze the voltage of the other muscles involved in this movement. Our conjecture is that this may be explained by the different cranial structures of females and of males. Females and males may consequently differ in the length and direction of their muscle fibers, and thus in the strength and direction of the force generated during the mandible's closing movement. This supposition requires further study.

In our clinical experience, we have observed wearing of the front teeth in the male group, mainly as a result of compensatory wearing in Class II. This has also been found in research on dental students, which showed that more wear was observed on the anterior teeth in the Angle II relation, but that less wear was seen both in general and on the premolars in anterior protected articulation.<sup>4</sup> The findings that show that the activity of the masseter muscles in the male group is greater in Class II than in Class I, and also suggests that if orthodontic treatment could be carried out during the time of growth (though not after, when only the relation between the teeth can be corrected), the direction of growth of the bone to which the muscles are attached could be altered, helping the patient obtain the proper relationship between the activity of the muscles. This should be seen mainly as a means of preventing the pathological wearing of teeth in males.

The T-scan III system can be integrated with the BioEMG III system, allowing synchronized clinical data to be recorded and analyzed simultaneously. The measurements can then also be reviewed and compared during playback.<sup>18</sup> At present, the T-scan III/BioEMG integration software is considered the

best tool available for this, as it allows simultaneous recording and analysis of the sEMG of selected muscles and of the distribution of the occlusal force, while correlating specific occlusal moments with specific electromyographic changes. The research has some strengths point in which we can include that all participants were of a similar age - mean 18 years old. We chose this age of the participants because the development of the stomatognathic system should be finished and the influence of the external pathological stimuli is minimal. As far as we know our study group was one of the largest of the same age. Additionally, we had the possibility to record simultaneous occlusal contacts and muscle electromyography. The limitation of our study was the fact, that the only group which was not representative in enough numbers was ith occlusal Class III. The results obtained in this work require further, more detailed study.

## CONCLUSION

The activity of masseter muscles during clenching the teeth is bigger in the male than in the female group. Activity index is related to gender.

## CONFLICT OF INTEREST

The study protocol was approved by the local ethical committee. The authors declare they received no funding for this investigation. The authors declare they have no conflict of interests.

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