Electromyographic comparisons between clenching, swallowing and chewing in jaw muscles with varying occlusal parameters

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Received: 06/05/2007
Accepted: 01/10/2007

Indexed in:
-Index Medicus / MEDLINE / PubMed
-EMBASE, Excerpta Medica
-SCOPUS
-Indice Médico Español
-IBECS

Moreno I, Sanchez T, Ardizone I, Aneiros F, Celemin A. Electromyographic comparisons between clenching, swallowing and chewing in jaw muscles with varying occlusal parameters. Med Oral Patol Oral Cir Bucal. 2008 Mar1;13(3):E207-13.

http://www.medicinaoral.com/medoralfree01/v13i3/medoralv13i3p207.pdf

Abstract

The aim of this study is to determine the influence of Angle molar class, presence of a posterior crossbite, anterior guidance, as well as gender in the muscular activity of the masticatory system in a population of healthy dental students.
Study design: Surface electromyography recordings are made for the masseter, anterior and posterior temporalis and digastric muscles; in three different tests: clenching at maximum intercuspation, swallowing and chewing.
Results: The results obtained show that: men achieve a higher masseter activity at maximum effort than women. Women achieve higher values than men, for the digastric muscles in deglution. Angle class II show higher activity than other classes for the temporalis muscle in deglution, while class III show higher activity than other classes for all muscles in maximum effort. The anterior guidance does not cause significant differences. The presence of a posterior crossbite affects the behaviour of anterior temporalis and masseter muscles.
Conclusion: The results of this study show the influence of the occlusal parameters on the muscular activity of the stomatognatic system.

Key words: *Electromyography, occlusion, masticatory muscles.*

Introduction

In 1977 Helkimo suggested that the activity of the masticatorial muscles at maximum effort depends on occlusal factors such as the number of posterior occlusal contacts (1).
This notion is defended by a large number of subsequent studies where occlusal parameters are analyzed: presence of interferences or prematurities, number of posterior contacts, canine guidance... When a rigid unilateral interference is placed, there is a motor facilitation on the masseter muscle on the side of the interference and motor inhibition on the opposite side during forceful clenching (2). According to Baba(3), an increase in the activity of the anterior temporalis ipsilateral muscle will also occur. The presence of interferences during lateral excursions produces an increase in the activity of non working temporalis and masseter (4).
A higher number of posterior contacts gives a stable intercuspal support that allows elevator muscles to achieve higher levels of muscular activity during clenching and chewing (4,5).
When a canine guidance is compared with group function or bilateral balanced occlusion, it was shown that the two last ones show a higher activity of the elevator muscles. This result is obtained from multiple studies using different

occlusal appliances in healthy subjects in order to simulate experimental occlusal patterns (6-8). It is shown that a canine protected occlusion causes a reduction of elevator muscles in maximal voluntary clenching and especially in the temporal muscle on the nonworking side. This can be explained by mecanorreceptors of the periodontium having the function of regulating forces, the smaller the periodontius surface (canine guidance) the less force is made by the muscle (5,7). On the other hand other studies did not find differences in EMG activity of masseter between the use of interocclusal devices designed for canine guidance or for group function, suggesting that appliances do not act like teeth (4,9).
On the other hand,, Christensen (11) studied the masseter and anterior temporalis muscular pattern during normal function, that is, in healthy subjects with no muscular alterations. They concluded that the masseter contributes to most of the isometric force made during maximal clenching (10-12), while temporalis is a postural muscle controlling mandibular movements in excursive function (4,13,14).
According to Throckmorton, the key factors to muscular force are: size and length of muscles. When the same muscular tension is generated, the smaller muscles will be more active than the bigger ones, with the biggest being capable of generating bigger tensions. For this reason males expect higher maximum bite forces than females (15).
In our study, we analyze the influence of the following occlusal parameters: Angle molar class, presence of a posterior crossbite and type of anterior guidance on electromyographic (EMG) activity of masseter, temporalis and digastric muscles, in a group of dental students. The null hypothesis is that there will be no significant differences amongst groups with different variables.

Material and Method

Subjects were chosen from university students within the age between 22 to 29 years old. 45 subjects were selected (mean age 24), 12 men and 33 women with no dysfunction of the stomatognatic system. The volunteers accepted to participate in the study.
A complete dental history is made for each subject and intraoral photographs are taken to identify the occlusal parameters studied: right and left Angle molar class, presence of posterior crossbite in more than one tooth, and anterior guidance (normal guidance, overbite and anterior open bite). The normal vertical overlap of upper incisors is one third of the clinical crown of lower incisors (2-4 mm), the malocclusion with higher vertical overlap than normal is called overbite, and the overlap absence is called anterior open bite.
Bilateral EMG recordings of masseter, anterior and posterior temporalis, digastric muscles were perfomed with a 8 channels surface electromyographer (Myotronics ® K6-i). In order to reduce the impedance, the electrode positioning area is prepared by shaving and by using a cleansing cream to remove any excess of oil and dead cells from the epidermis (Nuprep ®). Likewise, before placing the electrodes, a small amount of conductive paste is applied onto each one (Ten 20 conductive®).
We used 8 bipolar and 1 monopolar (ground) electrodes Ag/AgCl 10mm diameter type.The position of the electrode is determined by muscle palpation, asking the patient to make a muscle effort (clenching for masseter as well as temporalis, and swallowing for digastric), and fixing them to the skin with adhesive tape. Each bipolar electrode contact was placed with a 19mm gap following the direction of the muscle fibres. The ground electrode is placed on the back of the patient's neck.
The subject must be sitting against the back of a chair, as relaxed as possible, positioning the head in such way that the Frankfort plane is parallel to the floor. Before starting the registers, we will check that the electric activity is being recorded properly for all muscles.
In order to record the muscle activity, all the subjects are trained in the different tests we aim to perform. In all cases, the electromyographic tests are carried out by a single operator.
Swallowing registration: the subject places a mouthful of water in the oral cavity without swallowing it. The muscle activity is recorded when the person is asked to swallow it.
Chewing registration: the patient is given 3 pieces of potato chips of a suitable size to allow them to be placed between the dental arches. The chewing muscle activity is recorded during 15 seconds after the patient starts chewing. The subject must not swallow during the recording.
Maximum voluntary clenching: From rest in maximum intercuspation the subject must make the highest possible effort during 3 seconds, returning to the initial rest. This action is repeated three times during recording.
All these recordings are done twice and performed in the same session with the electrodes in the same position.
- *Analysis of data*
Values obtained are the average of electric activity of each muscle given in micro-volts. Two records are taken from each test and a weight average is calculated. All the data is gathered as to conform a worksheet and statistically analyse data with SPSS 1.1.programme. Statistical tests applied are parametric and non parametric: Student's t-test, Mann-Whitney U test, Analysis of variance (ANOVA), Kruskal Wallis' test. A result is considered to be statistically significant when $p< 0.05$.

Results

Table 1 present the mean values of the EMG activity for right masseter muscle (RMM), left masseter (LMM), right anterior temporalis (RTA), left anterior temporalis (LTA), right temporalis posterior (RTP), left temporalis posterior(LTP), right digastric (RDA) and left digastric (LDA) during swallowing (fig1), chewing (fig2) and maximal clenching tests (fig3). The EMG values are given in micro-volts. (Table 1)

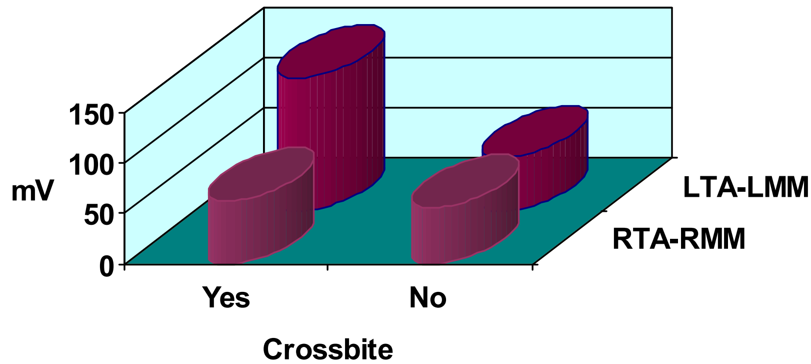

Fig. 1. Deglution registration. Left anterior temporalis (LTA), left masseter (LMM), right masseter (RMM), right anterior temporalis (RTA), left posterior temporalis (LTP), left digastric (LDA), right digastric (RDA), right posterior temporalis (RTP).

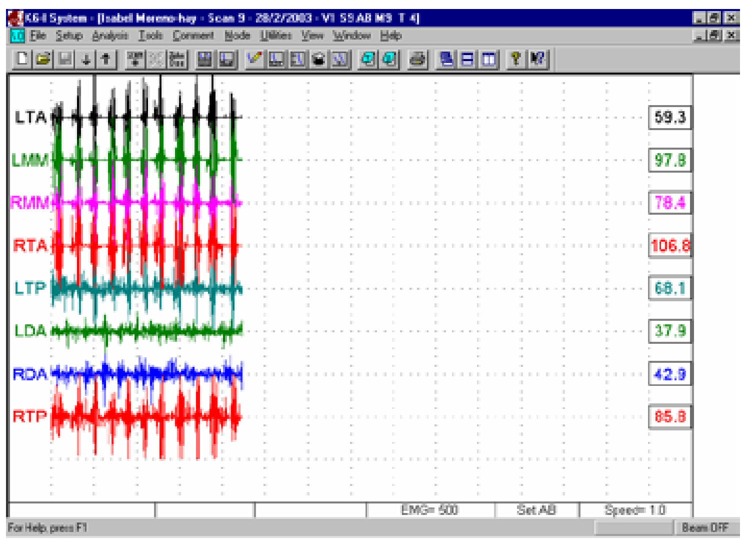

Fig. 2. Mastication registration. Left anterior temporalis (LTA), left masseter (LMM), right masseter (RMM), right anterior temporalis (RTA), left posterior temporalis (LTP), left digastric (LDA), right digastric (RDA), right posterior temporalis (RTP).

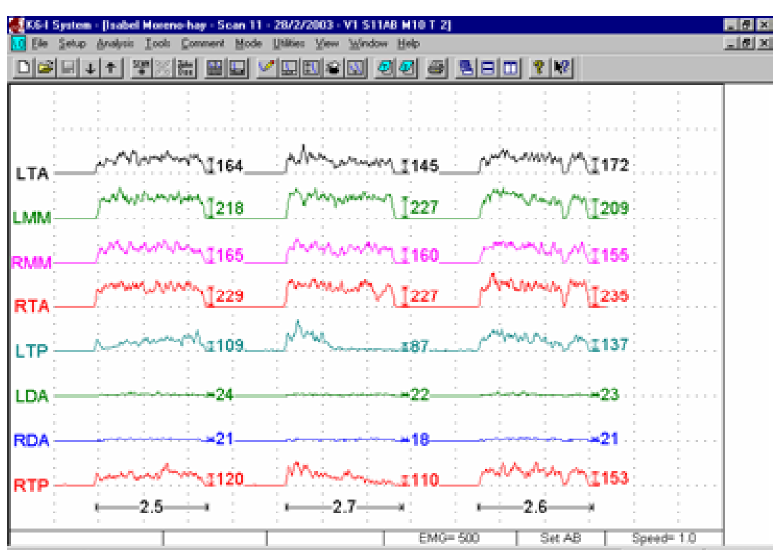

Fig. 3. Maximum voluntary clenching registration. Left anterior temporalis (LTA), left masseter (LMM), right masseter (RMM), right anterior temporalis (RTA), left posterior temporalis (LTP), left digastric (LDA), right digast.

Table 1. Mean and standard deviation of EMG values in three different test given in microvolts of the entire sample. Left anterior temporalis(LTA), left masseter (LMM), right masseter (RMM), right anterior temporalis (RTA), left posterior temporalis (LTP), left digastric (LDA), right digastric (RDA), right posterior temporalis (RTP).

	DEGLUTION	MASTICATION	MAXIMUM EFFORT
RTA	6.91 ± 5.35	60.39 ± 25.32	166.08 ± 75.94
LTA	6.73 ± 6.06	68.32 ± 25.73	177.48 ± 69.00
RMM	6.03 ± 5.14	61.93 ± 25.79	147.91 ± 72.01
LMM	5.12 ± 3.19	62.78 ± 29.44	153.44 ± 77.21
RTP	8.97 ± 4.68	40.73 ± 16.47	98.94 ± 61.91
LTP	7.80 ± 5.79	43.79 ± 17.49	94.73 ± 63.25
RDA	11.47 ± 5.29	34.13 ± 12.16	29.72 ± 25.23
LDA	11.50 ± 5.14	34.30 ± 12.736	30.15 ± 32.73

Gender:

The first results to be described are the differences according to gender. In our sample 26.6% were men and 73.33% were women. When deglution values and gender are taken into consideration there are no significant differences for parametric tests. However, when applying the Mann-Whitney U non parametric test we found significant differences between men and women regarding digastric muscles (LDA p=0.0197) (RDA p=0.0133), women showing higher values (LDA=22.50 µV; RDA=23.62 µV) than men (LDA=12.75 µV; RDA=15.50 µV). Nevertheless, during the mastication tests no significant differences can be seen between both sexes (p>0.05).

The maximum effort tests show differences between men and women for masseter muscles. LMM (p=0.0273) and RMM (p=0.0093), men values (LMM= 195.09 µV± 92.13µV; RMM= 193.21 µV ± 55.74) are higher than women (LMM=138.28µV± 66.27; RMM= 131.43 µV ± 70.79).

Angle Molar Class:

The following result is the difference between molar Class I, II or III. ANOVA test is used. We subdivided the sample in right and left molar class, as this can vary in the same person. Right and left molar class is analyzed with ipsilateral and contraleteral muscles. 31 individuals fall within right class I, 8, right class II; 6, right class III. In the left side 30 individuals presented class I; 8, class II; 7, class III.

In deglution, we obtain significant differences between right molar class I and II for LTP (p=0.0452), being the electromyographic value higher for class II. However, no significant differences were found when analysing the left molar class.

In mastication significant differences appear for RTA between right class I and right class II (p=0.0116), and between left class I and II (p=0.0127). LTP also showed differences (p= 0.0302) between left class I and II. RTP, is statistically different (p=0.0082) between right class I and II; the differences found in the left side were between class I and II and between class II and class III (p=0.008). In all cases class II achieved the highest EMG values.

With maximum effort tests we have seen how subjects with molar class III showed the highest EMG values for all pairs of muscles except for the digastric, with statistically significant differences (p=0,0279) for LTA in the left side between class II and I, and between class II and III. (Table 2)

Posterior crossbite:

Within the chosen sample, only 7% of the population showed a crossbite. When applying the parametric and non-parametric tests for deglution and mastication, no statistically significant differences were found.

However, during the maximum effort tests, we obtained

	RIGHT CLASS I	RIGHT CLASS II	RIGHT CLASS III
RTA	149.25 ± 52.85	206.88 ± 110.34	220.55 ± 58.10
LTA	178.40 ± 63.94	185.16 ± 70.73	187.35 ± 76.92
RMM	155.45 ± 68.08	147.64 ± 105.33	201.37 ± 20.90
LMM	159.25 ± 75.69	178.70 ± 85.90	191.82 ± 85.90
RTP	82.56 ± 49.89	143.58 ± 68.45	144.65 ± 81.71
LTP	85.47 ± 51.97	137.56 ± 61.56	121.73 ± 73.01
RDA	39.53 ± 33.19	25.60 ± 13.32	13.45 ± 7.18
LDA	38.89 ± 35.97	28.24 ± 21.01	12.75 ± 3.19

	LEFT CLASS I	LEFT CLASS II	LEFT CLASS III
RTA	160.39 ± 61.11	167.56 ± 109.33	181.48 ± 85.21
LTA	185.40 ± 54.81*	123.46 ± 72.89*	226.80 ± 50.63*
RMM	154.06 ± 78.26	139.76 ± 90.52	176.20 ± 33.95
LMM	165.26 ± 82.98	179.68 ± 93.18	171.36 ± 57.78
RTP	93.20 ± 56.81	112.72 ± 77.48	115.54 ± 85.43
LTP	99.24 ± 58.02	90.58 ± 54.96	103.72 ± 81.00
RDA	30.94 ± 26.92	29.60 ± 20.63	45.98 ± 40.05
LDA	31.07 ± 23.98	25.48 ± 16.61	49.38 ± 56.84

Table 2. Maximun effort test analyzed in relation to right and left molar class. There's a tendency of molar class III to achieve the highest values in microvolts. (*= p< 0.05). Left anterior temporalis(LTA), left masseter (LMM), right masseter (RMM), right anterior temporalis (RTA), left posterior temporalis (LTP), left digastric (LDA), right digastric (RDA), right posterior temporalis (RTP).

that the LMM (p=0.0118) showed differences depending on the presence or absence of a left crossbite, sharply reducing its activity values. For a better comprehension of this result, we analyze the difference of values between the left side anterior temporalis and masseter (LTA-LMM) and the presence of a left crossbite is analysed, obtaining a statistically significant value (p=0.013). (Chart 1)

Anterior guidance:

The sample was classified in three groups: 14 subjects with overbite, 8 subjects with anterior open bite and the remaining 23 subjects with a normal range of vertical overlap. ANOVA test is used and no significant differences were found for deglution, mastication or maximum effort tests.

Discussion

Due to the existing lack of consensus amongst professionals for normality in electromyographic patterns, Cooper, in 2004(16) tried to compile several diagnostic criteria from those practitioners working with electromyography and kinesiography, reaching the conclusion that a criteria to assess normality (physiology) is the presence of symmetry between right and left side. It reported that a minimal acceptable clench EMG was 125 µV for closing muscles (anterior temporalis and masseter). The individuals of our sample were healthy students and Cooper's physiological conditions were fullfilled: the minimal value (125 µV) is largely exceeded and symmetry is also present. (Table 1)

However, in our study, the anterior temporalis muscle is more active than masseter during maximal clenching, swallowing and chewing (Table 1). These results differ from the ones obtained by others authors reporting that the masseter muscle contributes to the major part of the isometric force made during maximal clenching, prevailing over the anterior temporalis muscle (4). At low levels of bite force, the myoelectrical activity of the anterior temporalis muscle thus exceed the masseter muscle. As bite force increases, so does the EMG masseter muscle (11). The activity of anterior temporal muscle is higher if there is no dental posterior contact exists, controlling jaw in excursive movements (4,15,17,18).

A study obtained mean EMG value for masseter during maximum clenching 462 ± 213 µV and for anterior temporalis 341± 139 µV in a control group (19). In our sample we reached values in the range of 170 µV for anterior temporalis and 150 µV for masseters. (Table 1)

During chewing, the masticatory pathway in the proximity of intercuspal position is a functional pathway related to the elevator muscle activity (masseter and temporalis) (20). In our sample, the muscle showing highest variable values is the anterior temporalis. The values we have obtained in the range of 60-70 µV (table 1) are similar to the ones of Kimoto's study: anterior temporalis (63.9±39.9 µV; 54.0±44.6 µV); masseter (76.9±62.9 µV; 28.7±33.7 µV).

The results for the deglution test showed that the highest electromyographic activity values belong to the digastric muscles. During swallowing, we fix both dental arches as we seal with the tongue the oral cavity. This positioning of the jaw results in an activation of the temporalis muscles, specially the posterior ones (17), while the masseter remains inactive.

The differences found between sexes match up with Throckmorton's theory where a difference in muscle length and bulk would justify men's higher isometric force (15,21). We can not explain the fact that women's digastric activity is higher than in men during swallowing, as Throckmorton (15) did not explain why there were no differences in voluntary maximum incisor bite force between males and females.

Occlusion influences the activity of muscles of the stomatognatic system, and so did Angle molar class in the results we obtained. The most affected muscle by this occlusal parameter was the temporalis, and especially the posterior section.

It is controversial whether the temporalis muscle works as one or if each section has its proper activity. Alhgren

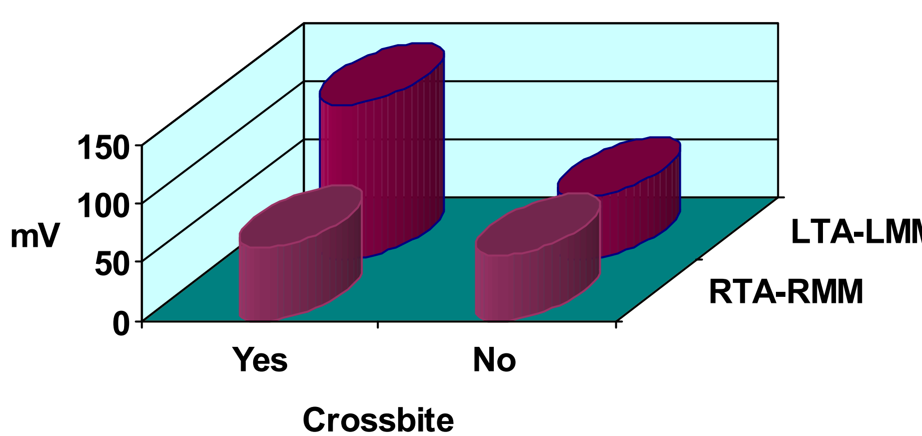

Chart 1. The presence of posterior crossbite increases the difference of activity between LTA and LMM. Left anterior temporalis(LTA), left masseter (LMM), right masseter (RMM), right anterior temporalis (RTA).

(13) did not found statistical differences between the three divisions of the muscle during voluntary clenching, but during jaw's retruded position, the posterior temporalis was more active, but other studies suggest that there are similar neural control mechanisms for both parts of temporalis muscle so they don't have different functions (22).
When the vertical dimension is raised and a protrusive positioning of the jaw is done, there's an activity decrease of temporalis muscle, fact that is important when a therapeutic appliance is designed (23). It has been speculated that a retrognathic face has a high activity of posterior temporalis and a prognathic face has a high activity in the anterior temporalis when clenching in intercuspal position (13,24).
From the results of our study we found that for molar class II, there was an increase in the electrical activity of the contralateral temporalis muscle, in both anterior and posterior sections. Furthermore, in the ipsilateral side of molar class II, the posterior temporalis activity was as well more active. These results are not coincident with Harper (24) ones, where classes II give lower values than classes I in maximal effort in maximum intercuspation for masseter and temporal anterior.
On the other hand, in Class III all muscles showed a tendency to be more activated than classes I and II, specially in maximum effort tests, even though there were no statistically differences ($p<0.05$). This muscle condition could be a risk factor in the development of craniomandibular disorders (5,25,26).
When there is a unilateral crossbite it affects the ipsilateral muscular activity. This malocclusion resulted in a high decrease of the ipsilateral masseter activity during maximum effort tests, so the major part of the force was generated by anterior temporalis muscle. Muscle asymmetry can be, as well, a risk factor for temporomandibular disorders (5,26).
No significant results were obtained when comparing the different types of anterior guidance, probably because the tests analysed do not highlight their influence on the muscular activity (deglution, mastication and maximum effort). An analysis of the results would be required by means of an effort test in protruded position. Other studies have suggested that the direction of the closing pathway is related to the occlusal morphology during the last millimetres of the closing phase; in the sagittal closing pathway the lingual form and inclination of the upper anterior teeth will influence the elevator muscle activity (20).
To refine statistical results it would be advisable a larger sample, with more individuals for variable analyzed.

Conclusions

The results obtained show the existence of differences between both sexes in maximum effort tests. In maximum effort, men achieved (43%) higher muscular activity than women for masseter muscles. On the other hand, during deglution, women achieved (20%) higher muscular activity than men for digastric muscles .
The temporalis muscle is the most affected in Angle molar class II during swallowing and chewing. Classes III presented more activity for all pairs of muscles (excepting digasric) than classes I and II in maximum effort test.
Despite the low frequency of a posterior crossbite in this sample, it has demonstrated an important effect upon the activity of ipsilateral masseter in maximum clenching. The major force is produced by anterior temporalis muscle, while masseter remains nearly inactive.
No significant differences were found between anterior open bite, overbite and normal anterior guidance.

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ACKNOWLEDGEMENTS
Mª Carmen Moreno: Service of Rehabilitation and Electromyography Services of the Faculty of Odontology at Universidad Complutense of Madrid (Spain).