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ORIGINAL ARTICLE

Effect of natural mediotrusive contact on electromyographic activity of jaw and cervical muscles during chewing

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Abstract

Objective. This study evaluated the effect of a natural mediotrusive contact on the electromyographic (EMG) activity of the anterior temporalis and sternocleidomastoid muscles during chewing in healthy subjects. ***Materials and methods.*** The study sample included two groups of 15 subjects each (Group 1: with natural mediotrusive contact; Group 2: without natural mediotrusive contact). Bilateral surface EMG activity was recorded on anterior temporalis and sternocleidomastoid muscles during unilateral chewing of a half cookie and unilateral chewing of a piece of apple. Anterior temporalis and sternocleidomastoid muscle activity was normalized against activity recorded during maximal voluntary clenching in intercuspal position and maximal intentional isometric head–neck rotation to each side, respectively. The partial and total asymmetry indexes were also calculated. Data were analyzed using Mann-Whitney, Wilcoxon and unpaired *t*-test. ***Results.*** EMG activity of anterior temporalis and sternocleidomastoid muscles showed no significant difference between the groups. EMG activity of anterior temporalis was similar between working and non-working sides during chewing in both groups. EMG activity of sternocleidomastoid muscle was higher in the working side than in the non-working side in Group 2 subjects. Asymmetry indexes were not significantly different between groups. ***Conclusions.*** The similar EMG pattern and asymmetry indexes observed suggest the predominance of central nervous control over peripheral inputs on anterior temporalis and sternocleidomastoid motor neuron pools.

Key Words: *Electromyography, mastication, masticatory muscles, neck muscles*

Introduction

The effect of mediotrusive contacts on muscular activity has been a topic of debate for decades and its clinical relevance is still unclear. In the literature, the side toward which the mandible moves is called laterotrusive, working or functioning side, while the other side is called mediotrusive, non-working, balancing or non-functioning side [1].

According to the glossary of prosthodontic terms [2], non-working side occlusal contacts are defined as contacts of the teeth on the side opposite to the side toward which the mandible moves in articulation. The non-working side interference is an undesirable contact of the opposing occlusal surfaces on the non-working side. In occlusion studies, however, clear distinction between mediotrusive contacts and occlusal interferences is not always done [3], frequently both concepts are used as synonymous.

Okeson [4] stated that mediotrusive contacts are differently perceived from other occlusal contacts by the central nervous system and should be avoided in developing an optimum functional occlusion. This agrees with the concept of mutually protected occlusion proposed by Schuyler [5] in the 1950s. It has been suggested that mediotrusive contacts can cause changes in the activation and coordination of jaw muscles [6]. Therefore, some authors have attributed a potential risk to occlusal interferences and recommended their elimination [7,8], while others suggest

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that this kind of contact does not cause major problems [3,9] and could even constitute a more protective than harmful element for the stomatognathic system [10].

A recent study [11] performed on 21 healthy subjects showed no difference in the EMG activity of the anterior temporalis (AT) muscles during chewing between natural dentition (without interference) and splints with a mediotrusive contact. Many studies performed using an artificial interference have only assessed the immediate effect on EMG activity without including long-term adaptation. Therefore, it is important to determine if a natural mediotrusive contact in well-adapted subjects influences the pattern of muscular activity.

In the present study we choose to record the activity of the AT muscle because it is an important closing and positioning muscle of the mandible [4]. In addition, the AT muscle is subjected to a fine proprioceptive control of its activity, since it presents a higher number of muscular spindles compared to the masseter muscle [12]. Cervical and jaw muscles show a close functional relationship in the cranio-cervical-mandibular system during jaw-opening/jaw-closing tasks [13] and during chewing tasks [14]. A different recruitment pattern during chewing has recently been reported for the sternocleidomastoid (SCM) and trapezius muscles; while SCM activity was observed in all cycles, trapezius activity was only observed in some cycles [14]. Therefore, it is important to know if the presence of a natural mediotrusive occlusal contact influences SCM activity.

EMG activity of AT muscles has been recorded during different chewing tests, but most of them were unilateral. As far as we know, SCM activity has mainly been recorded unilaterally during gum chewing [14–16]. Therefore, information on bilateral muscle activity of jaw and cervical muscles during habitual chewing is still lacking. The hypothesis was that the presence of a natural mediotrusive contact modifies the EMG activity pattern and the asymmetry indexes. The aim of this study was to evaluate the patterns of EMG activity and the asymmetry indexes of AT and SCM muscles in healthy subjects with and without a natural mediotrusive contact during chewing.

Materials and methods

Sample studied

The study was carried out in a group of 15 subjects with mediotrusive contact (Group 1: eight males and seven females, mean = 20.4 ± 1.3 years) and a group of 15 subjects without mediotrusive contact (Group 2: five males and 10 females, mean = 20.1 ± 1.2 years).

In our study mediotrusive contact was defined as an occlusal contact between support cusps of the natural second molars on the non-working side during a slightly forced lateral excursive jaw displacement, which did not interfere with the occlusal contact during laterotrusive guidance movement on the working side.

This occlusal feature was identified by a 50 μm thick polyester strip (Hawe Striproll® 687, KerrHawe SA, Switzerland) within the first millimeters of the lateral excursion [17]. We considered the contact between the second molars, since it is the most prevalent [18]. In order to homogenize the laterotrusive movement, subjects were instructed to maintain the intensity and direction of the jaw displacement. Jaw movement was checked in all subjects by the same examiner.

To determine the working side (WS), each subject was asked about the side more frequently used during chewing. If the subjects had no clear preference, they had to chew a piece of apple to visually determine the WS. Group 1 only included subjects with a mediotrusive occlusal contact on the opposite side to the more frequently used for chewing. All subjects had complete natural dentition (excluding third molars), protrusive incisive guidance, Angle Class I, laterotrusive canine guidance or group function, normal overjet and overbite, no unilateral or bilateral crossbite, alternating unilateral chewing pattern, no prior orthodontic treatment, no history of orofacial pain or craniomandibular-cervical-spinal disorders, no history of cervical or dental trauma or fractured teeth and no large restorations, which involved the incisal edge or one or more cusps. None of the subjects were on medications that could influence muscle activity and none reported systemic diseases or showed clinically apparent facial asymmetry. The subjects were enrolled among students from the Faculty of Dentistry or the Faculty of Medicine from the University of Chile, during a period of 12 weeks. All experimental procedures were conducted in accordance with the Helsinki Declaration of 1975, as revised in 1983, and approved by The Ethics Committee of the Faculty of Dentistry, University of Chile (number 2012/07). Informed consents were obtained from all participants.

Electromyographic recording

Bipolar surface electrodes (BioFLEX: BioResearch Associates, Inc., Brown Deer, WI) were located on the right and left AT and SCM muscles. The skin area was cleaned with alcohol to reduce skin impedance and to enhance the signal-to-noise ratio. The lower electrode was placed on the AT muscles 1 cm above the zygomatic arch and 1.5 cm behind the orbital border. The upper electrode was placed 1.5 cm over the lower electrode and parallel to the main direction of muscle fibers [19]. The electrodes were placed on the SCM muscles in the anterior border (middle portion), 1 cm above and below the motor point [20].

A surface ground electrode was attached to the forehead.

EMG activity was recorded using a 4-channel computerized instrument in which the signals were amplified (Model 7P5B preamplifier, Grass Instrument Co., Quincy, MA), filtered (10 Hz high pass and 2 kHz low pass), with a common mode rejection ratio higher than 100 dB. The output was filtered again (notch frequency of 50 Hz), full-wave rectified and then integrated (time constant of 0.33 s) and recorded online on a computer exclusively dedicated to acquisition and processing of EMG signals. EMG signal was acquired at a sample rate of 200 Hz (50 Hz each channel) with a 12 bits A/D converter (MAX191) connected to the computer through an RS-232 port. The system was calibrated before each record.

Test foods

The foods chosen for chewing tasks were cookies (Kuky clásica, Nestlé® Chile) and raw apple with peel (variety Pink Lady). Each cookie was cut into halves (4 cm × 2 cm × 1.4 cm) and the apple was cut into pieces of 3 cm × 2.5 cm × 2 cm. The size of pieces of cookie and apple were similar in order to decrease this effect. These two test foods were chosen because they present different hardness and texture, which may affect the muscle activity.

Experimental procedures

Bilateral EMG activity was recorded while the subject was sitting, with his/her head in the postural position and the eyes open looking straight ahead. The seated position was chosen to register EMG activity because it allowed researchers a better standardization of the recordings. Each subject underwent three EMG recordings of AT and SCM muscles during the following tasks: unilateral chewing of a half cookie (Cookie) and unilateral chewing of a piece of apple (Apple).

AT and SCM muscle activity was normalized against activity recorded during maximal voluntary clenching in intercuspal position and maximal intentional isometric head–neck rotation to each side, respectively. EMG activity was recorded during 5 s. Before performing the maximal isometric head–neck rotation, the subject was instructed to avoid shoulder movements; then, EMG activity was recorded, while his head was blocked by one of the researchers [21].

During cookie and apple chewing, participants chewed one piece of food and performed habitual chewing on the WS. Three trials were made for each type of food and a new piece was given for each trial. Each subject placed a piece of test food in his/her mouth before starting the EMG recording.

No trial lasted more than 15 s. To avoid muscular fatigue, a rest period of 1 min between each trial was allowed. In addition, a 3 min resting period between tasks was included [19]. In each chewing task, mean EMG activity was obtained over at least 8.4 s of continuous recording, the minimum time of stable EMG signal obtained. This selected frame was measured every 0.1 s and later averaged with purpose-designed software. The mean value of the three trials at each task for each subject and each muscle was normalized based on the formula used by Okano et al. [22]:

Normalized Muscular Activity (NMA) ratio = EMG recorded during each chewing task/EMG recorded during standardization task.

In order to quantify asymmetrical masticatory muscle activity, the partial and total asymmetry index (AI) was calculated according to Naeije et al. [23]:

Partial AI = (WS muscle − NWS muscle)/(WS muscle + NWS muscle)%,

Total AI = (WS SCM + WS AT − NWS SCM − NWS AT)/(WS SCM + WS AT + NWS SCM + NWS AT)%

The AI may vary between −100 and +100%. Negative numbers show the predominance of the NWS muscle, while positive numbers indicate WS muscle predominance. A zero value reflects a similar muscular activity between NWS and WS.

Statistical analysis

Estimated sample size for two-sample comparison of means with statistical power of 80% was used.

The Shapiro-Wilk test was applied to determine the normality of the sample. EMG activity data presented a non-normal distribution; therefore, the Mann-Whitney U-test was used to compare between groups and the Wilcoxon signed rank-sum test was used to compare between sides. After the AI calculation, data presented a normal distribution and the unpaired *t*-test was used to compare groups. The ANOVA for repeated measures test was used to test EMG measurement reproducibility.

Significance was set at $p < 0.05$. The data were analyzed using SPSS software (IBM SPSS Statistics®v19).

Results

Reproducibility of EMG recordings was assessed from repeated measurements (three trials) obtained from different subjects over different days. ANOVA results showed no systematic differences ($p > 0.05$).

Figures 1 and 2 show EMG activity recorded in AT and SCM muscles, respectively. The comparison of normalized EMG activity between Groups 1 and 2 in the working and in the non-working sides during cookie and apple chewing is shown in Table I. No significant difference was found in AT muscle and in SCM muscle ($p > 0.05$).

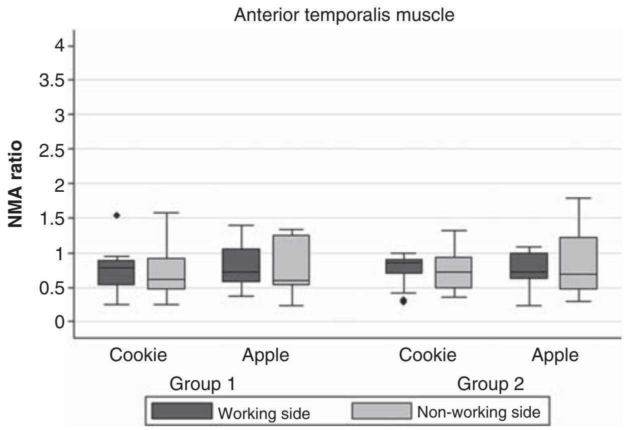

Figure 1. Box plot graph showing median and IQ range of anterior temporalis EMG activity on group with mediotrusive contact (Group 1) and without mediotrusive contact (Group 2) on working and non-working sides recorded during unilateral chewing of a half cookie (Cookie) and unilateral chewing of a piece of apple (Apple). Normalized Muscular Activity (NMA) ratio = EMG recorded during chewing/EMG recorded during maximal voluntary clenching in intercuspal position.

The comparison of EMG activity from AT muscle between working and non-working sides in Groups 1 and 2 during both chewing tasks showed no significant difference ($p > 0.05$), as depicted in Table I.

The comparison of EMG activity from SCM muscle between working and non-working sides in Group 1 showed no significant difference ($p > 0.05$), whereas significant differences were observed for Group 2 (without mediotrusive contact), showing a higher activity on the working side than non-working side during cookie and apple chewing, as shown in Table I.

In regard to AI, Table II shows the comparisons between Groups 1 and 2 during both chewing tasks. No significant difference was observed in the partial and total AI during cookie and apple chewing ($p > 0.05$).

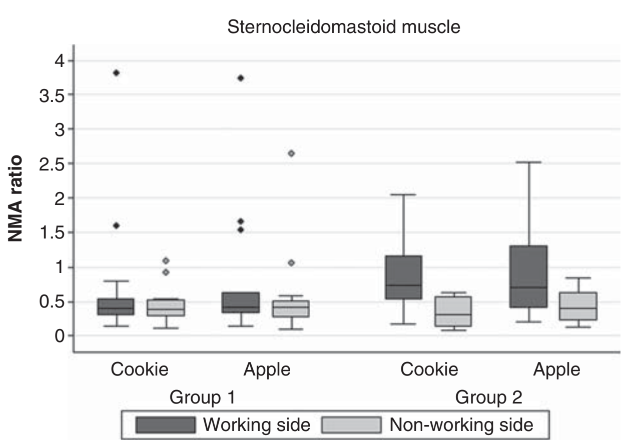

Figure 2. Box plot graph showing median and IQ range of sternocleidomastoid EMG activity on group with mediotrusive contact (Group 1) and without mediotrusive contact (Group 2) on working and non-working sides recorded during unilateral chewing of a half cookie (Cookie) and unilateral chewing of a piece of apple (Apple). Normalized Muscular Activity (NMA) ratio = EMG recorded during chewing/EMG recorded during maximal intentional isometric head–neck rotation to each side.

Discussion

This study evaluated the effect of a natural mediotrusive occlusal contact on the activity of jaw and cervical muscles during chewing. The main finding of this study was a similar pattern of EMG activity and similar asymmetry indexes between subjects with and without a natural mediotrusive occlusal contact in both AT and SCM muscle pairs.

The similar EMG activity observed between both groups in the working side and non-working side, during cookie and apple chewing, suggests the predominance of central supra-segmentary control in the motor neuron pool that controls AT or SCM muscles over peripheral feedback mechanisms [24].

Most of the investigations have been conducted to evaluate the immediate influence on the muscular activity produced by the insertion of an artificially occlusal interference (as splint or onlay), without including long-term adaptation. Ethical concerns regarding the potential damage that artificial interference could produce on the subject [25] make natural mediotrusive contact a good model to study this phenomenon. It should be noted that research about the effect of a mediotrusive contact on the SCM muscle activity is scarce, making it difficult to compare our results.

This is, probably, the first study that compares, in well-adapted healthy subjects with and without a natural molar mediotrusive contact, the effect of this occlusal feature on bilateral EMG activity of the AT and SCM muscles during habitual food chewing.

The similar EMG activity of AT muscle between working side and non-working side is in disagreement with the report of Nishigawa et al. [6], who observed higher activity in AT muscle of the working side compared to the non-working side during gum chewing in subjects with and without natural mediotrusive contact. This disparity may be explained at least by three reasons: (a) the different material chewed, cookie, apple and gum, which possess different rheological characteristics that could have differential influence on EMG activity; (b) in Nishigawa's study the comparison between WS and NWS was not performed, only the asymmetry index was calculated; and (c) the conditions used in our work, i.e. natural mediotrusive contact, habitual chewing side and common foods, possibly diminished the intensity of peripheral feedbacks, allowing the predominance of central nerve circuits during chewing [26,27].

SCM muscle showed higher EMG activity on the working side in the group without mediotrusive contact. This result agrees with Kohno et al. [15], who recorded bilateral EMG activity during gum chewing.

Table I. Comparison of normalized EMG activity between Group 1 and Group 2, and between working side and non-working side, recorded during unilateral chewing.

			p-value			
					WS vs NWS†	
	Muscle	Test food	WS	NWS	Group 1	Group 2
Group 1 vs Group 2‡	AT	Cookie	0.395	0.576	0.650	0.609
	AT	Apple	0.868	0.803	0.776	0.394
	SCM	Cookie	0.065	0.604	0.955	0.009*
	SCM	Apple	0.152	0.983	0.649	0.011*

AT, anterior temporalis; SCM, sternocleidomastoid; Cookie, chewing of a half cookie; Apple, chewing of a piece of apple; WS, working side; NWS, non-working side.
‡Mann-Whitney *U*-test; †Wilcoxon signed rank-sum test; *Significant difference at $p < 0.05$.

It is noteworthy that the principal role of the SCM during unilateral contraction is to tilt the head towards the ipsilateral side and to rotate the head to the contralateral side [28]. Therefore, this muscle could be more sensitive to changes in jaw posture during chewing, resulting in an increase of EMG activity in the working side.

During chewing, Kohno et al. [15] found high EMG activity in SCM muscle near the mastoid insertion and low activity at the middle part of this muscle. This is relevant, since in our study the electrodes were located in the middle portion of the SCM muscle. The lack of responsiveness in the mediotrusive contact (Group 1) may be due to the fact that this feature provides a contact point that balances the jaw movement, which may cause a biomechanical change with smaller motor unit recruitment, explaining the reduced EMG activity on the working side.

It is important to point out that the concomitant activation of SCM muscle during chewing may serve a role in stabilizing the head in space while jaw muscles move the mandible to achieve a finely controlled tridimensional movement pattern, with optimal force, to accomplish food-crushing and transport for preparing to swallow [14,16,28,29]. This also supports the concept of a functional trigemino-cervical coupling during jaw activities [13].

Although a natural mediotrusive occlusal contact should not initially interfere with the laterotrusive guidance during chewing movement (all subjects had a functional canine guidance or group function), when occlusal contact takes place on both sides (in Group 1) a change in the normal rhythmic cycle of chewing could occur and, consequently, a change in the muscular engram, which represents a muscle formula for particular mandibular placement in all three dimensions [30].

From an overall point of view our results support the idea of functional and/or structural adaptation mechanisms in the cranio-cervical-mandibular system, upon the presence or absence of natural mediotrusive occlusal contacts. This is in line with the idea that biological systems cannot be viewed as rigid and immutable [31,32].

In relation to partial and total AI, results did not show differences between the groups studied. This result agrees with Pröschel et al. [33], who found that during gum chewing muscular activity was symmetric, because there was no significant difference between working and non-working sides. It is

Table II. Comparison of normalized partial and total asymmetry index between Group 1 and Group 2 recorded during unilateral chewing.

		Group 1		Group 2			
AI	Test food	Mean (%)	SD	Mean (%)	SD	95% CI	*p*-value*
AT	Cookie	2.6	21.8	1.5	14.3	-14.8 to 12.7	0.877
SCM	Cookie	5.8	32.7	31.2	38.0	-1.1 to 51.9	0.060
AT	Apple	0.8	19.6	-2.1	18.2	-17.2 to 11.1	0.661
SCM	Apple	10.0	36.9	26.4	35.2	-10.6 to 43.3	0.225
Total	Cookie	6.0	24.0	14.8	23.6	-9.0 to 26.6	0.323
Total	Apple	5.6	24.1	11.8	22.2	-11.2 to 23.4	0.477

AI, asymmetry index; AT, anterior temporalis; SCM, sternocleidomastoid; Cookie, chewing of a half cookie; Apple, chewing of a piece of apple.
*Unpaired *t*-test.

important to note that these authors used the same ratio EMG activity of AT muscle in healthy subjects without mediotrusive contacts. Our result, however, disagree with Blanksma and van Eijden [34], who recorded unilateral EMG activity of AT muscle in subjects without mediotrusive contacts during right and left chewing. They found that working-condition muscle regions were significantly more active than balancing-condition muscle regions.

During clenching tasks in intercuspal position a more symmetrical activation of the muscle pairs is expected. We considered, however, it important to check the activation magnitude of jaw and neck muscles during chewing, a dynamic task, allowing us to compare the work efforts of chewing task between working and non-working sides for each muscle [6].

The present study has at least three limitations: (a) retruded contact position/intercuspal position (RCP/IP) relationship was not recorded. In Ramfjord's [35] study, an occlusal discrepancy between RCP and IP demonstrated an asymmetrical, so-called unharmonious pattern of muscular activity during a functional condition. Clark and Evans [36] pointed out that no proper description of 'normal' EMG activity in masticatory muscles exists; (b) it is not possible to determine if the normal EMG pattern changed when the mediotrusive contact started and if it returned to a normal pattern in the long-term; and (c) the influence of a mediotrusive contact on other jaw muscles (as masseter), by which future studies that will address these issues are required.

Within the above-mentioned limitations of our study, we rejected our hypothesis because there is no difference in the EMG activity pattern and asymmetry index of the AT and SCM muscles between healthy subjects with and without a natural mediotrusive occlusal contact.

In this study we did not find that the presence of a natural mediotrusive contact causes an alteration of the EMG patterns and muscular symmetry in AT and SCM muscles. It is, however, important to note that these results are applicable only to well-adapted healthy individuals and cannot be extrapolated to patients that develop myofascial pain.

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