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ORTHODONTICS

Comparison of muscle activity between subjects with or without lip competence: Electromyographic activity of lips, supra- and infrahyoid muscles

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ABSTRACT

\textbf{Aim:} This study compares the electromyographic (EMG) activity of the muscles from the lips and hyoid bone in subjects with or without lip competence.

\textbf{Methodology:} Two groups of 20 subjects each, with or without lip competence were studied. EMG activity of the superior orbicularis oris (SOO), inferior orbicularis oris (IOO), suprahyoid (SH) and infrahyoid (IH) muscles was recorded with the subject seated in the upright position during the following tasks: (1) at rest; (2) speaking; (3) swallowing; (4) forced deep breathing; (5) maximal voluntary clenching; and (6) chewing.

\textbf{Results:} EMG activity was significantly higher in subjects without competent lips than with competent lips in the SOO and IOO muscles during tasks 3 and 4, SOO during task 2 and IOO during task 6. EMG activity was similar in the SOO and IOO muscles during tasks 1 and 5, SOO during task 6 and IOO during task 2. Activity of the SH and IH muscles was similar in both groups for all tasks.

\textbf{Conclusions:} Higher activity in subjects without competent lips implies a higher muscular effort due to the requirement of lip sealing during functional activities. Hyoid muscular activity was not modified by the presence or absence of lip competence.

Introduction

It is well known that activity of the lip and tongue muscles and the hyoid bone is closely related to the dental arch and/or craniofacial morphology; thus, observation of the dynamics of perioral soft tissues at rest, during speech, swallowing, breathing, clenching and chewing is extremely important when the relationship between malocclusion and oral function is being studied.\cite{1,2,3,4}

Competent lips are obligatory to have balance between the buccal and tongue muscles. A subject is classified as having competent lips when his lips are in light contact at clinical rest.\cite{5,6,7,8,9} Lip competence implies a tonus in the lip muscles to provide passive lip contact with no clinical contraction of the mentalis muscle.\cite{10} A subject is classified as having incompetent lips when his lips are apart at clinical rest or when his lips are in contact but present higher activity of the mentalis muscle, clinically verified by shrinkage of the chin skin.\cite{4} Further, subjects with short lips are not able to habitually close the lips without effort.\cite{4,9} Incompetent lips contribute to chronic mouth breathing which is a risk factor for adeno-tonsillar hypertrophy and has been associated with maladaptive development of the maxillofacial skeleton.\cite{11}

Electromyography (EMG) is a low-cost, non-invasive and widely-used method to assess the degree of muscle contraction during physiological and/or pathological conditions of the stomatognathic system.\cite{12,13,14,15,16} Surface EMG comprises the sum of the electrical contributions produced by the active motor units as detected by electrodes fixed on the skin.

In adult subjects, Harradine and Kirschen \cite{8} found similar EMG activity of the lip and mentalis muscles, independent of the presence or absence of lip competence. On the other hand, at clinical rest, Marx \cite{17} found greater activity of the lip and mentalis muscles in children with lip incompetence. Gustafsson and Ahlgren \cite{5} also found that lip closure, mastication, and swallowing were performed with significantly greater activity of the superior
orbicularis oris (SOO), mentalis and masseter muscles in children with incompetent lips than in those with competent lips. Tosello [4] observed this same EMG behavior in the SOO, inferior orbicularis oris (IOO) and mentalis muscles during swallowing in children. Tomiyama et al. [10] found that subjects with incompetent lips showed higher EMG activities, at clinical rest and during chewing with the lips in contact compared with those with competent lips. Thus, subjects with incompetent lips have difficulty in chewing due to an inability to achieve lip seal, which affects their masticatory function.[10]

The above-mentioned studies show a pattern of higher EMG activity in subjects with lip incompetence than in subjects with competent lips, except for Harradine and Kirschen. [8] Scientific evidence is lacking regarding the effects of the presence or absence of lip competence on EMG activity of supra- and infrahyoid muscles. Therefore, this study compares the EMG activity of the superior and inferior orbicularis oris, supra- and infrahyoid muscles between subjects with or without lip competence to achieve integral knowledge about the EMG activity of these muscles in the context of the cranio-cervical-man-
dibular system.

**Methods**

**Ethical**

A research protocol was done in the Oral Physiology Laboratory of Faculty of Medicine, University of Chile. Participants gave informed written consent before participating in the study, and they could withdraw from the study at any point in time.

**Subjects**

This cross-sectional study included two groups of 20 healthy subjects each, one without lip competence (mean age 19.3 years; range, 18–24 years) and the other with lip competence (mean age 19.75 years; range, 17–27 years). The sample size required to achieve the statistical power of 80% was 20 subjects in each group, calculated considering α error at 0.05 and β error set at 0.20. During clinical exam, each subject was asked to remain standing with their feet 10 cm apart, to look straight ahead and to breathe normally for 2 min as a baseline. Two examiners (NAG and RM) independently classified each subject as having competent lips when he/she had his/her lips in light contact [5–9] and without contraction of the mentalis muscle [4] or as having incompetent lips when he/she had his/her lips apart at clinical rest or when his/her lips were in contact but presenting higher activity of the mentalis muscle, which was verified clinically by shrinkage of the chin skin.[4] Both examiners were trained to diagnose competent or incompetent lips by a specialist in orthodontics and dental-maxillofacial orthopedics of the School of Dentistry, from January to December of 2015. High consistency was observed across both examiners (95.24%, Kappa 0.9050); Agreement of both examiners was needed for subject classification. In the case of no agreement, the subject was not included.

Subjects with or without lip competence included in the study had complete natural dentition (excluding the third molars), no history of orthodontic treatment in the last 12 months, and no history of orofacial pain or craniomandibular-cervical disorders. Subjects with a history of trauma in the orofacial region, undergoing cleft lip and palate repair, suffering environmental allergies, common cold, and those on medication that could have influenced muscle activity were excluded. The participants were students enrolled at the Dental or Medical School of the University of Chile, and 40 subjects who met the inclusion criteria mentioned above were included in the study.

**Electromyography**

Bipolar surface electrodes (BioFLEX, BioResearch Associates, Inc., Brown Deer, WI, USA) were used for recording the EMG activity of the left muscles (Figure 1). Impedance was decreased by careful skin abrasion with alcohol. Electrodes were placed on a line running from the lip commissure to the subnasal point or mandibular midline for the SOO or IOO muscles, respectively. For the SH muscles, electrodes were placed following the direction of the fibers of the anterior digastric muscle, 1 cm from the digastric fossa and 1.5 cm behind the first. For the IH muscles, electrodes were placed on a line 1 cm laterally to the anterior median line, approximately near the anterior prominent part of the thyroid cartilage. A large surface ground electrode (approximately 9 cm²) 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, USA) and 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 0.1 s), and recorded online on a computer exclusively dedicated to the acquisition and processing of EMG signals. The 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 recording.
Each subject underwent three unilateral EMG recordings of the left SOO, IOO, SH and IH muscles while sitting upright in a chair with the head in postural position, looking straight ahead, with the feet flat on the floor and with arms resting on their thighs during the following sequence of experimental tasks (Figure 2): (1) at clinical rest; (2) speaking the word “Mississippi”; (3) swallowing saliva; (4) forced deep breathing; (5) maximal voluntary clenching in intercuspal position; and (6) chewing chocolate with almonds. Unilateral recordings were performed in a 4-channel recording system with the aim to record upper and lower lip, and supra- infra hyoid muscles, simultaneously. Before the EMG recording, an examiner explained the six tasks to each subject so that they could perform each one correctly. The instructions that were given for each task were the following: (1) to leave his/her jaw in resting posture; (2) to pronounce the word “Mississippi”, a phonetic method that was chosen for being a functional activity commonly used by dentists in most oral reconstructive procedures [18]; (3) to perform the habitual swallowing of saliva, a task that was chosen since it is a habitual physiological function; (4) to breathe in total lung capacity, holding the breath for 7 s, a period that was selected to ensure maximum and sustained muscle activity without producing a respiratory function disorder; (5) to clench his/her teeth as hard as he/she could for 7 s in intercuspal position, a task that was chosen because many individuals clench their teeth while awake; the period of 7 s in task 5 was chosen to ensure maximum and sustained muscle activity without producing pain and/or muscular fatigue; and (6) to chew chocolate with almonds using their left...
Results

For subjects with incompetent or competent lips, the mean age values ± SD were 19.3 ± 1.7 and 19.75 ± 2.5 years, respectively, the BMI values (kg/m²) were 22.92 ± 3.3 and 23.41 ± 4.5, respectively, and the waist (cm)/Height(cm) ratio was 0.45 ± 0.05 and 0.47 ± 0.06, respectively (Table 1). No significant difference was observed between the groups for any variable (p > 0.05, Mann–Whitney U-test).

Table 2 shows that EMG activity at clinical rest was similar between subjects with or without lip competence in all of the muscles studied.

Table 3 shows that EMG activity speaking the word “Mississippi” was significantly higher in the SOO muscle in subjects with incompetent lips than in subjects with competent lips (p < 0.05). EMG activity of the IOO, SH and IH muscles was not significantly different between the two groups.

Tables 4 and 5 show that EMG activity during the swallowing of saliva and forced deep breathing was significantly higher in the SOO and IOO muscles in subjects with incompetent lips than in subjects with competent lips, whereas EMG activity of the SH and IH muscles was similar between the two groups.

Table 6 shows that EMG activity during maximal voluntary clenching in the intercuspal position was similar between subjects with and without lip competence in all of the muscles that were studied.

Table 7 shows that EMG activity during chewing was significantly higher in the IOO muscle in subjects with incompetent lips than in subjects with competent lips. EMG activity of the SOO, SH and IH muscles was similar between the two groups.

Statistical analysis

Data were analyzed using the SYSTAT 13 program (Systat Software Inc. (SSI), San José, CA, USA). When EMG presented a normal distribution (p > 0.05; Shapiro–Wilk test), a t-test for independent samples was used to compare the EMG activity of each muscle between both groups during tasks, whereas when EMG presented a non-normal distribution (p < 0.05; Shapiro–Wilk test), a Mann–Whitney U-test was used to compare the activity of each muscle between both groups during tasks. To compare age, gender, BMI and waist/height ratio, a Mann–Whitney U-test was also used. A value of p < 0.05 was considered significant.
The higher EMG activity of the SOO and IOO muscles during saliva swallowing in subjects with incompetent lips is in agreement with the findings of Gustafsson and Ahlgren [5] and Tosello et al. [4]. This finding implies higher muscular effort due to the requirement of lip sealing during the swallowing of saliva and is important because it is a very frequent activity, occurring between 600 and 2400 times each day during waking hours,[19–21]

This is the first study showing significantly higher EMG activity of the SOO and IOO muscles during forced deep breathing in subjects with incompetent lips, implying a higher muscular effort in subjects with lip incompetence in order to minimize airflow throughout the mouth.

Higher EMG activity in the SOO muscle during speech and in the IOO muscle during chewing in subjects with incompetent lips supports the hypothesis of a higher muscular effort caused by the requirement to also seal the lips. In summary, the pattern of increased EMG activity observed in some tasks in subjects with incompetent lips implies a higher muscular effort that could be a determining factor of their adaptability capacity. Although in the present study the occlusal characteristics were neither assessed nor compared between the samples studied, the EMG pattern observed in the incompetent group would be very important when the relationship between malocclusion and oral function is studied. While most of the theories accept genetics as the main or underlying cause of this relationship, the importance of local or environmental factors, such as oral posture and oral soft tissue characteristics, is also widely accepted, since these factors can have both a deteriorating and/or enhancing influence.[22]

Subjects with incompetent lips have difficulties in speech, swallowing, and chewing due to the inability to achieve lip seal. Therefore, in the long term, enhanced muscle activity could modify the dental arch and/or craniofacial morphology. Ideal rest jaw posture with nasal breathing should be achieved, with soft lip contact. Patients with *mentalis* muscle strain are almost universally mouth breathers, and such unfavorable jaw rest posture will ultimately cause their faces to fall back over time.[11]
studied. This factor could be important, since different EMG activity in elevator muscles has been found across age, with greater activity in children and youth, and decreasing from adults to elderly people.\[23\] In another study, older (53–88 years) than young participants (21–35 years) had lower mentalis activity during non-stimulated swallows.\[24\] This is the first study to compare EMG activity of the SH and IH muscles during different tasks in subjects with and without lip competence. The similar EMG activity of the SH and IH muscles between both groups suggests that the predominant stabilizing role of the hyoid bone is not significantly modified by the presence or absence of lip competence. This finding suggests the existence of complex interactions within the cranio-cervical-mandibular system. On the other hand, similar activity of the SH and IH muscles in the different tasks agrees with findings from previous studies, which have indicated that these muscles are directly or indirectly involved in chewing, speaking, swallowing, breathing and maximal voluntary clenching.\[25–32\]

The present study has at least four limitations: (1) The age of the subjects studied was between 17 and 27 years. Therefore, present EMG results cannot be extrapolated to children and elderly subjects. (2) Surface electrodes could capture and/or pick up activity from neighboring muscles. (3) The existence of subgroups within the incompetent lip group cannot be discarded, a matter that will be assessed in a future study. (4) The presence or absence of restrictions of the lingual frenulum (ankyloglossia) was not assessed.

From an overall point of view, the present findings suggest the existence of complex functional peripheral and/or central neuromechanisms over the pool of motor neurons that control the SOO, IOO, SH and IH muscle chains, which compose the cranio-cervical-mandibular system.

**Conclusions**

The major finding of the present study is the higher EMG activity observed in the superior and inferior orbicularis oris muscles in subjects with incompetent lips during some of the tasks studied, implying a higher muscular effort due to the requirement of lip sealing during functional activities. The similar EMG activity of supra- and infrahyoid muscles observed in subjects with or without lip competence in any of the tasks studied implies that activity of

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<table>
<thead>
<tr>
<th>Muscles</th>
<th>Incompetent lip</th>
<th>Competent lip</th>
<th>p-value</th>
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<tr>
<td></td>
<td>25% Percentile</td>
<td>Median</td>
<td>75% Percentile</td>
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<td>Superior orbicularis oris</td>
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<td>6.38</td>
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</table>

NS: not significant (t-test; Mann–Whitney U-test).

\*p < 0.05; **p < 0.01 (Mann–Whitney U-test).

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<tr>
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<td>75% Percentile</td>
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<tr>
<td>Superior orbicularis oris</td>
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<tr>
<td>Intrahyoid</td>
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<td>21.74</td>
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</table>

NS: not significant (Mann–Whitney U-test).

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<td>Median</td>
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<td>20.72</td>
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</table>

NS: not significant.

\*p<0.05 (Mann–Whitney U-test).
these muscles, in their predominant role of stabilizing the hyoid bone, is not significantly modified by the presence or absence of lip competence.

**Ethics approval**

Protocols based on ethical principles that have their origin in the Declaration of Helsinki were used.

**Contributors**

All authors helped in data analysis, study design and writing.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

**References**
