# Electromyographic Comparison of Lips and Jaw Muscles between Children With Competent and Incompetent Lips: A Cross Sectional Study

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***Objective:*** *This cross-sectional study evaluates the electromyographic (EMG) activity of lips and anterior temporalis muscles of children with competent or incompetent lips.* ***Study design:*** *Forty children were classified clinically according to their lip competence into two groups of 20 each: 1) competent lips group (CLG), and 2) incompetent lips group (ILG). Surface EMG activity of the superior orbicularis oris (SOO), inferior orbicularis oris (IOO), and anterior temporalis (AT) muscles was recorded with the children seated in the upright position during the following tasks: 1) at rest; 2) speaking; 3) swallowing; 4) puffing out the cheeks.* ***Results:*** *ILG showed lower EMG activity than CLG in the SOO and IOO muscles at rest, similar activity in both muscles during speaking, similar activity in the SOO muscle and lower in the IOO during swallowing. ILG showed significantly higher activity than CLG in both muscles while puffing out the cheeks. In the AT muscle, ILG showed lower activity than CLG at rest, during speaking and swallowing, whereas activity was similar while puffing out the cheeks.* ***Conclusion:*** *The difference in EMG activity recorded in children with incompetent lips and with competent lips suggests that the status of their musculature could affect the position and stability of their upper/lower anterior teeth.*

***Keywords****: Anterior temporalis muscle, competent/incompetent lips, electromyography, orbicularis oris muscles.*

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## INTRODUCTION

The growth and development of the maxillofacial structures are influenced by a complex interaction of many factors, being the effect of the neuromuscular component crucial at rest as well as during breathing, speaking, chewing and swallowing. An adequate balance of muscular forces is required to achieve a stabilized environment for the growth and development of the maxillofacial structures and to allow a stable occlusion.[1–7] Therefore, the maintenance of the healthy function of the perioral soft tissues is important because dysfunction of the lips and tongue may induce malocclusion and, in some instances, it may cause a relapse of orthodontically aligned teeth.[8,9]

The perioral muscles including *orbicularis oris* are critical for the maintenance of the balance between the inner and the outer forces on the teeth in the rest position; therefore, lip incompetence could be considered an etiological agent of malocclusion.[10–17]

EMG studies of lips activity comparing between children with competent and incompetent lips have found contradictory results. In some studies, higher EMG activity in children with incompetent lips at rest[18,19] and during swallowing,[18] was observed; whereas, in others studies, similar activity between both groups at rest,[20] during swallowing,[19,20] speech[20] and puffing out the cheeks[21] was observed.

Therefore, EMG pattern of lips activity between children with incompetent and competent lips is still unclear. Higher or lower lips activity in children with incompetent lips than competent lips could affect the position and stability of their upper/lower anterior teeth.

The anterior *temporalis* muscle is involved in the control of the jaw position at rest and during functions like speech or swallowing.[22,23] Differences in the EMG activity of this muscle between children with different facial growth [22] or swallowing patterns have been reported;[23] nevertheless, there is lack of evidence regarding the EMG activity of this muscle in children with competent and incompetent lips.

Based of the above considerations, there is a need to know about lips and jaw EMG pattern between children with competent and incompetent lips at different magnitude of muscular activity. Therefore, the aim of the present study is to compare the EMG activity of the superior *orbicularis oris* (SOO) and inferior *orbicularis oris* (IOO) and anterior *temporalis* (AT) muscles between children with competent and incompetent lips.

## MATERIALS AND METHOD

The Human Research Ethics Committee reviewed and approved the protocol and consent form for this study (Protocol Nº: 24; 07, Ed 10/11/2014).

The participants were enrolled at the Faculty of Dentistry, University of Chile, and the parents (legal guardians) signed an informed consent form after a detailed explanation of the experimental protocol and the possible risks involved. No advertisement was made for participant recruitment. Subjects were recruited in the order they arrived for the screening session, thus forming a convenient sample.

### Sample size

The sample size was calculated according to Gustafsson and Ahlgren,[18] considering the EMG activity of the SOO muscle during swallowing task. Size effect was calculated according to Cohen's d test (1.32) and based on a significance level of 0.05 and a power of 95%, using the G*Power program version 3.1.9.3 (University of Düsseldorf, Germany, 2017, available at: http://www.gpower.hhu.de).

### Eligibility criteria

Participants had no history of kinesics, orthodontic and orthopedic treatment in the last 12 months, and no history of orofacial pain or craniomandibular-cervical disorders. Participants with a history of trauma in the orofacial region, undergoing cleft lip and palate repair, suffering environmental allergies, common cold, nasal obstruction and those on medication that could have influenced muscle activity were excluded. The period during which the examiner selected the study sample was 12 weeks.

During the clinical examination, each child was asked to remain seated, with his/her back supported, without head supported, looking straight and the mandible at clinical rest position. A specialist in orthodontics and dental-maxillofacial orthopedics (M.A.L.) clinically classified and assigned each participant to one of the following groups: 1) competent lips group [CLG], when their lips were in light contact without obvious muscular tension of the perioral musculature[18,20,24–27] 2) incompetent lips group [ILG], when they had their lips apart[19,21,26]. The competent lips group included 20 participants (10 males and 10 females, mean age 9.15 ± 1.66 years and a range from 7 to 13 years) and the incompetent lips group included 20 participants (7 males and 13 females, mean age 9.60 ± 1.46 years and a range from 7 to 12 years).

### Electromyography

Bipolar surface electrodes (BioFLEX, BioResearch Associates, Inc., Brown Deer, WI, USA) were used for recording the EMG activity of the left SOO, IOO and AT muscles. 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.[2,27]with or without lip competence were studied. EMG activity of the superior orbicularis oris (SOO (Figure 1) In the AT muscle, the lower electrode was placed 1 cm above the zygomatic arch and 1.5 cm behind the orbital border, and the superior electrode was placed parallel to the main direction of muscle fibers[28] (Figure 1). A single examiner positioned the electrodes to maintain consistency in electrode positioning relative to muscle fibers orientation (R.M.). A large surface ground electrode (approximately 9 $cm^2$) was attached to the forehead. EMG activity of SOO, IOO and AT muscles was recorded simultaneously 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 obtained 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 child underwent three EMG recordings of the left SOO, IOO and AT muscles while sitting upright in a chair with the head in postural position, looking straight ahead and with the arms resting on their thighs during the following sequence of experimental tasks: 1) at rest; 2) speaking the word "Mississippi"; 3) swallowing of saliva; 4) puffing out the cheeks. Before the EMG recording, an examiner explained the four tasks to each participant so that they could perform them correctly. The instructions that were given for each task were the following: 1) to leave his/her jaw at rest; 2) to pronounce the word "Mississippi". This phonetic method was chosen for being a functional activity commonly used by dentists in most oral reconstructive procedures;[29] 3) to perform the habitual swallowing of saliva, visually checked by the movement of the hyoid bone. This task was chosen since it is a habitual physiological function; 4) puffing out the cheeks for 10 s to ensure maximum and sustained SOO and IOO muscular activity. This task is not a frequent functional activity but may allow to determine EMG pattern of these muscles on an extreme activity, i.e., when a child inflates a balloon. No instructions regarding lip position were given for any of the tasks.

Recordings of EMG activity lasted 10 seconds, and a 20-second resting period was allowed between tasks. To obtain the average value of each curve, measurements were taken every 0.1 s using a computer program. The mean value of three curves obtained for each task and for each participant was used for the comparison between both groups.

## Statistical analysis

The Shapiro-Wilk test showed a normal distribution of age and gender within each group. Therefore, to compare the age and gender between groups, a *t*-test and the $\chi^2$ test (Chi-square) were used, respectively. Ladder transformation was used to allow the normalization of EMG data. Comparison of EMG activity was performed by using the t-test for independent samples. A value of $p < 0.05$ was considered statistically significant. The data were analyzed using STATA, Release 10.0 (SAS Institute, Inc., Cary, NC, USA).

## RESULTS

The explanatory variables age and gender did not show significant differences between both groups ($p$ = 0.370; $p$ = 0.337, respectively).

EMG activity of SOO was significantly lower in ILG than CLG during task 1 ($p$=0.009), and significantly higher in ILG than CLG during task 4 ($p$=0.001). On the other hand, similar EMG activity between both groups during task 2 ($p$=0.398) and 3 ($p$=0.078) were observed (Figure 2).

EMG activity of IOO was significantly lower in ILG than CLG during task 1 ($p$=0.001) and 3 ($p$=0.029), and significantly higher in ILG than CLG during task 4 ($p$ =0.014). On the other hand, similar EMG activity between both groups during task 2 was observed ($p$=0.654) (Figure 3).

EMG activity of the AT muscle was significantly lower in ILG than in CLG during task 1, 2 and 3 ($p$=0.001), whereas it was similar in task 4 ($p$=0.053) (Figure 4).

**Figure 2: Normalized electromyographic (EMG) data of superior *orbicularis oris* muscle at rest, during speaking, swallowing, and while puffing out the cheeks in participants with competent lips and incompetent lips.**

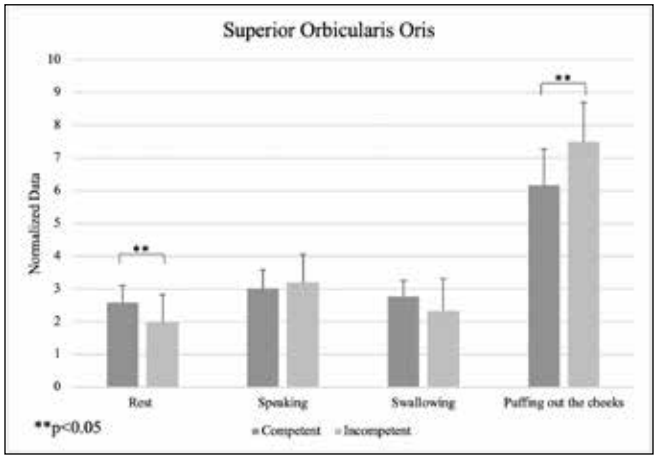



**Figure 1: Frontal and lateral view of the electrode positions in a participant with competent lips.**

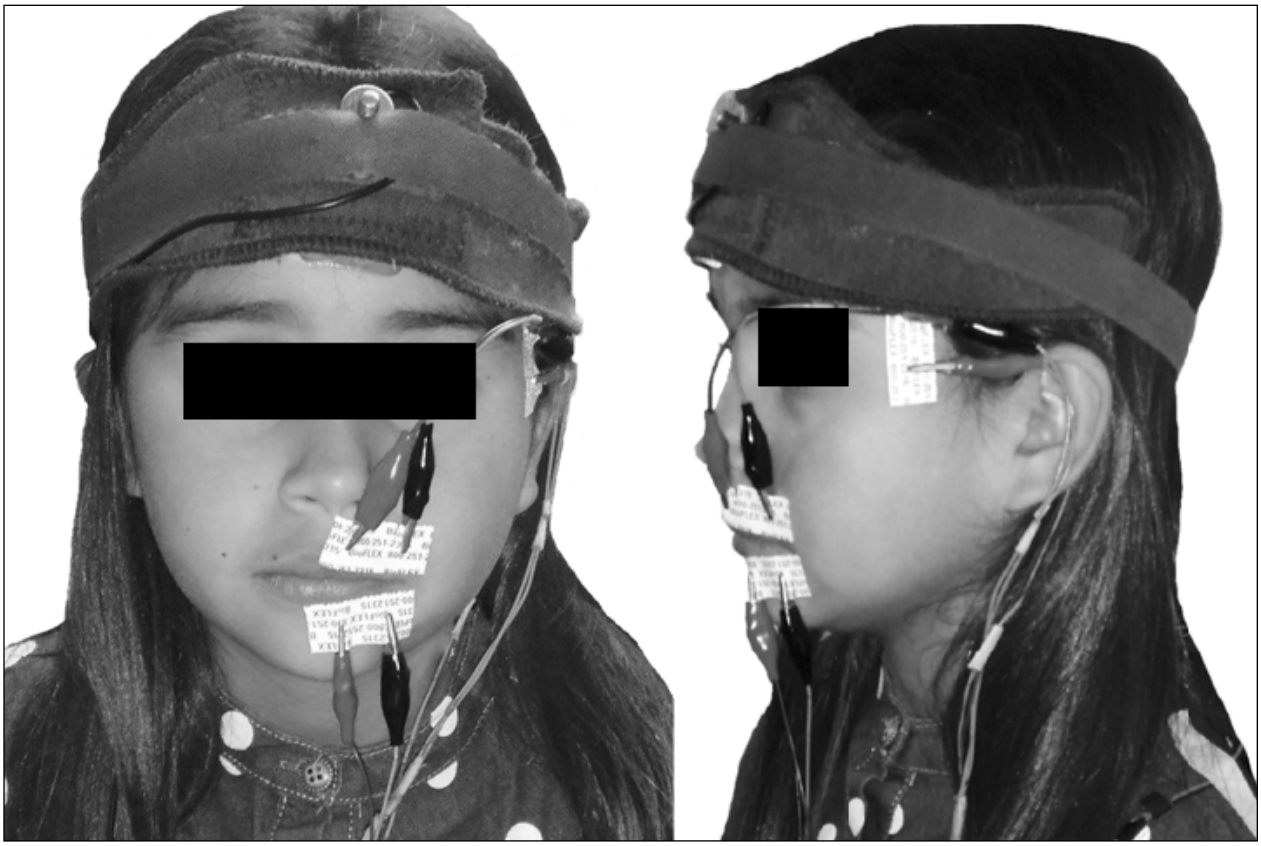


**Figure 3: Normalized electromyographic (EMG) data of inferior *orbicularis oris* muscle at rest, during speaking, swallowing, and while puffing out the cheeks in participants with competent lips and incompetent lips.**

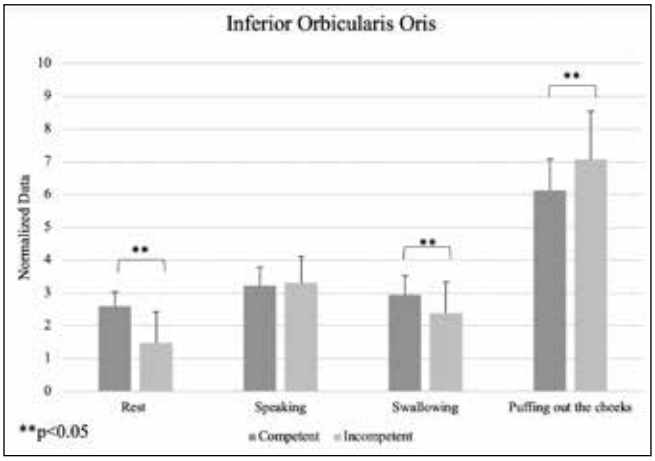
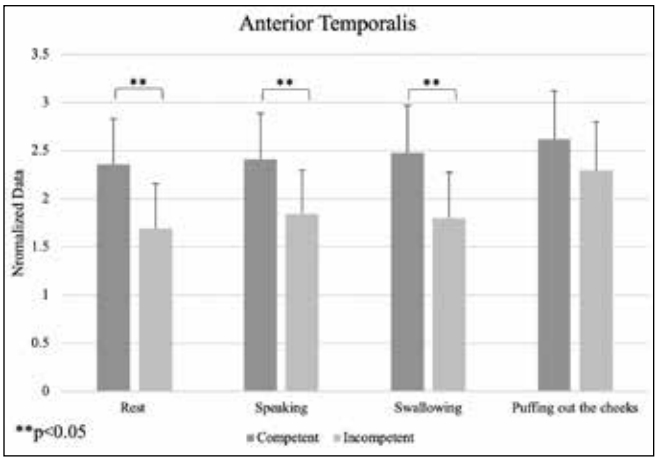



**Figure 4: Normalized electromyographic (EMG) data of anterior *temporalis* muscle at rest, during speaking, swallowing, and while puffing out the cheeks in participants with competent lips and incompetent lips.**




## DISCUSSION

The lower EMG activity at rest in children with incompetent lips in comparison with those with competent lips suggests a hypotonic status of their musculature with few motor units recruited and established by the natural elasticity of the muscles.[30] This result is in disagreement with previous studies which found higher EMG activity in the children with incompetent lips than in children with competent lips,[18,19] and is also in disagreement with Harradine & Kirschen[20] who found no differences in the EMG activity between both groups. The methodological strategies to measure the lip activity at rest could explain the different results observed, i.e. other authors evaluated rest activity with labial contact for both groups. Lower EMG activity at rest observed in ILG when compared with CLG could influence the position and stability of the incompetent children teeth, since the activity at rest goes on almost 24 hours a day.

The similar EMG activity observed in the SOO and IOO muscles during speaking is in agreement with Harradine & Kirschen,[20] who found no significant differences of EMG activity between groups during speaking. These results imply that the speak function in the SOO and IOO muscle is not influenced by the degree of competence of the lips, which could be compensated by mentalis muscle activity to achieve the lip seal, as suggested by Harradine & Kirschen.[20]

During swallowing, the SOO showed similar EMG activity between both groups, which is in agreement with Tosello *et al* [19] and Harradine and Kirschen[20] and in disagreement with Gustafsson and Ahlgren[18] who found higher SOO EMG activity in the incompetent group. On the other hand, the IOO muscle showed lower EMG activity during swallowing in children with incompetent lips compared with children with competent lips, which is in disagreement with Tosello et al.[19] and Harradine & Kirschen[20] who did not find significant differences in the IOO EMG activity between both groups. The lower EMG activity observed in IOO muscle supports the idea that children with incompetent lips had hypotonic IOO muscle; therefore, the activity of the mentalis muscle is required to achieve the lip sealing during swallowing, as suggested by several authors.[18–20]

The EMG activity observed in the SOO and IOO muscles when puffing out the cheeks in children with incompetent lips was significantly higher than in children with competent lips, which is in disagreement with Tosello *et al* [21] who found no significant differences between children with competent and incompetent lips. This result suggests a greater activity in the ILG to achieve an accurate lip seal in order to maintain the air inside the mouth.[21,26] This is a clear sign of difficulty to close the lips[15] and consequently an alteration in the neuromuscular coordination of the entire system.[11] Higher EMG activity observed in ILG when compared with CLG while puffing out the cheeks could influence the position and stability of the incompetent children teeth, because it is an intense but not frequent muscular activity.

The EMG activity of AT muscle in the ILG was significantly lower than in the CLG in tasks 1, 2 and 3. This new finding could be related to muscle weakness as a consequence of the open mouth posture. A further study is required to confirm and explain the mechanisms underlying this EMG pattern.

EMG recording is a non-invasive method used to evaluate the work of SOO, IOO and AT muscles in children with and without lip competence, since a linear relationship exists between the electrical activity and the force developed by a muscle, and therefore, the muscular work.[33–35] Moreover, surface EMG provides objective, valid, and reproducible data on muscle contractions,[36–38] which enhance our understanding of lip and jaw muscular activity in children with competent and incompetent lips.

From a global point of view, it is important for orthodontists to know about the existence of differences in the EMG pattern of SOO, IOO and AT muscles in children with incompetent lips, since this could affect the position and stability of teeth. The next challenge will be to correlate the activity of the perioral and anterior temporal muscles with relevant craniofacial characteristics of children with incompetent lips.

## CONCLUSION

The different EMG activity recorded in the superior *orbicularis oris*, inferior *orbicularis oris*, and anterior *temporalis* muscles in children with incompetent lips in comparison with children with competent lips at rest, and during speaking, swallowing and puffing out the cheeks suggest that the status of their musculature could affect the position and stability of their upper/lower anterior teeth.

## CONFLICT OF INTEREST

The authors have no conflict of interest in this study.

## ETHICS APPROVAL

Protocols based on ethical principles originating in the Declaration of Helsinki were used.

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