ความสัมพันธ์ของการทำงานของกล้ามเนื้อไดแกสตริกและแมสเซตเตอร์ขณะกลืนในกลุ่มตัวอย่างที่มีการกลืนแบบลิ้นดุนฟัน

Relationship of Anterior Digastric and Masseter Muscle Activity During Swallowing in Subjects With Tongue Thrusting

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บทคัดย่อ

การตรวจประเมินการทำงานของกล้ามเนื้อที่เกี่ยวข้องกับการเคลื่อนไหวของขากรรไกรและลิ้นขณะการกลืนน่าจะสามารถนำมาประยุกต์ใช้เพื่อการแยกแยะความผิดปรกติของการกลืนรวมไปถึงใช้เป็นต้นแบบในการพัฒนาตัวชี้วัดการปรับตัวของกล้ามเนื้อที่เกี่ยวกับการกลืนหลังการรักษา ดังนั้นจุดประสงค์ของการศึกษานี้เพื่อศึกษาเปรียบเทียบความสัมพันธ์ของกล้ามเนื้อแมสเซสเตอร์ และกล้ามเนื้อไดแกสตริกส่วนหน้าในกลุ่มตัวอย่างที่มีภาวะลิ้นดุนฟัน จำนวน 10 คน เปรียบเทียบกับกลุ่มตัวอย่างที่มีการกลืนแบบปกติ จำนวน 10 คน โดยใช้เครื่องมืออิเล็กโตรไมโอกราฟฟีในขณะกลืนของน้ำ 20 มิลลิลิตร และขณะกัดสบบนก้อนสำสีทรงกระบอก ผลการศึกษาพบว่าการทำงานของกล้ามเนื้อแมสเซสเตอร์ทั้งสองกลุ่มไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติ แต่การทำงานของกล้ามเนื้อกล้ามเนื้อไดแกสตริกส่วนหน้าในขณะกลืนน้ำในกลุ่มในกลุ่มตัวอย่างที่มีภาวะลิ้นดุนฟันสูงกว่ากลุ่มตัวอย่างที่มีการกลืนแบบปกติอย่างมีนัยสำคัญทางสถิติ จากผลการศึกษานี้สามารถนำไปประยุกต์ใช้ในการติดตามและประเมินการทำงานของกล้ามเนื้อไดแกสตริกส่วนหน้าในขณะกลืนน่าจะเป็นตัวบ่งชี้ในการประเมินว่าภาวะลิ้นดุนฟันยังคงอยู่หรือดีขึ้น

คำสำคัญ: กล้ามเนื้อไดแกสตริกส่วนหน้า กล้ามเนื้อแมสเซตเตอร์ การกลืน ภาวะลิ้นดุนฟัน อิเล็กโตรไมโอกราฟฟี

Abstract

Objectives: To assess the relationship of anterior digastric (DA) and masseter (MA) muscle activity in subjects with tongue thrusting during swallowing.

Research Methodology: 10 consecutive adult subjects exhibiting a pattern of tongue thrusting during swallowing and ten adult subjects with normal swallowing patterns were selected. Surface electromyographic activity (SEMG) of the DA and MA muscles were measured during swallowing and performing maximum voluntary

clenching (MVC) on cotton rolls for the normalization of the SEMG data. The mean values of normalized SEMG data of each muscle and a ratio of DA and MA muscle activity (DA/MA ratio) were compared using the t-test. The level of statistical significance was set at 5 % ($P < 0.05$).

Results: The mean values of normalized SEMG of MA during swallowing were not significantly different from subjects that exhibited tongue thrusting swallowing than among those exhibiting normal swallowing patterns. However, the mean values of normalized SEMG of the DA muscle in subjects exhibiting tongue thrusting during swallowing were found to be significantly higher than in the subjects with normal swallowing patterns. The DA/MA ratio in the subjects with tongue thrusting during swallowing was significantly higher than in those with normal swallowing pattern.

Conclusions: Hyperactivity of the DA muscle and a high DA/MA ratio during were found in subjects with tongue thrusting. These findings indicate that the DA muscles play an important role in the swallowing process of subjects with tongue thrusting. The relationship of DA and MA may be useful as a quantitative indicator in the monitoring of the correction process of tongue thrusting habits by observing the adaptation of those muscles.

Keywords: Anterior digastric muscle, Masseter muscle, Swallowing, Tongue thrusting, Electromyography

Introduction

Tongue thrusting is a habit wherein the tongue posture is placed forward between the upper and lower anterior teeth during the course of swallowing (William R. Proffit & Mason, 1975). This habit is related to the persistence of an infantile swallowing pattern and creates a protrusion of the anterior teeth resulting in an anterior open bite (Artese et al., 2011). With regard to the equilibrium theory, tongue posture and position are important factors that influence and maintain the position of the teeth (W. R. Proffit, 1978). Improper tongue position, during periods of both rest and function, are considered the major etiologic factors that influence the relapse of orthodontic treatment (Artese et al., 2011; Huang et al., 1990).

Objectives

1) To evaluate the activity of DA and MA muscle activity in subjects exhibiting tongue thrusting during the act of swallowing and for those exhibiting normal swallowing patterns.

2) To assess the relationship of DA and MA muscle activity in subjects exhibiting tongue thrusting during the act of swallowing and in subjects exhibiting a normal swallowing pattern.

Literature Review

According to the tongue position during the normal swallowing process, the tip of the tongue is placed on the anterior part of the palate. At this time, minimal contraction of the perioral muscles occurs when the teeth come in contact. This occurs along with a contraction of the masticatory muscles, such as the masseter and temporalis muscles, in order to stabilize the mandible without a protrusive or forward tongue posture (Peng et al., 2004).

In an atypical swallowing pattern, the most active muscles are those that are innervated by the facial nerve; specifically, the digastric muscle which acts to move the mandible downward and backward and the hyoglossus muscle that acts to move the tongue backward. Additionally, there is hyperactivity of the orbicularis and mentalis muscles, and a reduced contraction of the masticatory muscles occurs in combination with the tongue tip being in contact with the palatal surface of the anterior teeth or between the anterior teeth. These phenomena can be observed to occur in patients with anterior open bite, wherein the tongue tip typically protrudes between the maxillary and mandibular anterior teeth to achieve an oral seal during the act of swallowing. Consequently, the dorsum of the tongue is positioned in a forward and inferior position (Kawamura et al., 2003).

With regard to the routine act of swallowing, this process is subdivided into 3 phases: oral, pharyngeal, and esophageal (Miller, 1982). This process involves the engagement of a number of muscles. The first group of muscles is the perioral-facial muscle group such as the orbicularis oris and buccinator muscles. This group of muscles functions to provide an anterior seal of the lips during the oral phase of swallowing (Murray et al., 1998). Elevator muscles, such as the temporalis, masseter and medial pterygoid, play a role in mandible stabilizing (McNamara & Moyers, 1973). In combination with the muscle of the tongue, the submental muscles (SM),

mylohyoid, geniohyoid and digastric muscles, contract to initiate a swallow and function as the laryngeal elevators that pull the larynx upward (Miller, 1982). The function of perioral muscle activity finishes before the pharyngeal phase of swallowing, while the masseter activity continues during the pharyngeal phase of swallowing. Ultimately, the contraction of the SM continues until the completion of the oropharyngeal swallowing process (Ertekin & Aydogdu, 2003).

Typically, the muscle activity that occurs during the act of swallowing can be investigated using electromyographic methods. One of the most widely used applications is surface electromyography (SEMG). This application is associated with a non-invasive type of procedure and its measurements are highly reliable (Qi et al., 2016). Instead of studying the SEMG analysis of the many muscles involved in the act of swallowing, it is more practical to assess the SEMG activity for just a few very important muscles (Ertekin & Aydogdu, 2003). With regard to our literature review, the MA muscle can be superficially recorded together with the SM group. Furthermore, their function is in full sequence and can be conveniently monitored by SEMG (Ertekin & Aydogdu, 2003). Therefore, the objective of this study was to use SEMG to evaluate the activities of the anterior digastric (DA) and MA muscles during the act of swallowing in subjects that exhibited tongue thrusting during the act of swallowing.

Conceptual Framework

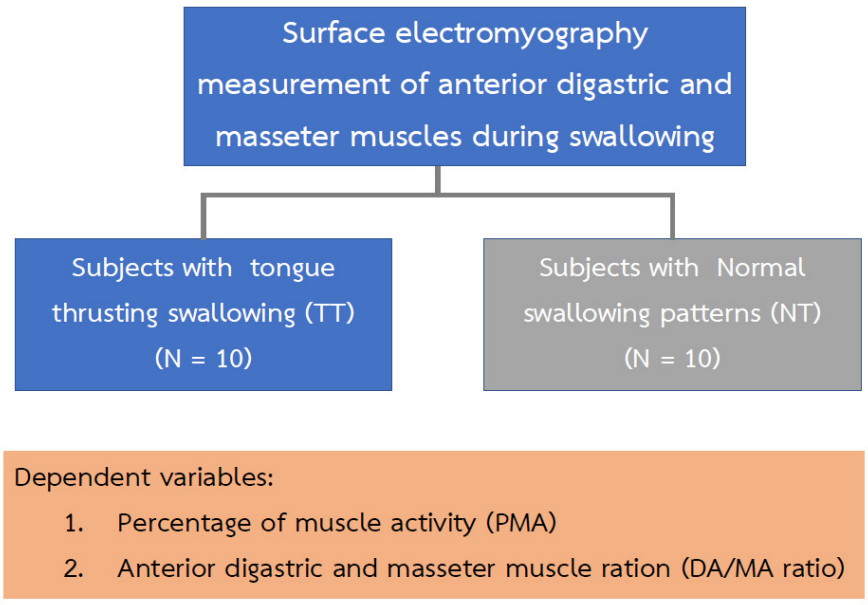

Figure 1 conceptual framework of the study

Research Methodology

Subjects

The subjects in this study were recruited from 340 adult subjects that were undergraduate and graduate students of Bangkokthonburi University, Thailand during a period extending from 2017 to 2019. This study was approved of by the Human Ethics Committee of Bangkokthonburi University (11/2561).

For the subject selection process, the inclusion criteria of the subjects included the following: adult subjects (ranging in age from 20 to 35 years), all subjects had a healthy natural dentition with healthy periodontal tissue and no missing teeth with the possible exception of the third molar (at least 28 teeth); no subjects were diagnosed with TMD according to the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD), no subjects had previous or current tumors or trauma to the head and/or neck region or had received any previous orthodontic treatment or myofunctional therapy. All subjects had a body mass index ranging from 18.5 to 24.9.

The exclusion criteria used in this study eliminated any subject who had received botulinum toxin injections in the facial area six months prior to taking part in the study. The exclusion criteria also eliminated those who consumed any medication that could possibly influence muscle activity.

The subjects were then classified into 2 groups; the tongue thrusting swallowing (TT) group or the normal swallowing (NT) group, using the BTU tongue thrusting evaluation protocol and the modified Payne technique (Rivera-Torres, 1992). After the selection process, ten subjects (5 women and 5 men with a mean age of 26.0 ± 4.68 years) were selected for the TT group and 10 subjects (4 women and 6 men with a mean age of 27.67 ± 1.81 years) were enrolled in the NT group. All subjects involved in this study had signed written informed consent forms.

Surface electromyographic measurement

The activity of the anterior part of the left and right anterior digastric muscles (LDA, RDA) and the left and right masseter muscles (LMA, RMA) was measured in all subjects using SEMG (BioEMG III, BioResearch, Inc., Brown Deer, WI, USA). The SEMG recordings were completed for two situations. The first record employed a test for swallowing that involved 10 ml of water, while the second test was conducted

during MVC using 1.0 X 3.0 cm cotton rolls on the molar areas on both sides of the mouth.

Before the tests, subjects were instructed to sit upright in a chair while maintaining a natural head position. All subjects were advised about the objectives of this study and were also informed about the relevant protocol well before the first measurement was taken. At the initial stage of the experiment, the skin was cleaned with 95 % alcohol.

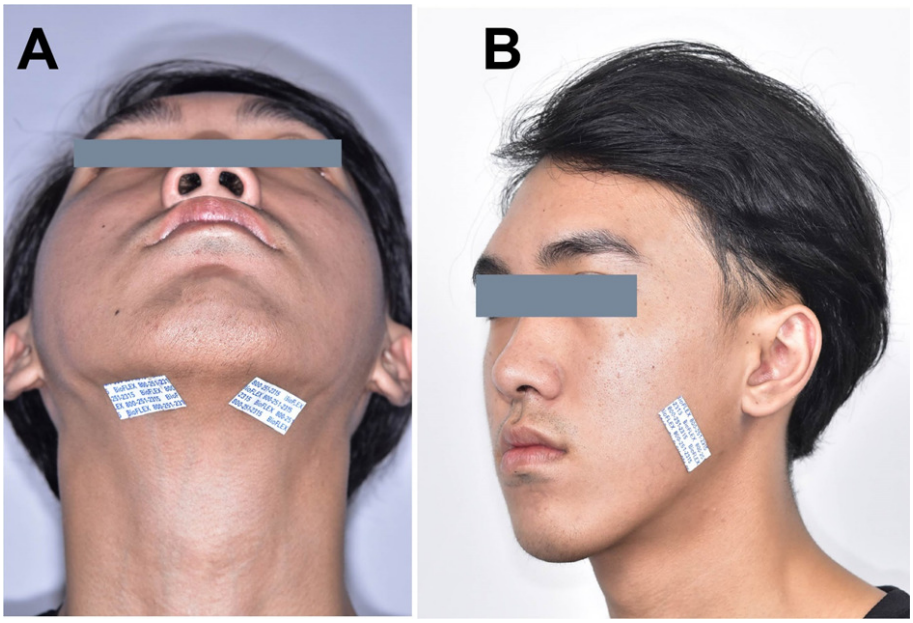

Figure 2 Positions of surface electromyographic electrodes, A: anterior digastric muscles, B: Masseter muscles.

For SEMG electrode placement, Bipolar surface electrodes with 100 mm2 of Ag/ AgCI, (BioFLEX, BioResearch Inc) were positioned over the muscle orientation. For the DA muscles, muscle orientation was defined as the area determined by palpation using the fingertip as it was pressed against the tissue at the posterior to the inferior tip of the mastoid. The belly of the muscle was confirmed by asking the patient to repeatedly protrude and retrude the mandible. (Figure 2A) For the RMA and LMA, the electrodes were positioned parallel to the muscle fibers of the subject, with the upper pole of the electrode strategically placed at the intersection between the tragus–labial commissure and the exocanthion–gonion lines. (Figure 2B) All electrodes were administered according to the technique described by Tecco et al (Tecco et al., 2015). Additionally, a plate ground electrode was placed on the

shoulder's subject. All the SEMG measurements were carried out and recorded by the same investigator.

Muscle Activity analysis

Before comparisons, the muscle activity between the groups were indicated. Mean SEMG potential values were normalized using the mean SEMG potentials recorded during MVC on cotton rolls. These values serve as a reference that enable researchers to calculate the percentage of muscle activity (PMA) following the procedure used by Tecco et al. (Tecco et al., 2015). The PMA was expressed as follows:

PMA = (SEMG during swallowing SEMG (μV)) / (SEMG of MVC on cotton rolls (μV)) X 100

The average PMA values of the DA and PMA muscle activity from the left and right of each muscle were calculated to represent muscle activity.

To evaluate the relationship of DA and MA muscle activity, the ratio of DA and MA muscle activity (DA/MA ratio) were expressed as follows:

DA/MA ratio = (PMA of DA during swallowing / PMA of MA during swallowing) X 100

Measurement Reliability

To account for any possible SEMG measurement errors, five subjects were randomly selected and all measurement procedures were repeated at the same points after a 10-minute period. All procedures were performed by the same investigator. The Intraclass Correlation Coefficient (ICC) was tested using the F-test. The ICC values of the SEMG measurement obtained from this study ranged from 0.85 to 0.89.

Statistical analysis

Data normality was assessed using the Shapiro–Wilks test and the degree of distribution was found to be normal. Differences in the mean PMA and the DA/MA ratio values between groups were compared using the t-test. The level of statistical significance was set at 5 % ($p < 0.05$). All data were analyzed using SPSS Statistics 23 for Windows.

Results

Descriptive data for the PMA value of DA and MA, and the DA/MA ratio values recorded during the act of water swallowing, are shown in Table 1. For the PMA of DA, with respect to the t-test, the mean PMA of DA in the TT group was higher than in the NT group with a statistically significant difference ($P < 0.05$). For the mean PMA values of MA, no significance difference was observed in the mean PMA of MA between the two groups. Additionally, subjects in the TT group presented significantly higher outcomes in terms of the mean DA/MA ratio values of MA when compared to those same values in subjects in the NT group ($P < 0.05$).

Table 1 Comparison of PMA in DA and MA muscles during the act of swallowing in the TA and NT groups

Parameter	TT (N = 10)		NT (N = 10)		F	*P*-value
	Mean	±SD	Mean	±SD		
PMA of DA	70.57	7.73	7.88	2.24	5.72	*
PMA of MA	38.64	8.47	41.57	8.56	0.37	NS
DA/MA Ratio	189.77	40.61	18.76	2.43	21.06	*

PMA; percentage of muscle activity, DA; anterior digastric muscle, MA; masseter muscle,
TT: Subjects with tongue thrusting group, NT: Subjects with normal swallowing group,
SD; Standard deviation*, *P*- value < .05, NS: not significant

Discussions

With regard to the findings in this study, the DA muscle activity that was employed during the oral phase of swallowing was different among subjects with tongue thrusting from those with normal swallowing patterns. The subjects with tongue thrusting revealed a relatively high ratio of DA/MA during the course of swallowing.

Regarding the oral phase of normal swallowing, this process starts with the tongue pressing bolus or liquid against the hard palate. The bolus or liquid is then transferred to the posterior part of the tongue toward the oropharynx. The suprahyoid muscles of the floor of the mouth, such as the digastric muscles, are particularly important in elevating the tongue (Ertekin & Aydogdu, 2003).

Subsequently, the elevator muscles, such as the masseter muscles, are contracted to stabilize the mandible against contraction of the suprahyoid muscles (Hiraoka, 2004). A slight contraction of the lips and cheeks is crucial to prevent the bolus or liquid from escaping from the mouth (Ertekin & Aydogdu, 2003).

With respect to the subjects that exhibited either atypical swallowing or tongue-thrusting swallowing, the tongue-thrusting swallowing characteristics also include a forward tongue posture wherein the tongue contacts with the anterior teeth during the act of swallowing. Hyperactivity of the orbicularis oris, mentalis and suprahyoid muscles, in combination with the act of swallowing without the occurrence of tooth contact, was observed (Peng et al., 2004).

In this study, the mean PMA values of DA during the act of swallowing in the TT group were higher than for those same values in the NT group. This finding is supported by Takahashi et al (Takahashi et al., 2005), who reported on the effects of tongue posture with regard to orofacial muscle activity. Their findings revealed that a hyperactivity of the suprahyoid muscle occurred when the patient placed the tongue against the anterior teeth, while a low level of suprahyoid muscle activity was found when the patient placed the tongue against the palate.

With regard to the PMA of the MA muscle recorded during the act of swallowing, this parameter did not reveal any statistically significant differences among all groups. This finding can imply that the MA muscle in both groups function by the same pattern to stabilize the mandible during the act of swallowing.

In considering the DA/MA ratio of the muscles during the course of swallowing, this value was indicative of the relationship between the DA and MA in terms of muscle activity. In this study, the mean DA/MA ratio in the TT group was dramatically higher than for that value in the NT group. This finding indicates that the DA muscles play a crucial role during the act of swallowing in subjects with tongue thrusting. Differences observed in those muscle activities may be used to indicate the presence of a tongue thrusting habit that may occur during the act of swallowing. In terms of a clinical implication, assessment of the activity of those muscles using this ratio may be an adjunctive indicator that could help researchers detect abnormal tongue function and monitor treatment outcomes in patients exhibiting tongue thrusting.

Suggestions

Notably, this study did have some limitations. The first limitation was that this study evaluated only two specific muscles that are involved in the process of swallowing. The second limitation was that this study did not evaluate certain other potentially relevant factors, such as facial morphology and the tongue posture, that could influence orofacial muscle activity. Further investigations involving consideration of those factors in subjects exhibiting tongue thrusting during the act of swallowing are needed.

Conclusion

Hyperactivity of the DA muscle and the high TA/MA ratio that occurs during the act of swallowing was observed in subjects with tongue thrusting. These findings indicate that the DA muscles play an important role in the swallowing process of subjects exhibiting tongue thrusting. Importantly, the relationship of DA and MA may be a useful quantitative indicator that could be used to monitor the correction process for a tongue thrusting habit by observing the adaptation of those muscles.

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