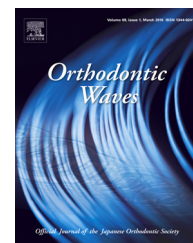


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## Original article

## Study of training for improving lip incompetence

Saori Yoshizawa<sup>\*</sup>, Mai Ohtsuka, Tomoo Kaneko, Junichiro Iida

Department of Orthodontics, Division of Oral Functional Science, Graduate School of Dental Medicine, Hokkaido University, Sapporo, Japan

## ARTICLE INFO

## Article history:

Received 30 March 2016

Received in revised form

2 June 2016

Accepted 21 July 2016

Available online 1 August 2016

## Keywords:

Lip incompetence

Orthodontic(s)

Myofunctional therapy

Oral rehabilitation

Muscle biology.

## ABSTRACT

**Purpose:** We have been using myofunctional therapy in orthodontic treatment to improve orofacial disorders. Our previous study showed that lip training increased orbicularis oris muscle strength and endurance. The aim of this study was to determine the effectiveness of hypoxic lip training for improving lip incompetence.

**Subjects and methods:** Twenty healthy subjects (10 males and 10 females,  $23.6 \pm 2.3$  years old) with lip incompetence participated in this study. We recorded the sealed lip ratio calculated by using the formula “(lip-sealing time/total recorded time)  $\times$  100” during relaxation (listening to soothing music) and during concentration (performing a mathematical calculation). Then the subjects performed a standardized hypoxic lip training (5 repetitive contractions with 80% of maximum tensile strength of the orbicularis oris muscle) with a traction plate. Training was repeated daily for 4 weeks. To estimate training effects, the sealed lip ratios during relaxation and concentration were recorded before training (T1), at 2 weeks (T2) and 4 weeks (T3) after the start of training, and at 4 weeks (T4) and 8 weeks (T5) after the end of training.

**Results:** The sealed lip ratios in both the relaxation and concentration conditions significantly ( $p < 0.003$  after Bonferroni correction) increased during the training period. Although the sealed lip ratios slightly decreased during the post-training period, they were not significantly different from those at T3.

**Conclusions:** Hypoxic lip training increases the sealed lip ratio and is thus effective for improving lip incompetence. Sealed lip ratios were maintained after 8 weeks of training.

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## 1. Introduction

In orthodontic treatment, myofunctional therapy (MFT) is used to improve orofacial disorders such as mouth breathing and abnormal tongue and lip resting postures. Coordination of the functions of the lips, cheeks, tongue, and jaws is essential in normal chewing and swallowing [1].

Lip competence is the condition whereby the lips are in light contact when the mandible is in its clinical rest position [2,3]. It has been reported that lip incompetence is associated with mouth breathing and ventilation disorders [4]. Lip incompetence has various negative effects leading to articulation defects, dysphagia, and periodontal disease as a consequence of dry mouth [5] and to the development of various types of malocclusion such as maxillary protrusion

<sup>\*</sup> Corresponding author at: Department of Orthodontics, Graduate School of Dental Medicine, Hokkaido University, Kita 13, Nishi 7, Kita-ku, Sapporo, Hokkaido, 060-8586, Japan. Tel.: +81 11 706 4287; fax: +81 11 706 4287.

E-mail address: [saori.yoshizawa@den.hokudai.ac.jp](mailto:saori.yoshizawa@den.hokudai.ac.jp) (S. Yoshizawa).

<http://dx.doi.org/10.1016/j.odw.2016.07.001>

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and open bite [6]. In contrast, lip competence has an important role in the growth and development of the craniofacial complex [7]. Therefore, improving lip incompetence may help to resolve these problems.

There are several types of MFT training for improving lip incompetence including button pull exercises [8]. However, the effectiveness of these methods for improving lip incompetence must be estimated more objectively.

In the field of sports medicine, it has been reported that hypoxic muscle training, which is training under a condition that reduces the oxygen concentration in muscle, is effective for increasing muscle strength. On the other hand, aerobic exercise, which is training under a condition with a high oxygen concentration in muscle, is effective for increasing the endurance of muscles, which is persistence of muscle activity [9].

In a previous study, we measured oxygenation dynamics in the orbicularis oris muscle by using near-infrared spectrometry and evaluated training methods to improve the strength and endurance of the orbicularis oris muscle [10,11]. We revealed that aerobic training, which involved 20 repetitions with 50% of maximum tensile strength for the orbicularis oris muscle for 5 s and rest for 5 s, was effective for improving orbicularis oris muscle endurance. On the other hand, we showed that hypoxic training for the orbicularis oris muscle, which involved 5 repetitions with 80% of maximum tensile strength for the orbicularis oris muscle for 5 s and rest for 5 s, was effective for improving both orbicularis oris muscle strength and endurance [11]. Ohtsuka reported that aerobic lip training, which increases orbicularis oris muscle endurance, improves lip incompetence in a patient with lip incompetence [12]. Guyton and Hall reported that muscles that contract at more than 50% of maximum force of contraction will rapidly develop muscle strength even if the contractions are performed only a few times each day [13]. Our previous study also showed that hypoxic training for the orbicularis oris muscle increases its strength.

The aim of this study was to determine the effectiveness of hypoxic orbicularis oris muscle training for improving lip incompetence.

## 2. Subjects and methods

### 2.1. Subjects

The subjects were 20 healthy Japanese volunteers (10 males and 10 females) who were undergraduate or graduate students of Hokkaido University with lip incompetence as defined in previous report. There have been various definitions of lip incompetence in past studies. In this study, we used the Satimary's definition based on cluster analysis [14]. Satimary reported that lip-incompetent patients had a sealed lip ratio (percentage of lip-sealing time/total recorded time) of less than 30.1% at rest and less than 13.2% during a concentration task. These were the parameters by which we defined lip incompetence [14]. The mean age of the subjects was  $23.6 \pm 2.3$  years (males:  $24.3 \pm 2.2$  years, females:  $22.9 \pm 2.3$  years). Exclusion criteria were any nasopharyngeal complaints, a previous history of orthodontic

treatment, missing anterior teeth, any skeletal malocclusion ( $ANB < 3.0^\circ$  and  $5.5^\circ < ANB$ , using a non radiographic ANB angle measurement device [15]), and an abnormal overbite and/or overjet ( $\sim 2.0$  mm and  $3.0$  mm $\sim$ ).

### 2.2. Study design

This study was a single-arm exploratory study to investigate the effectiveness of hypoxic lip training for improving lip competence. To estimate the effectiveness of training, the orbicularis oris muscle strength and endurance and the lip sealing time during relaxation and concentration were recorded before training (T1) and 2 weeks (T2) and 4 weeks (T3) after hypoxic lip training started. Then to estimate the sustainability of the effect of training during the post-training period, muscle strength and endurance and lip sealing time were recorded at 4 weeks (T4) and 8 weeks (T5) after the termination of hypoxic lip training (Fig. 1). All of the measurement conditions (temperature, humidity, room lighting, period of the day in which measurements were conducted, and written instructions) were the same for all subjects.

### 2.3. Estimation of sealed lip ratio

A lip seal detection sensor ( $2.0$  mm  $\times$   $5.0$  mm  $\times$   $200$   $\mu$ m) was attached to the lower lip via a skin adhesive (Varicare®, Conva Tec, NJ, USA) in a position where the lower lip would come into contact with the upper lip (Fig. 2). Measurements recorded by a lip contact sensor and electrical recording device [16] were used for estimating the sealed lip ratio. The sealed lip ratio was calculated using the following formula: Sealed lip ratio = (lip sealing time/total recorded time)  $\times$  100 [16]. The touch sensor



**Fig. 1 – Study design.** T1, start of hypoxic lip training; T2, 2 weeks after the start of training; T3, 4 weeks after the start of training; T4, 4 weeks after the end of training; T5, 8 weeks after the end of training.



**Fig. 2 – Evaluation of sealed lip ratio.** A lip seal detection sensor ( $2.0$  mm  $\times$   $5.0$  mm  $\times$   $200$   $\mu$ m) was attached to the lower lip via a skin adhesive in a position where the lower lip would come into contact with the upper lip.

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