Efficiency of Closed Mastication of Gummy Evaluated with Gnatho-hexagraph

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Abstract

The aim of this study was to determine whether chewing with closed lips improved masticatory efficiency compared with open lips. A total of 21 adults comprising 10 men and 11 women with a mean age of 26.2±3.5 years and normal masticatory function were included in the study. The study participants were instructed to chew a fresh gummy under two conditions for 30 seconds each, one after the other: the first with closed lips, and the second with open lips. The average size of the fragmented gummies was calculated and graded from 1 to 4 according to a specific scale. Masticatory efficiency was evaluated using this “gummy mastication value” and the Gnatho-hexagraph II to observe and analyse jaw movement during chewing. Differences in chewing time and mouth-opening distance were also compared. The gummy mastication value for open and closed lips mastication was 2.51±0.56 and 3.25±0.50, respectively (p<0.01). Masticatory efficiency was significantly greater during closed-lip mastication. The number of chewing strokes over 20 seconds decreased while chewing time and mouth-opening distance increased in cycle 1 with open-lip mastication. In conclusion, the present results revealed that chewing efficiency improved with closed-lip mastication, indicating that instruction to seal the lips while eating is appropriate and necessary.

Key words: Chewing instructions — Gnatho-hexagraph II — Masticatory efficiency — Closed-lip mastication — Objective evaluation

Introduction

Improving chewing ability is one of the functional objectives of orthodontic treatment. Enhancement of this function is important in the development of the ability to consume food, one of the stated goals of the Japanese Association of School Dentists. As part of
this policy, elementary and junior high school students with mixed dentition are encouraged to chew with their lips closed.

Orthodontists often encounter patients who complain that they are unable to keep their lips closed while at rest or eating\(^1\). Two factors have been identified in lip incompetence\(^1\): antero-posterior positioning of the maxillary and mandibular incisors together with overall disharmony of the dentofacial complex\(^2,3,18,19\); and altered oral function to allow breathing in response to nasal obstruction\(^2,3,18,19\). Sakaguchi \textit{et al.}\(^17\), Sugawara \textit{et al.}\(^20\) and Sugawara\(^21\) reported that chewing time and chewing cycle time were significantly prolonged in adults required to masticate with compromised lip competence due to artificially induced nasal obstruction, suggesting that such conditions have a negative effect on masticatory function. Another study, however, found that masticatory efficiency was unaffected under such conditions in children\(^1\). Meanwhile, one study observed a negative correlation between nasal airway resistance and lip-closing force\(^16\). Noro\(^14\) also noted a reduction in lip-closing force with mouth-breathing in younger people. Taken together then, these studies suggest an association between mouth-breathing due to nasal obstruction and weak lip-closing force. Lip-closing force is affected by a number of variables, including upper incisor angulation and skeletal pattern\(^4,6,15,23\). Studies of children with undeveloped masticatory function reported a positive correlation between lip-closing force and masticatory ability\(^8\). Various studies have investigated the relationship between masticatory efficiency and lip-closing force. However, to our knowledge, no studies to date have investigated the effect of lip position (that is, open or closed) on chewing ability. The aim of this study was to determine whether mastication with closed lips improved masticatory efficiency.

**Materials and Methods**

A total of 21 adults comprising 10 men and 11 women with a mean age of 26.2 ± 3.50 years and normal masticatory function were included in the study (Table 1). Non-sugar gummies (\textit{Kamuzo kun}, Mamarishimo Co., Ltd.) developed for chewing lessons and examining masticatory function were used (Fig. 1). The study participants were instructed to chew a fresh gummy under two conditions for 30 seconds each, one after the other: the first with closed lips, and the second with open lips. The second fragmented gummy was measured and the average size calculated.
and graded from level 1 to 4 using a specially developed scale (Fig. 2). This number represented the “gummy mastication value”. Thereafter, 7 participants were selected at random and requested to chew gummies under the same conditions again but for only 20 seconds each. The Gnatho-hexagraph II (GC Co., Ltd.), a jaw motion measurement system, was used to observe and analyse jaw movement during mastication. The number of chewing strokes was calculated over 20 seconds. The following values were obtained: the average stroke value per 20-second cycle; the same for between 3 and 5 seconds (as the initial stage of mastication) and for between 15 and 20 seconds (final stage of mastication); chewing time; and mouth-opening distance. The Wilcoxon signed-rank test was used for the statistical analysis.

Results

The gummy mastication value for open and closed lips was $2.51 \pm 0.56$ and $3.25 \pm 0.50$ respectively; efficiency was significantly greater with closed lips ($p<0.01$) (Fig. 3; Table 2).

The Gnatho-hexagraph II analysis revealed that number of chewing strokes over 20 seconds for open and closed lips was $25.14 \pm 3.89$ and $28.14 \pm 4.02$ respectively, showing a decrease with open lips (Table 3). Chewing time in cycle 1 with open lips was longer than with closed lips at both the initial and final stages of mastication. In addition, mouth-opening distance was longer with open than with closed lip mastication. Chewing time in cycle 1 and mouth-opening distance were significantly prolonged ($p<0.01$) and increased ($p<0.05$), respectively, at 3 seconds with open- compared to closed-lip mastication (Figs. 4 and 5). Observation revealed that the width of jaw movement was reduced and chewing characterized by chopping strokes when open-lip mastication was employed, whereas closed-lip mastication yielded a wider degree of movement and grinding strokes (Fig. 6).

Discussion

Eating with the lips closed is advantageous in that the time the food remains in the oral
vestibule is reduced because it is easier to move the bolus around under these conditions, with the lips working more effectively with the tongue to promote efficient mastication. As can be seen in Fig. 6, the width of jaw movement was reduced and chewing characterized by chopping strokes when open-lip mastication was employed, whereas closed-lip mastication yielded a wider degree of movement and grinding strokes. This narrowing with open-lip mastication probably results from the need to prevent food from spilling out of the oral cavity. Coordinated movement of the lips, jaw, buccinators muscle, and tongue are all required to prepare the bolus for swallowing. Incompetent function of any one of these parts upsets the balance and decreases masticatory efficiency. Although mouth-opening distance was greater, the cycle time was longer and number of strokes reduced with open-lip mastication. We believe that this is because the buccinators muscle and tongue have to compensate for the lack of lip support and work harder to gather the bolus with closed-lip mastication (Figs. 4 and 5). These results are consistent with those of an earlier study by Sakaguchi et al. on the number of mastication strokes over a certain period under artificially induced nasal obstruction (Table 3). Taken together, they

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**Fig. 4 Chewing time in cycle 1**

Chewing time in cycle 1 with closed lips was faster than with open lips.

**Fig. 5 Mouth-opening distance**

Mouth-opening distance with closed lips was shorter than with open lips.

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**Fig. 6 Jaw movement record**

Masticatory motion with closed lips was characterized by grinding strokes, whereas that with open lips showed chopping strokes.

(a) Open-lip: width of chewing course was narrower than with closed lips.

(b) Closed-lip: width of chewing course was wider than with open lips.
also show that poor lip positioning decreases masticatory efficiency and grinding movement. Here, gummies with a hardness of approximately 390.6 N were used, which is greater than that of commercially available gummies. The elasticity was 0.91, which is comparable to French bread; cohesiveness was 0.81, which is similar to spaghetti; and adhesion was $-0.76 \text{g} \cdot \text{sec}$, which is equal to a pork cutlet. Hard chewing gum was selected in this study, as it has been shown to promote grinding strokes\(^{24}\). Therefore, we believed that this would enable us to detect proper grinding strokes during closed-lip mastication\(^ {12,13,22}\).

The purpose of this study was to investigate the effects of closed- and open-lip mastication on chewing ability using gummies and the Gnatho-hexagraph II. In cases of lip incompetence, orthodontic or orthognathic surgical treatment may be needed to improve lip-sealing function in addition to verbal guidance.

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