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Masticatory Efficiency before and after Orthognathic Surgery Using Chewing Gum Containing Spherical Resinous Microparticles

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Abstract: Evaluation of masticatory performance is an important objective of orthognathic surgery. The purpose of this study was to examine masticatory performance including masticatory efficiency using chewing gum containing spherical resinous microparticles before and after orthognathic surgery. We evaluated 18 patients who underwent orthognathic surgery for masticatory efficiency (gum chewing), occlusal contact area (silicone bite) and occlusal pressure (pressure-sensitive sheet recording), and masticatory muscle activity (electromyographic evaluation of the masticatory muscles). Examinations were performed immediately before surgery, and 3, 6, and 12 months after surgery. No significant difference in masticatory efficiency as a standard degree of comminution was found among any of the chewing sites or examination time points, and the patients showed a variety of changes in masticatory efficiency. Masticatory performance excluding masticatory efficiency was apparent after surgical recovery. These results suggest that masticatory efficiency as a standard degree of comminution varies before and after orthognathic surgery on a patient-to-patient basis.

Key words: masticatory efficiency, masticatory performance, orthognathic surgery, chewing gum

Introduction

The primary objective of orthognathic surgery is to improve masticatory performance. Numerous studies have documented masticatory performance such as chewing cycle kinematics[1-3], measurement of the occlusal force[4-8] and occlusal contact area[4,6,7,9], and low-adhesive colour-developing chewing gum[10] in patients who needs orthognathic surgery.

Masticatory performance tests are classified into indirect and direct tests. Indirect testing involves electromyographic evaluation of masticatory muscle[1,11], chewing cycle kinematics[1-3],

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measurement of occlusal contact[12] such as the occlusal contact area and number of teeth in contact, and measurement of occlusal force[12, 13]. Direct testing involves subjective measurements applying “a chewing index”[14] and mastication of test foods such as peanuts[15], rice[16], gummy jellies[17–20], and chewing gum[21, 22].

Masticatory efficiency is one measure of masticatory performance, and is defined as the objective masticatory function required to achieve a standard degree of comminution[23]. Chewing gum containing spherical resinous microparticles is potentially suitable for evaluating masticatory efficiency because it is a uniform specimen that does not change because of swallowing, and natural chewing can be reproduced[21]. We aimed to examine masticatory performance, including masticatory efficiency, using chewing gum containing spherical resinous microparticles before and after orthognathic surgery.

Materials and methods

The study included 18 patients (9 males and 9 females with a mean age of 27 years and 5 months and 28 years and 0 months, respectively, at the time of orthognathic surgery) who underwent orthognathic surgery at our department from August 2013 to December 2015. The patients had undergone mandibular setback surgery (with or without maxillary surgery), and had no congenital abnormalities such as cleft lip and palate or congenital anodontia excluding the third molars. Each patient provided informed consent after sufficient explanation of the purpose and method of this study, and the Ethics Committee of the School of Dentistry, Showa University approved the study protocol (approval number: 2012-033).

Masticatory performance tests

Masticatory efficiency (gum chewing test)

Patients were instructed to place chewing gum containing spherical resinous microparticles (Examastica Co., Tokyo, Japan) in the oral cavity for 10 s, and then masticate at a pace of one cycle per second (Fig. 1a). The mastication duration was set to 25 cycles, with free chewing, right-side chewing, and left-side chewing, each performed three times. After that, the base of

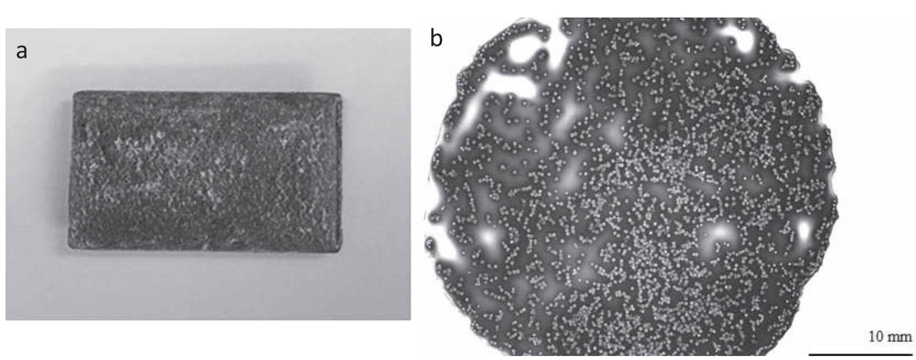

Fig. 1. a: Chewing gum containing spherical resinous microparticles: length 11 mm × width 18 mm × height 5 mm.
b: Magnified image showing the size of the particles: 280 μm.

the gum was softened and melted, the pulverized particles were removed then flattened, and the number of particles contained in the gum base was measured microscopically by the same operator to examine masticatory efficiency, as described by Kanaya *et al*[21]. The main components of the gum were sweetener (maltitol, xylitol, acesulfame k), reduced sugar syrup, gum base, carnauba wax, perfume, softener, and colouring agent (charcoal). Each piece of gum contained 2000 carnauba wax particles, 280 μm in diameter (Fig. 1b). The application of masticatory load caused particles to be crushed and lose their original form.

Number of occlusal contact points and occlusal contact area (silicone bite)

To undertake the silicone bite test, patients sat on a chair such that the occlusal plane was parallel to the floor. After confirming the stability of the intercuspal position, a silicon occlusion record was taken using blue silicone (GC Co., Tokyo, Japan) placed in the oral cavity for 2 min and 45 s, and then removed. To measure the occlusal force, patients were instructed to bite the silicone bite with normal force. We then measured the number of teeth in contact and the occlusal contact area on the silicone bite using a BITE-EYE (GC Co.).

Occlusal pressure (pressure-sensitive sheet recording)

Patients seated with their occlusal plane parallel to the floor were again checked for intercuspal stability, and then asked to clench a sheet of Dental Prescale 30HW (GC Co.), with maximum clenching for 3 s at the intercuspal position. After occlusion, the Dental Prescale was analyzed using DePROS709 (GC Co.), and occlusal pressure (the force applied per unit area) was evaluated as described previously[13].

Masticatory muscle activity (electromyographic evaluation of masticatory muscles)

Patients sat on a chair so that the occlusal plane was parallel to the floor. After confirming that the patient's teeth were in the intercuspal position, the maximal muscle activity of the right anterior temporalis, right posterior temporalis, right masseter, left anterior temporalis, left posterior temporalis, and left masseter was recorded using electromyography (MP 100 System, Biopack Systems Ltd., Goleta, CA, USA), and the integral value for each muscle was calculated. This examination was performed immediately before surgery, and at 3, 6, and 12 months after surgery.

Statistical analysis

Measurements were performed four times: before surgery, and at 3, 6, and 12 months after surgery. The Friedman test was used to test for significant changes among the groups in each measured value. After the significances of the values were proven, a paired t-test was used to evaluate serial comparisons among time intervals. We used Microsoft Excel add-in software Statcel 3rd edition (OMS, Tokorozawa, Saitama, Japan) for statistical analyses. Statistical significance was set at $P < 0.05$.

Results

Masticatory efficiency (gum chewing test)

There was no significant difference in masticatory efficiency using the gum containing spherical resinous microparticles among the chewing sites or examination time points (Table 1).

Number of occlusal contact points (silicone bite)

There was a significant difference in the number of teeth in occlusal contact (Table 1), whereby at 3, 6, and 12 months after surgery, the total number of teeth in occlusal contact was significantly greater than that before surgery (Table 2).

Occlusal contact area (silicone bite)

There was no significant difference in occlusal contact area among the study groups (Table 1).

Occlusal pressure (pressure-sensitive sheet recording)

A significant difference was observed in occlusal pressure (Table 1). At 3 and 12 months after surgery, the total number of teeth in occlusal contact was significantly less than that before surgery. At 6 and 12 months after surgery, the total number of teeth in occlusal contact was significantly less than that 3 months after surgery, while 12 months after surgery, the total number of teeth in occlusal contact was significantly less than that at 6 months after surgery (Table 2).

Masticatory muscle activity (electromyographic evaluation of masticatory muscles)

There was a significant difference in the left masseter muscle activity before and after surgery (Table 1).

Table 1. Masticatory performance indicators (n = 18)

		Before surgery Median [Min-Max]	3 months after surgery Median [Min-Max]	6 months after surgery Median [Min-Max]	12 months after surgery Median [Min-Max]	*P* value
Chewing efficiency: free mastication		0.82 [0.35-1.4]	0.79 [0.30-1.61]	0.90 [0.24-1.41]	0.96 [0.39-1.17]	
Number of occlusal contact points: total (both sides)		14.5 [1-26]	18.0 [6-33]	20.0 [6-33]	20.5 [11-40]	**
Occlusal contact area: total (both sides)	mm^2	13.45 [4.1-30.1]	12.3 [3.2-31.7]	11.8 [4.9-27.6]	16.6 [7.8-29.5]	
Occlusal pressure	Mpa	1.30 [0.4-8.1]	4.15 [0.1-29.7]	0.30 [0.1-7.9]	2.10 [0.6-10]	**
Right anterior temporalis		0.74 [0.19-1.41]	0.41 [0.19-1.30]	0.49 [0.16-1.32]	0.49 [0.16-1.71]	
Right posterior temporalis		0.28 [0.09-0.91]	0.28 [0.09-0.73]	0.23 [0.1-0.75]	0.33 [0.01-0.88]	
Right masseter		0.51 [0.10-1.08]	0.35 [0.10-0.89]	0.34 [0.12-2.13]	0.44 [0.13-1.31]	
Left anterior temporalis		0.51 [0.01-1.59]	0.37 [0.07-1.30]	0.48 [0.14-1.81]	0.55 [0.13-0.78]	
Left posterior temporalis		0.25 [0.05-0.79]	0.26 [0.08-1.05]	0.29 [0.07-1.06]	0.31 [0.22-0.97]	
Left masseter		0.50 [0.15-1.26]	0.26 [0.15-0.77]	0.45 [0.16-0.89]	0.37 [0.16-1.05]	*

*indicates $P < 0.05$

**indicates $P < 0.01$

Table 2. Serial comparison among each time interval (n = 18)

	Before versus 3 months after surgery	Before versus 6 months after surgery	Before versus 12 months after surgery	3 months versus 6 months after surgery	3 months versus 12 months after surgery	6 months versus 12 months after surgery
Number of occlusal contact points: total (both sides)	*	**	**			
Occlusal pressure	**		**	*	*	*

* indicates $P < 0.05$
** indicates $P < 0.01$

Discussion

The purpose of orthognathic surgery is to improve occlusal relationships, facial aesthetics, and function of the masticatory system in patients with dentoskeletal deformities[4-6, 11]. A comprehensive evaluation of masticatory performance is difficult using a single test method, and multilateral evaluation using various tests is usually necessary[1, 4, 11]. The direct tests conducted in this study were evaluation of the chewing of gum containing spherical resinous microparticles, number of teeth in contact, and occlusal contact area. As an indirect test, we evaluated masticatory muscle activity (electromyographic evaluation of masticatory muscles).

The use of chewing gum containing spherical resinous microparticles can reproduce natural mastication, and there is only a low possibility that the particles will be swallowed because the specimens do not come apart after mastication. When using chewing gum containing spherical resinous microparticles, evaluating masticatory efficiency is based on destruction of the particles, which is not influenced by the degree of mixing of the gum after mastication, and is represented numerically. In this study, the patients showed a variety of changes in masticatory efficiency following orthognathic surgery, from unchanged to increased efficiency. Masticatory efficiency increases when a chewing pattern remains stable[21], while patients with mandibular prognathism exhibit a chopping pattern during mandibular movement[24], and show less lateral movement than patients with normal occlusion[25]. It is thus inferred that the changes in the chewing pattern after orthognathic surgery are unique to each patient.

The total number of teeth in occlusal contact was significantly increased at 3, 6, and 12 months after surgery compared with that measured immediately before surgery. This finding is similar to that in a previous study in which the number of teeth in occlusal contact was lower prior to orthognathic surgery and immediately before orthognathic surgery compared with the number in contact after surgery[18]. The occlusal pressure was significantly increased 3 months after surgery compared with that before surgery, and decreased thereafter; this was also similar to a previous report[26]. The jaw position is not stable after surgery, and the pressure between the force caused by occlusion and the surface of teeth receiving the force does not readily disperse[26], possibly accounting for the increased occlusal pressure 3 months after surgery compared with that immediately after surgery. A considerable amount of time after orthognathic surgery is required for masticatory muscles to adapt to a new mandibular position[3,7]. The occlusal relationship of the upper and lower teeth was also greatly improved after orthognathic surgery, and hence the number of occlusal contact points and occlusal contact area were higher at 3, 6, and 12 months after surgery compared to that measured before the procedure. Because of the increased number of occlusal contact points, smooth dispersion of pressure became possible, and the occlusal pressure decreased.

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Conflict of interest disclosure

None of the authors have a conflict of interest to declare.

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