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Original Article

Palatal Coverage Disturbance in Masticatory Function

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Oral sensorimotor function is essential for mastication. We hypothesized that palatal coverage would disturb mastication and sensorimotor function. Masticatory efficiency, which was expressed by the declination rate of particle size, and oral stereognosis ability (OSA) were measured for 20 dentate subjects. Both measurements were first performed without an experimental palatal plate. These measurements were then repeated with the plate on the day of the plate insertion, then again on the 3rd and 7th day. After 2 months, another series of measurements for the OSA test were performed without the plate with the same time-course. Masticatory efficiency significantly decreased with the plate. OSA score, which continuously increased during the experimental period, showed no difference between with and without the plate. Positive correlation between masticatory efficiency and the OSA score was found only without the plate. It was suggested that coordination between mastication and the sensorimotor function was disturbed by palatal coverage.

Key words: oral sensorimotor function, oral stereognosis, masticatory function, masticatory efficiency, palatal coverage

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Introduction

Stomatognatic system has been closely examined using neuro-physiological approaches[1-5]. It is well known that a central feedback system controls masticatory movement. The textural stimuli of food onto transformed periodontal receptors modulate chewing forces with the positive feedback system[6]. Palatal mucosal mechanoreceptor also functions to identify the precise position of food bolus in the mouth[7]. It was reported that oral size perception resulted from a combination of sensory inputs from the palate and the tongue[8]. Receptors located deeply in the palatal mucosa were closely related to masticatory performance and swallowing[9]. Hirano et al.[10] also reported that positive correlation existed between masticatory ability and oral sensorimotor ability. These studies show that both oral motor and sensory ability would reflect masticatory ability, leading to the process of well-controlled mastication.

Oral sensory ability controls masticatory movement even for edentulous people when chewing with their dentures. It was reported that the receptors existing in oral tissues other than periodontal ligament, regulated contraction of elevator muscles during mastication of complete denture wearers[11].

However, denture wearing demands the coverage of an oral mucosa. Maxillary dentures inevitably cover palatal palate extensively to enlarge retentive forces and intensity in mechanical strength of the dentures. According to reports, the tissue contour in the middle part of the palate area remained stable after teeth extractions[12], and that morphological changes in this area were less than in other areas[13]. This proposes the following question, that is, the coverage of the palatal palate by dentures possibly may induce impairment natural contour of palatal palate, leading to disturbance of oral function. Specifically, maxillary complete dentures, which have often extended posterior borders to the vibrating area in order to enhance retention of the dentures, will not only induce blocking of the stimuli externally input onto denture-bearing tissues, but also infringe tongue space due to the thickness of the denture base. These interferences induced may eventually diminish oral sensory and motor ability when wearing maxillary dentures. This consideration hypothesizes that palatal coverage would decrease oral sensorimotor ability, so that it disturbs masticatory efficiency, resulting in decline of masticatory ability. However, the alteration of masticatory ability and oral sensorimotor ability induced by palatal coverage has not been closely disclosed.

The purpose of this study was to investigate the effects of palatal coverage on masticatory ability, oral sensorimotor ability and the relationship between these abilities.

Materials and Methods

Subjects

20 volunteer subjects (12 males and 8 females, age range 24-31 years old, average 26.8±2.09 years) participated in this study. They had no neuromuscular problems and exhibited 28 or more teeth continuously in dental arches.

They had been given their informed consent according to the World Medical Association's Declaration of Helsinki. This investigation was approved by the Ethics committee, Tokyo Medical and Dental University.

Experimental Palatal Plate Fabrication

A maxillary impression for each subject was made by irreversible hydrocolloid impression material (Aroma Fine Mixer Type®, GC, Tokyo, Japan). The working cast was poured using a type II plaster (New Plastone®, GC, Tokyo, Japan). Then a sheet of wax with 1.5 mm thickness (Paraffin Wax®, GC, Tokyo, Japan) was placed across the palate area as covered from marginal gingiva to the anterior boundary of the vibrating area. The wax pattern on the cast was flasked, dewaxed and then packed using heat polymerized acrylic resin (Acron®, GC, Tokyo, Japan). After processing, the palatal plate was deflasked, and finished in a conventional manner, and then adjusted so as not to make contact with the opposing teeth during occlusion. Subjects were instructed to wear it during the daytime for a 7-day experimental period.

Masticatory Efficiency Measurement

Particle size reduction as a function of chewing strokes was employed to evaluate masticatory efficiency. Subjects were instructed to chew freely 3.0 g of peanuts for 5, 10, 15, 20 and 30 strokes. The collected portions for three repetitions were washed on a 75-μm aperture sieve with running water and dried in an oven at 80°C for 24 hours. After drying, the chewed peanuts were raveled carefully and subjected to a sieving procedure using a sieving instrument (Robot Sifter® Seishin, Tokyo, Japan). The sieve apertures used to determine the degree of comminution were 4750, 2360, 1700, 1180, 850, 600, 355 and 75 μm. The sieves were chosen as the apertures were evenly distributed after logarithmic transformation. After weighing the portions remaining on each sieve, the median particle size by weight (x_{50}) for each chewing stroke was mathematically determined by substituting the weight of comminuted particles on each sieve into the Rosin-Rammler equation[14]. Then a variable, which expresses exponential decrement of the x_{50} for each chewing stroke, was determined by curve-fitting using the least-squares method[15]. This variable was represented as masticatory efficiency.

Oral Stereognosis Ability Test

An oral stereognosis ability test was used to evaluate oral sensorimotor ability. Test pieces comprised 12 forms, of shapes that included circles, ellipses, squares, rectangulars, triangles and semicircles in large and small size (Fig. 1). Test pieces were made of raw carrot to allow subjects to perform free oral manipulation without any discomfort and for the safety

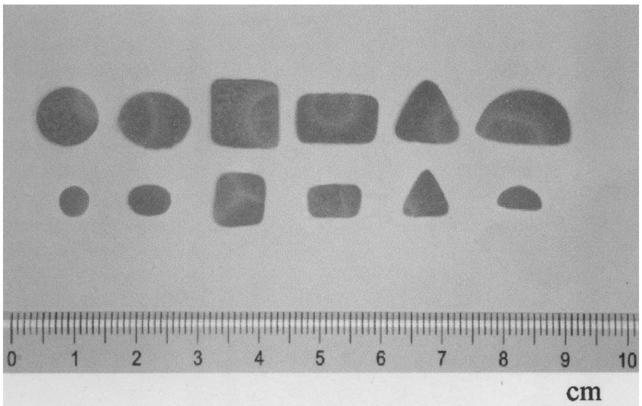

Fig. 1. Test pieces used for the oral stereognosis ability test. Top and bottom were large size and small size test pieces, respectively.

aspiration[16].

Before the OSA test, the experimental procedure was explained to the subject and all the test pieces and corresponding drawings were shown. The test was carried out in a quiet environment with no practice trials. A test piece was placed on the tongue with a pair of tweezers to be kept out of the subject's sight. Following this, the subject was allowed to freely manipulate the test piece in the mouth in order to identify it, without biting it or using the lips. After identifying the item, the subject selected a matching drawing. The score for each answer was weighed using a three-point scale. The score for a correct answer was 2 points. The score for an incorrect answer was 0 point. If the subject chose an incorrect, but similar item, such as circle for ellipse, square for rectangular, and triangle for semicircle or vice versa, then 1 point was awarded. The test was repeated three times for each form in random order, total score of 36 trials were calculated, resulting in full marks of 72 points. The total score was used as the OSA score. The correct answers and the scores were not informed to the subjects during the experimental period.

As baseline session, masticatory efficiency and OSA were measured without wearing the palatal plate. Both measurements were performed immediately after the palatal plate insertion, and then repeated on the 3rd and the 7th day after the insertion. Additionally, measurement series for another OSA test was carried out without wearing the palatal plate in the same protocol after 2 months.

Data Analysis

The mean value of masticatory efficiency was statistically analyzed using one-way repeated-measured ANOVA. The mean value of the OSA score at each measurement session with and without the palatal plate was statistically analyzed using two-way repeated-measured ANOVA. Post hoc analysis performed using the Bonferroni test. Spearman's correlation by ranks was used to analyze relation between masticatory efficiency and the OSA score with and without the palatal plate at each measurement session. The significance level was set at 0.05.

Results

Masticatory efficiency was significantly influenced by wearing the palatal plate (Table 1). Figure 2 indicates that masticatory efficiency was decreased compared

Table 1. One-way repearted-measured ANOVA results of masticatory efficiency during measurement session with the palatal plate

source of variation	df	MS	F value	P value
days	3	0.005	9.715	<0.001

df=degree of freedom. MS=mean square.

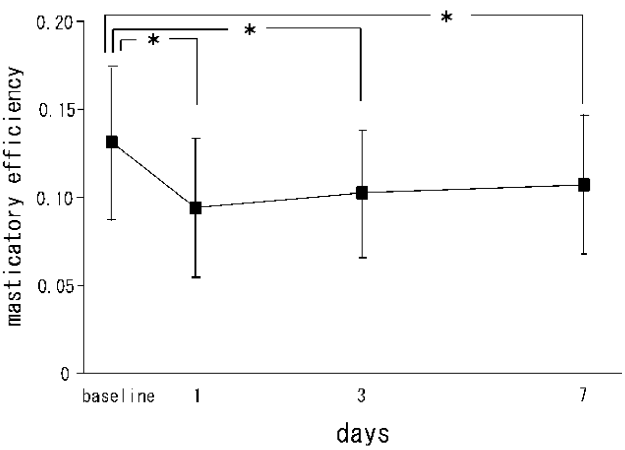

Fig. 2. Change of masticatory efficiency during measurement session with the palatal plate. Results indicate Mean±standard deviation of masticatory efficiency during the session. Masticatory efficiency is significantly decreased compared with baseline for 7 days after the insertion of the palatal plate. *: $P<0.05$

with baseline (Mean±SD: 0.1311±0.04382) for 7 days after the insertion of the palatal plate (1 day after the insertion: 0.09446±0.03956, 3 days after: 0.1027±0.03581, 7 days after: 0.1079±0.03910).

The OSA score was not influenced by wearing the palatal plate, while being significantly influenced by repetition of the OSA test (Table 2, Fig. 3).

Correlations between masticatory efficiency and the OSA score for all measurement sessions are shown in Table 3. A significantly positive correlation was found at baseline (ρ=0.697; $P<0.05$), but was lost at all measurement sessions after the palatal plate insertion (1 day after the insertion: ρ=0.363; P=0.114, 3 day after: ρ=0.148; P=0.518, 7 days after: ρ=0.286; P=0.214). However, positive correlation was found between masticatory efficiency at baseline and the OSA score without the palatal plate at all measurement sessions (1 day: ρ=0.738; $P<0.05$, 3 day: ρ=0.671; $P<0.05$, 7 day: ρ=0.700; $P<0.05$).

Table 2. Two-way repearted-measured ANOVA results of OSA score during measurement sessions

source of variation	df	MS	F value	P value
with/without palatal plate	1	177.6	1.468	0.233
days	2	129.7	27.04	<0.001
interaction	2	9.058	1.889	0.158

df=degree of freedom. MS=mean square.

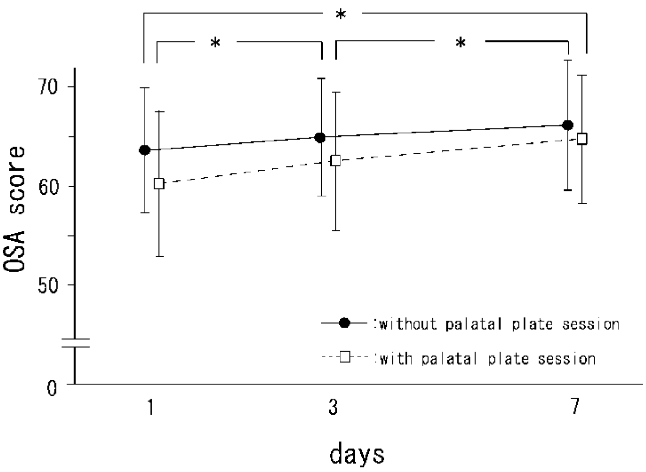

Fig. 3. Change of OSA score during measurement sessions. The OSA score is not influenced by wearing the palatal plate, while being significantly influenced by repetition of the OSA test. ＊: P＜0.05

Table 3. Correlations between masticatory efficiency and OSA score in each measurement session

measurement session						
baseline		days	with palatal plate		without palatal plate	
P value	ρ		P value	ρ	P value	ρ
0.003	0.679*	1	0.114	0.363	0.001	0.738*
		3	0.518	0.148	0.004	0.671*
		7	0.214	0.286	0.002	0.700*

* P<0.05

Discussion

Numerous methods have been employed to evaluate masticatory ability[17-20]. For objective evaluation, sieving methods have often been applied[21]. Based on the idea that mastication is a result of both selection of food bolus to be chewed and breakage processes of chewed bolus[22], particle size reduction as a function of the number of chewing strokes has been used to evaluate the masticatory function. We employed masticatory efficiency that could express the decrement reduction of median particle size. Selection of particles to be pulverized is also essential in order to comminute foods efficiently and properly in addition to biting, pulverizing and grinding[22]. In another words, oral sensory receptors must perceive the physical character of foods, of which information initiates coordination of oral motor functions to prepare food bolus for swallowing. By wearing the palatal plate, the exotic-stimuli applied to the palatal mucosa are blocked. This blockage would interfere with precise perception of food bolus textures and its location within the mouth. Additionally, wearing the palatal plate causes infringement of tongue space, leading to restriction of tongue movement[23]. Consequently wearing the palatal plate during the 7 days experimental period would invoke disturbances in preparing food bolus for chewing, which was expressed in the reduction of masticatory efficiency observed in the present study.

Oral stereognosis ability test can evaluate not only oral perception but also oral motor ability[24]. The OSA test can be considered to be one of the appropriate methods for our purpose, which is to detect the effect of wearing the palatal plate on disturbance of oral sensation and motor function.

The change in the OSA score after wearing the palatal plate showed different characteristics from alteration with masticatory efficiency. Wearing the palatal plate did not cause a change in the OSA score. The invariability was conforming to the previous study that showed the effect of palatal coverage to OSA[25].

On the other hand, the OSA score increased in the following measurement sessions. OSA tests require subjects to manipulate the test piece only by the tongue. The manipulation is not so difficult and the subjects are easily able to improve skills with repetition, resulting in an increase of the OSA score. This could be due to the learning effect, which made the synthesis of numerous sensory inputs easier with the three measurements repeated for 7 days. It was also reported that the number of false responses in OSA tests was decreased with repetition[26].

The mask of the palatal mucosa by palatal coverage reduced the superflous stimuli for ball size perception, leading to more precise sensing by the tongue[8]. This result did not coincide with our result in the OSA score. This inconsistency would have been caused by the diversity between each task. The OSA test would simply require tongue manipulation skill[8]. Therefore, the palatal mucosa may not play a major role in OSA testing in comparison with ball size perception. It is possible that oral stereognosis ability could not exactly express the disturbed status of oral sensorimotor ability caused by wearing the palatal plate. Consequently, the invariability of oral stereognosis ability could be observed even with the palatal plate.

The impact of wearing the palatal plate in relation between masticatory efficiency and OSA was clearly revealed. Without the palatal plate, a positive correlation existed between masticatory efficiency and OSA score as in the previous report[10]. While wearing the palatal plate, the correlation disappeared for 7 days after the insertion. Without the palatal plate, the OSA score, which kept increasing during the experimental period due to the learning effect, maintained positive correlation to baseline's masticatory efficiency. These results indicated that the disappearance of the correlation would not be due to the learning effect of OSA testing, but due to the disturbance caused by the palatal plate wearing.

The difference in changes between masticatory efficiency and the OSA score during the experimental period may have been due to the required tongue motor skill. Tongue manipulation skill must be more demanding for mastication than for the OSA test. The OSA test is considered to exhibit sensory ability more than motor ability[27]. This characteristic difference would explain that the positive correlation between masticatory efficiency and OSA disappeared due to interference caused by the palatal plate.

A large particle is comminuted selectively during mastication[21]. Similarly, information for the selection of foods collected by sensorimotor function is important for smooth mastication[10]. The disappearance of the positive correlation between masticatory efficiency and OSA score caused by wearing the palatal plate is believed to disturb tongue motor skill in mastication.

It was clearly revealed that palatal coverage during the experimental period disturbed sensorimotor coordination in mastication. In particular, masticatory ability would decrease by the reduction of tongue motor skill induced by the palatal plate. These findings suggest that sufficient attention should be paid for the oral motor ability of individual denture wearer for determination of denture design.

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