Association Between Oral Stereognostic Ability and Masticatory Performance in Aged Complete Denture Wearers

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Purpose: Clinically excellent dentures have shown a limited influence on the function of denture wearers, suggesting that patient factors, such as salivary flow or oral sensory ability, may play an important role in oral function. The purpose of this study was to examine the oral sensory ability of aged edentulous patients in relation to masticatory performance. ***Materials and Methods:*** Subjects were 30 edentulous elderly patients with no oral symptoms or pathologies. Oral stereognostic ability (OSA) tests were conducted with test pieces of 12 shaped forms. The duration time for recognition was noted and the answers were recorded using a 3-point scale. Masticatory performance was determined by the concentration of dissolved glucose obtained from test gummy jellies, which are a standardized food developed for measuring masticatory performance. Bilateral maximum occlusal force in the intercuspal position was measured with pressure-sensitive sheets. Stimulated whole saliva was collected using the mastication method. A multiple linear regression analysis for masticatory performance was carried out. Statistical significance was set at $P < .05$. ***Results:*** The stepwise multiple linear regression analysis showed that masticatory performance was significantly associated with maximum occlusal force ($\beta = .65$, $P < .001$), OSA score ($\beta = .51$, $P < .001$), and hyposalivation ($\beta = -.26$, $P = .042$). The R^2 of the model was 0.67, indicating that about two thirds of the variation in masticatory performance could be statistically explained by this model. ***Conclusion:*** Reduced oral sensory function, low occlusal force, and hyposalivation appear to be associated with impairment of masticatory performance in aged complete denture wearers. *Int J Prosthodont 2007;20:245–250.*

A series of controlled studies has shown a relatively limited influence of denture factors, such as retention, stability, and occlusal relation, on oral function.[1] Similarly, clinically excellent dentures have failed to show any significant relationship with the function and satisfaction of denture wearers.[1,2]

Masticatory performance is commonly reduced in older adults. The impairment of masticatory performance is best explained by the loss of teeth associated with increasing age. However, previous studies have demonstrated that a loss of teeth with age per se is not necessarily associated with a loss of masticatory ability.[3–5] Therefore, it may be useful to identify other significant factors, such as salivary flow, oral sensory function, and motor ability in elderly patients.

In general, deterioration of most sensory abilities, such as visual, auditory, tactile, and chemosensory, appears to occur almost inevitably when humans age.[6] Humans reach an optimum sensory capacity in their twenties, and maintain this peak for several years, and then it begins to decline, with the rate of decline showing a wide individual variation.[7]

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Sensory function of the mouth includes the ability to assess shape, size, surface texture, and temperature. However, decline of this ability is difficult to recognize not only by patients, but also by clinicians. Various methods of measuring oral sensitivity have been used, including oral form recognition, interdental size- and weight-discrimination tests, 2-point discrimination, and so on.[8,9] Oral stereognostic ability (OSA) has been employed in many studies to evaluate oral perception. Some studies have suggested a decline of OSA with age,[10–13] but the results are not necessarily consistent.[8]

The purpose of this study was to examine the OSA of aged edentulous patients in relation to masticatory performance. Because decline of masticatory performance is a multifactorial problem, occlusal force, stimulated salivary flow rate, and OSA were measured and a multiple regression analysis for masticatory performance was carried out. The hypothesis was that a deterioration of oral sensory function is associated with a decline of masticatory performance in complete denture wearers.

Materials and Methods

Volunteer edentulous patients were randomly selected from outpatients of the Osaka University Dental Clinic, Osaka, Japan. The study population included 30 subjects (13 men and 17 women) with a mean age of 75.1 years (62 to 88 years, SD: 6.5). Each edentulous subject wore maxillary and mandibular complete dentures that were made in the clinic. The artificial teeth used were anatomic teeth with a 20-degree cusp incline made with resin composite. The denture-wearing experience of each subject was more than 3 months at the time of this study. All patients visited the clinic for a recall examination and were found to be free from oral symptoms and pathologies and significant medical conditions. The study protocol was approved by the Institutional Review Board of Osaka University Graduate School of Dentistry. All participants gave written informed consent for their participation.

The measurements were taken in the following order: OSA, stimulated salivary flow rate, occlusal force, and masticatory performance. The OSA test was conducted first to avoid any oral sensory stimulation before testing. One clinician conducted all OSA measurements. For all edentulous subjects, the date of insertion of their complete dentures was confirmed based on the clinical record. From this information, the length of time that each patient had been successfully wearing complete dentures was determined. Because of the poor reliability of a patient's memory, assessment of the length of denture-wearing experience, including any previous dentures, at the time of the interview was not considered accurate or valid.

OSA Tests

The OSA tests were conducted following the method of Garrett et al[1] and Hirano et al.[14] The test pieces comprised 12 shaped forms, which included circles, ellipses, semicircles, squares, rectangles, and triangles of both large (12 × 12 × 3 mm) and small (8 × 8 × 2 mm) types.[14] The test pieces were made of acrylic resin to which dental floss was attached. The dental floss protruded from the subject's mouth to prevent aspiration of the test pieces.

The test was carried out in a quiet environment where the subject was seated comfortably in an upright position. The test pieces were kept out of the subject's sight during the test. Subjects were told they should use their tongue and palate to identify the shape. They were instructed to respond as quickly as possible and to avoid biting on the test pieces. Pictures of all 12 test pieces were shown to the subject and the corresponding picture was pointed out for each shape. To prevent a learning effect, no practice trials were held. Each of the 12 pieces was presented twice. The 24 presentations were made in random order. Participants were not informed of the correct answers at any point during testing.

The 6 shape forms were grouped into 3 pairs of similar forms: circles and ellipses, squares and rectangles, and triangles and semicircles.[14] The duration time for recognition was noted and the answers were recorded using a 3-point scale. The discriminatory ability of test subjects has been reported to be a better predictor of OSA than a 2-point scale.[1,14,15] A correct identification was scored as 2 points; an incorrect identification within the same group of forms was scored as 1 point; and an incorrect identification of a dissimilar form was scored as 0. For example, when a circle form was presented, the correct answer of "circle" was scored as 2 points; an answer of "ellipse" was scored as 1 point; and an answer of any other shape (square, rectangle, triangle, and semicircle) was scored as 0. If all answers were correct, a full 48 points were scored. The score of the responses and the length of time needed for identification were analyzed as the OSA score and response time, respectively.

Maximum Occlusal Force

Bilateral maximum occlusal force was measured with 97- μm-thick pressure-sensitive sheets (Dental Prescale 50H R type, Fuji Film).[16,17] The participants performed maximum clenching in the intercuspal position with a sheet placed between the maxillary and mandibular dental arch of their complete dentures.[18]

The maximum occlusal force was measured by color development in the pressure-sensitive film as recorded

by special analytic equipment (Occluzer FPD703, Fuji Film). The uses, limitations, validity, and reliability of this method have been discussed and reported previously.[16,17]

Masticatory Performance

Masticatory performance was determined by the concentration of dissolved glucose obtained from the test gummy jellies, which are a standardized food developed for measuring masticatory performance.[19] The participants were instructed to chew the gummy jelly using 30 chewing strokes on their preferred chewing side (left, right, or both) and expectorate the bolus of comminuted particles as thoroughly as possible. The concentration of dissolved glucose from the comminuted gummy jelly was measured.[20] Masticatory performance was assessed by calculating the surface area of particles (mm^2) from the glucose concentration using linear regression. In a previous study,[20] a linear regression analysis showed that the concentration of glucose had a significantly high correlation to the surface area (mm^2) of the comminuted jelly ($r = 0.993$, $P < .01$).

Stimulated Salivary Flow Rate

Stimulated whole saliva was collected using the mastication method. The participants were asked to swallow all of the saliva in their mouth, chew a measured amount of paraffin wax (Orion Diagnostica) for 2 minutes at their own pace, and then expectorate into a graduated tube.[21] Participants were classified into 2 groups according to their salivary flow rates. Participants whose stimulated flow rate was less than 0.5 mL/min were placed in the hyposalivation group,[22] and the remaining participants were designated as the normal salivary flow group.

Data Analysis

Data analyses were completed using SPSS 13.0 software for Windows (SPSS). Masticatory performance and occlusal force were normally distributed; however, OSA score, response time, and stimulated salivary flow were not normally distributed in this study population. The OSA score and response time with regard to gender were compared using a Mann-Whitney *U* test. Pearson or Spearman rank correlation coefficients (*r* and *rs*, respectively) were used to evaluate the relationships between masticatory performance and the other variables.

A multiple linear regression analysis was carried out to test each explanatory variable's relationship with the outcome variable after controlling for the other factors. The outcome variable was masticatory performance. For explanatory variables, age, OSA score, response time, and maximum occlusal force were used as continuous variables. Gender and hyposalivation, which had only 2 categories, were scored as follows: females = 0, males = 1 and normal salivation = 0, hyposalivation = 1. Significant explanatory variables were entered into the model by a forward stepwise method. Variance inflation factors for each of the explanatory variables in the regression model were calculated to test for the presence of highly correlated explanatory variables.

Results

The OSA score in women (37.7 ± 9.3) was significantly higher than in men (29.0 ± 8.6) ($P = .020$); however, the response time was not significantly different ($P = .281$). The mean length of time that the participants had worn their present complete dentures was 22 months (3 to 48 months, SD: 15 months). The length of complete denture use did not have a significant correlation to the OSA score ($rs = -0.01$, $P = .980$) or the response time ($rs = 0.11$, $P = .576$).

Masticatory performance ($1{,}308 \pm 574$ mm^2) was not significantly different by gender ($P = .470$). Significant correlations were found between masticatory performance and maximum occlusal force ($r = 0.64$, $P < .001$), between masticatory performance and stimulated salivary flow rate ($rs = 0.37$, $P = .045$), and between masticatory performance and OSA score ($rs = 0.38$, $P = .037$) (Table 1). However, the OSA response time ($rs = -0.03$, $P = .889$) had no significant correlation to masticatory performance. There were no significant correlations among occlusal force, OSA score, response time, and stimulated salivary flow rate. Masticatory performance in the hyposalivation group was likely to be lower than in the normal salivation group ($P = .066$).

The stepwise multiple linear regression analysis showed that masticatory performance was significantly associated with maximum occlusal force ($\beta = .65$, $P < .001$), OSA score ($\beta = .51$, $P < .001$), and hyposalivation ($\beta = -.26$, $P = .042$) (Table 2). The R^2 of the model was 0.67, indicating that about two thirds of the variation in masticatory performance could be statistically explained by this model.

Discussion

OSA has been employed in many studies to evaluate oral perception. An individual who scores well in an OSA test has received sufficient sensory information with which to identify shapes explored in the mouth.[23] Stereognostic testing is designed to assess overall sensory ability and oral motor ability, not specific groups of sensory receptors.[6,15]

The selected shapes in this study provided sufficient difficulty, as evidenced from the wide range of dis-

Table 1 Correlations Between Masticatory Performance, Maximum Occlusal Force, OSA Score, Response Time, and Stimulated Salivary Flow Rate in Complete Denture Wearers (n = 30)*

	Occlusal force		OSA score		Response time		Salivary flow rate	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Masticatory performance 1,308 ± 574 mm^2	0.64†	< .001	0.38‡	.037	−0.03‡	.889	0.37‡	.045
Occlusal force 241 ± 150 N	1		−0.13‡	.480	0.21‡	.260	0.34‡	.063
OSA score 33.9 ± 9.9			1		−0.07‡	.707	−0.20‡	.283
Response time 403 ± 161 s					1		−0.06‡	.745

*Masticatory performance and occlusal force were normally distributed; however, OSA score, response time, and stimulated salivary flow were not normally distributed.
†Pearson correlation coefficient; ‡Spearman rank correlation coefficient.

Table 2 Multiple Linear Regression Analysis of Masticatory Performance by Stepwise Method*

Explanatory variable†	B	SE	β	*P*	VIF
OSA score	29.92	6.86	.51	< .001	1.09
Occlusal force (N)	2.50	0.45	.65	< .001	1.07
Hyposalivation	−389.6	182.3	−.26	.042	1.14
(Constant)	−243.6	269.4		.374	

*Outcome variable: masticatory performance (mm^2) (R = 0.82, R^2 = 0.67, F = 17.6, P < .001).
†Continuous variables: age (y), OSA score, response time (s), and occlusal force (N). Categorical variables: gender (females = 0, males = 1), hyposalivation (stimulated salivary flow rate ≥ 0.5 mL/min = 0, < 0.5 mL/min = 1).
B = partial regression coefficient; β = standardized partial regression coefficient; VIF = variance inflation factor.

crimination (scores from 12 to 48) among participants. Only 1 participant could identify all test pieces correctly, and there was no participant who could not correctly identify any of the test pieces. This would suggest that the test was valid in its ability to discriminate between participants' OSA.

Since 1950, fractional sieving, with various natural and artificial foods,[24] has been used as a technique of separating food after chewing to measure masticatory performance. However, it was reported that masticatory performance values assessed by calculating the area of the comminuted particles have a wider range than the sieving method, and this makes it possible to differentiate between participants.[25] Because of its significant advantages, such as speed and accuracy of measurement and discriminating ability, the gummy jelly is the preferred food for measuring masticatory performance.[18,19]

In the present study, the authors evaluated the bilateral occlusal force in the intercuspal position, which is involved in several critical stages of food breakdown. Occlusal force in complete denture wearers might be limited because the denture-supporting tissue is more subject to discomfort, compression, and denture shifting.[4,26] Consequently, the occlusal force generated in complete denture wearers reflects the tolerance of the denture-supporting tissues and stability of the denture.

It is not surprising that maximum occlusal force was the strongest contributor to masticatory performance. While it is virtually impossible to control for occlusal force by gathering matched individuals, the effects of other factors on masticatory performance must be measured in a multiple regression analysis with maximum occlusal force being controlled.

Multiple linear regression analysis suggests that sensory function plays a role in the masticatory performance of complete denture wearers that is equivalent in importance to maximum occlusal force. During every chewing cycle, a food particle has the chance of being placed between the teeth (selection) and then fractured into fragments of variable number and size (breakage).[27] Tactile feedback allows determination of food position in the mouth and of the proper force needed for mastication. In addition, it permits the delicate adjustments of tongue, lip, cheek, and palate position

needed for precise articulation.[8] Oral motor dynamics are required to manipulate objects for recognition.

In addition, multiple linear regression analysis showed that hyposalivation was significantly associated with masticatory performance after controlling for other factors. Hyposalivation may negatively influence the masticatory process by making it impossible for participants to gather food into a bolus before swallowing.[28] In analyzing the association of salivary flow, the authors found that dichotomization of the explanatory variable with a cutoff value of 0.5 mL/min[22] was reasonable, because the stimulated salivary flow rate (mL/min) was not found to be significant when the values were used as a continuous variable in the regression model. This implies that salivary flow rate is not linearly associated with masticatory performance and that there is a critical level of salivary flow rate for masticatory disorders.

As in other investigations,[5,29] gender did not have a significant effect on masticatory performance in this study. Interestingly, stimulated salivary flow rate and maximum occlusal force were likely to be higher in men; however, OSA was better in women.

In general, the older the individual, the lower his or her masticatory performance. However, age by itself did not exert a direct effect on masticatory performance in this study population. These results suggest that altered masticatory performance with age is a multifactorial problem[30] that results from an accumulation of insults not only to oral structures, such as teeth or mucosa, but also to function, such as oral sense or salivary flow.

It is important to recognize the limitations of this study. The study population was a relatively small number of convenient individuals who were cognitively healthy and able to visit a clinic by themselves. Consequently, the results reported here may be specific to this study sample and should not be generalized until these associations have been confirmed in other studies of a similar population.

Conclusion

Within the limitations of this study, declined oral sensory function, low occlusal force, and hyposalivation appear to be associated with impairment of masticatory performance in aged complete denture wearers.

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Literature Abstract

Nine- to 14-year follow-up of implant treatment. Part II: Presence of peri-implant lesions

The purpose of this study was to determine the prevalence of peri-implant lesions around titanium implants in function 9 to 14 years after placement. A total of 218 patients with 1,057 implants (Brånemark)—524 in the maxilla and 533 in the mandible—placed from 1988 to 1992 were provided with implant-supported fixed or removable restorations. New sets of intraoral radiographs were taken at 1- and 5-year (after placement of the suprastructure) recall examinations. At the final examination, performed at 9 to 14 years after suprastructure placement (from 2000 to 2002), 999 implants were available for examination. The following recordings were analyzed: number of implants, implant position, probing depth measured at 4 sites (mesial, distal, buccal, lingual), bleeding on probing, suppuration following probing, number and millimeter of implant threads not supported by bone at the mesial and distal aspects of the implant on the radiographs, and radiographic examination. The results revealed that if peri-implantitis is defined as bone loss ≥ 3 threads following the first year in function combined with bleeding and/or pus on probing, 16% of the patients and 6.6% of the implants would be diagnosed to have peri-implantitis after 9 to 14 years. The results of this study were different (higher peri-implantitis rates) from those previously reporteded for the Brånemark system, which may be due to the difference in observation time between studies. It is possible that peri-implantitis will be more frequently found with increasing time within the oral cavity. Differences in the supportive care program may also have affected the results. The patients in this study were not subjected to a uniform supportive periodontal treatment program, which may have increased the risk of developing peri-implant lesions. In conclusion, after 10 years in use without systematic supportive treatment, peri-implant lesions are a common clinical entity adjacent to titanium implants.

Jansaker AMR, Lindahl C, Renvert H, Renvert S. *J Clin Periodontol* 2006;33:290–295. **References:** 19. **Reprints:** Stefan Renvert, Department of Health Sciences, Kristianstad University, 291 88 Kristianstad, Sweden. E-mail: stefan.renvert@hv.hkr.se—*Huong Nguyen, Singapore*