Masticatory Performance in Postmaxillectomy Patients with Edentulous Maxillae Fitted with Obturator Prostheses

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Purpose: Oral cancer develops frequently in older populations. In Japan, the incidence of oral and pharyngeal cancer is 9,201 per year, with such tumors accounting for 1.74% of all cancers. Although obturator prostheses play an important role in the rehabilitation of postmaxillectomy patients, clinicians sometimes experience difficulty in placing obturator prostheses in edentulous maxillae, and criteria for the objective evaluation of treatment outcome have yet to be established. The present study aimed to investigate postsurgical factors influencing the masticatory performance of postmaxillectomy patients with edentulous maxillae fitted with obturator prostheses. ***Materials and Methods:*** The extent of the hard palate defect, status of the mandibular dentition, mouth-opening distance, and maximum occlusal force were investigated, and masticatory performance was measured using a testing gummy jelly in 27 postmaxillectomy patients with edentulous maxillae fitted with obturator prostheses. The influence of these items was evaluated quantitatively, and theoretical masticatory performance for each subject was calculated using multiple-regression analysis (quantification method type 1). ***Results:*** Although average masticatory performance was almost equivalent to that of healthy, independent older patients with occlusal support classified as Eichner C, considerable individual variation was noted among subjects. The order of strength of influence on masticatory performance was identified by category weight: extent of hard palate defect > status of posterior mandibular teeth > maximum occlusal force > mouth-opening distance. A relatively high correlation (R^2 = 0.78, P < .01, Pearson correlation coefficient) was evident between theoretical and actual values. **Conclusion:** Masticatory performance could be predicted by evaluating postsurgical factors in patients with edentulous maxillae fitted with obturator prostheses. *Int J Prosthodont 2007;20:145–150.*

Oral cancer is a major health care concern in elderly patients.[1,2] Among elderly patients, it is particularly important not only to detect and treat this condition early but also to rehabilitate postoperative patients. Obturator prostheses play an important role in the recovery of oral function in postsurgical maxillectomy patients.[3] Recently, it has been reported that obturator prosthesis function is closely related to patient quality of life.[4,5] However, elderly patients who lose the maxillary dentition before or during surgery tend to have difficulties, including loss of maxillary bone and abutment teeth, and often have limited mouth opening. Hence, prosthodontic rehabilitation of mastication is very difficult in such patients. While surgical reconstruction of the defect[5] or implant treatment[6] are possible solutions, application of such treatments in elderly patients is sometimes difficult because of generalized or chronic disease, psychologic and economic factors, and local conditions of supporting tissues.

For successful rehabilitation, it is important to maximize the quality of a conventional obturator prosthesis and to determine the treatment outcome associated with it, ie, to ascertain the limitations of masticatory per-

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Table 1 Investigated Items and Masticatory Performance for Each Category

Investigated items/ category	No. of patients	Masticatory performance (mm^2)
Extent of hard palate defect		
HP-1	12	1,707.3 ± 986.5
HP-2	9	1,482.3 ± 937.1
HP-3	6	161.5 ± 215.3
Status of posterior mandibular teeth		
D-1	13	1,846.0 ± 1324.5
D-2	7	1,238.4 ± 880.5
D-3	7	1,015.9 ± 898.6
Mouth-opening distance (mm)		
≥ 40	12	1,601.8 ± 1057.6
30-40	7	1,138.1 ± 1075.6
20-30	4	1,051.3 ± 1249.3
< 20	4	850.8 ± 768.5
Maximal occlusal force (N)		
≥ 100	15	1,704.1 ± 1096.1
< 100	12	769.6 ± 699.5
All subjects	27	1,288.8 ± 1038.2

formance in each patient. In the perioperative period, expressing rehabilitation goals as a quantitative value for masticatory performance would benefit both patients and practitioners. Masticatory performance has been measured using test foods, and several intraoral factors influencing it, such as status of the remaining dentition and prosthesis, occlusal support, maximal occlusal force, and motor skills of the tongue, have been investigated in normal subjects.[7–10] In postsurgical maxillectomy patients, it was reported that the extent of hard and soft palate resection was a significant predictive factor in the subjective evaluation of obturator function.[4,5,11] A questionnaire survey of food acceptance revealed that the existence of maxillary dentition and configuration and size of the defect were correlated with masticatory function.[12] However, few objective measures of the factors influencing masticatory performance have been undertaken,[13] leading to a lack of evidence for the rehabilitation of postmaxillectomy patients.

This study aimed to assess the relationship between masticatory performance and postsurgical factors among 27 postmaxillectomy patients with edentulous maxillae fitted with obturator prostheses and to calculate a theoretical value of masticatory performance for each patient using multiple-regression analysis of significant factors. For this purpose, masticatory performance was measured quantitatively using a gummy jelly.[14,15]

Subjects and Methods

Subjects

Twenty-seven subjects (13 men and 14 women; age range, 56 to 82 years; average age, 70.3 ± 6.9 years; average period after surgical resection, 38.6 ± 41.4 months) were selected from patients with edentulous maxillae fitted with obturator prostheses as a result of maxillectomy performed at Osaka University Dental Hospital. Written informed consent for participating in this study was obtained from each patient. Patients with dry mouth caused by radiation therapy[16,17] or side effects of medication[18] were excluded because of the possibility of diminished masticatory performance.[19,20] Participants were assessed by a clinician specializing in maxillofacial prosthetics, who determined that they had adapted to their prostheses.

Although the duration of obturator prosthesis wear varied among subjects, all had used their present prostheses for at least 3 months before the investigation and were thus considered to be well adapted.[21] Stability and retention of the dentures were also considered significant factors affecting masticatory performance.[22] In this study, each subject's prosthesis was investigated and relined if necessary to improve fit.

Investigated Items

After the many factors affecting masticatory performance were considered,[7–10] the following 4 items concerning postsurgical status were selected for the investigation: extent of hard palate defect, existence of posterior teeth in the mandible, mouth-opening distance, and maximum occlusal force.[3–5,11,12,23] Each item was investigated and categorized as follows (Table 1).

Extent of hard palate resection. Patients were divided into 3 groups with respect to the extent of the hard palate defect: those with a defect extending to less than half the hard palate (HP-1, n = 12), those with a defect of half the hard palate (HP-2, n = 9), and those with a defect encompassing more than half the hard palate (HP-3, n = 6). Although resection of the soft palate had been performed on 14 participants, the extent of resection was limited to the anterior margin neighboring the hard palate, and no patients had velopharyngeal incompetence during eating or speech. Therefore, soft palate resection was excluded from the investigated items in this study.

Existence of posterior teeth in the mandible. Subjects were divided into 3 groups with respect to the existence of posterior teeth in the mandible: those with posterior teeth opposing the nonresected side (D-1, n = 13), those with posterior teeth opposing the resected side (D-2, n = 7), and those with an edentulous mandible (D-3, n = 7).

Mouth-opening distance. Mouth-opening distance was measured vertically between the maxillary right teeth and the most anterior mandibular teeth (natural or artificial). Subjects were divided into 4 groups with respect to mouth-opening distance: ≥ 40 mm, 30 to 40 mm, 20 to 30 mm, and < 20 mm.

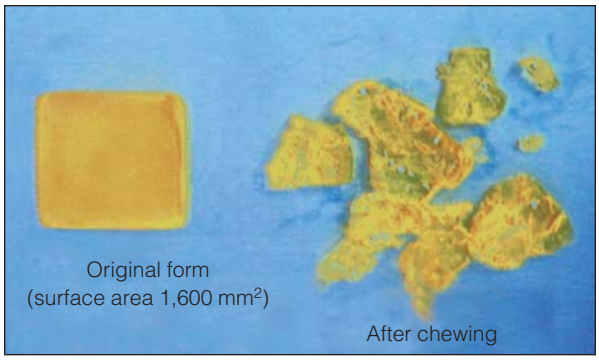
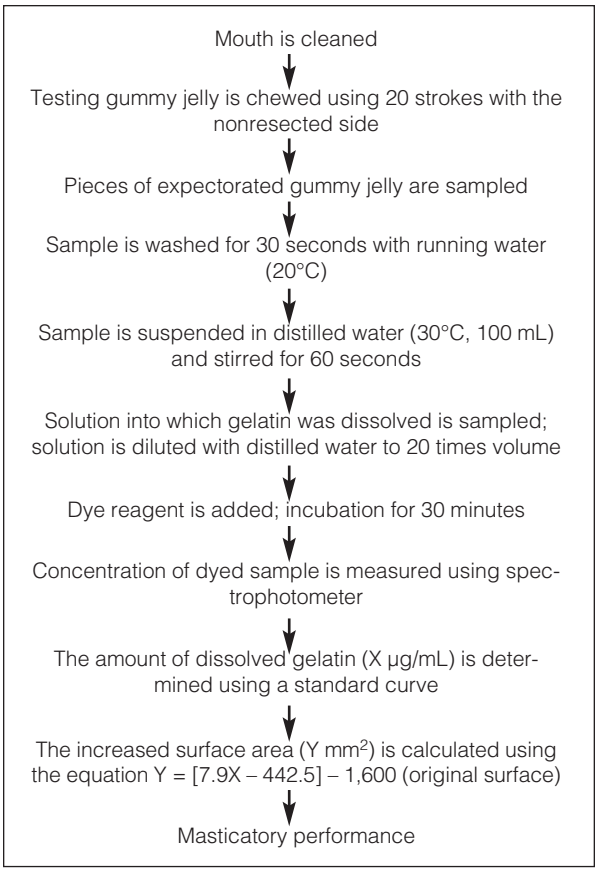


Fig 1 *(left)* Testing gummy jelly (no. 3).

Fig 2 *(right)* Process of measuring masticatory performance using a testing gummy jelly.



Maximal occlusal force. Maximal occlusal force was measured with pressure-sensitive sheets (Dental Prescale 50H R type, Fuji Photo Film).[24,25] While wearing their prostheses, subjects performed maximal clenching with a pressure-sensitive sheet placed between the maxilla and the mandible, and the occlusal force was measured with special analytic equipment (Occluzer FPD703, Fuji Photo Film). Maximal occlusal force in the 27 subjects ranged from 15 to 375 N (average: 161.9 ± 112.5 N). Subjects were divided into 2 groups with respect to the magnitude of maximal occlusal force: ≥ 100 N (average: 240.4 ± 88.7 N, n = 15) and < 100 N (average: 63.7 ± 31.3, n = 12).

Measurement of Masticatory Performance

A testing gummy jelly (20 × 20 × 10 mm, Ezaki Glico; Fig 1) was originally developed for measuring masticatory performance.[14,15] In this study, a testing gummy jelly suitable for complete denture wearers (#3) was chosen from among 6 textures (#1 to #6) available to evaluate the masticatory performance of obturator wearers. Masticatory performance was calculated as the increase in the surface area of comminuted pieces of gummy jelly from the original intact gummy jelly (1,600 mm²) through the process shown in Fig 2.

Statistical Analysis

Multiple-regression analysis (quantification method type 1) was performed to analyze the independent influence of each item. In this analysis, the magnitude of influence of each explanatory factor on masticatory performance can be identified by the category weight, and the theoretical value of the masticatory performance of each subject can be calculated by totaling the category weights and a constant. The Pearson correlation coefficient was used to analyze the correlation between actual and theoretical values of masticatory performance. Data were analyzed using SPSS 12.0 for Windows (SPSS). Statistical significance was set at $P < .05$.

Results

The masticatory performance of the 27 subjects ranged from 0 to 3,230 mm² (average: 1,290 ± 1,040 mm²). Average values and standard deviations (SDs) of masticatory performance in each category are shown in Table 1. The results of multiple-regression analysis (quantification method type 1) are shown in Table 2. Theoretical masticatory performance, represented by an increase in the surface area of the gummy jelly (mm²), could be calculated by totaling the category

Table 2 Results of Multiple-Regression Analysis (Quantification Method Type 1)

Investigated items/ category	Category weight	Range of category weight
Extent of hard palate defect		
HP-1	386.0	1,451.4
HP-2	195.5	
HP-3	-1,065.4	
Status of posterior mandibular teeth		
D-1	459.5	756.8
D-2	92.6	
D-3	-297.3	
Mouth-opening distance (mm)		
≥ 40	104.0	392.2
30-40	108.8	
20-30	-218.8	
< 20	-283.4	
Maximal occlusal force (N)		
≥ 100	288.1	603.1
< 100	-335.1	
Constant term	1,288.8	

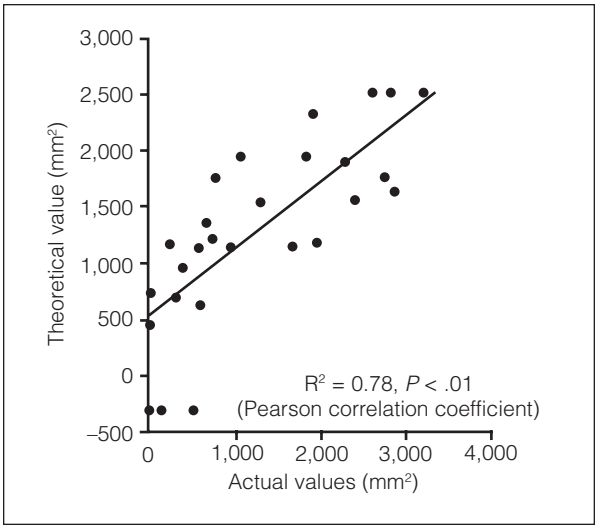


Fig 3 Comparison of theoretical and actual values of masticatory performance.

weights of each item and a constant (1,288.8), which was an average value across all subjects. The degree of influence on masticatory performance could be evaluated by the range of category weights of each item and the category weight of each category.

Extent of hard palate resection had the largest range of category weight (1,451.4) among the 5 items, with the category weight of HP-3 (-1,065.4) identified to be a strong factor in decreasing masticatory performance. Masticatory performance had a tendency to increase above the average when subjects had a surgical defect that encompassed less than half the hard palate (HP-1) and to decrease considerably when subjects had a surgical defect that encompassed more than half the hard palate (HP-3). The existence of posterior mandibular teeth had the second largest range of category weight (756.8). Masticatory performance exhibited a tendency to increase above average when subjects had posterior teeth on the nonresected side of mandible and to decrease when subjects had no remaining teeth in the mandible. Maximal occlusal force had the third largest range of category weight (603.1). Masticatory performance demonstrated a tendency to increase when maximal occlusal force was ≥100 N and to decrease when it was < 100 N. Mouth-opening distance had the smallest range of category weight (392.2) among the 4 items. Masticatory performance decreased in proportion to the decline in mouth-opening distance and was smaller than average when mouth-opening distance was < 30 mm.

Predictive values of masticatory performance were compared with actual values in all subjects (Fig 3). The predictive value of masticatory performance was larger than the actual value in 15 subjects and smaller than the actual value in 12 subjects, including 3 subjects in whom the predicted value was less than 0 mm². Good correlation was evident between theoretical and actual values ($R^2 = 0.78$, $P < .01$).

Discussion

This study attempted to quantitatively evaluate the masticatory performance of postmaxillectomy patients with edentulous maxillae fitted with obturator prostheses by measuring masticatory performance using a testing gummy jelly. Although average masticatory performance among the 27 patients (1,290 mm²) was much lower than that of healthy young dentate subjects (3,330 mm²),[14] it was very similar to that of independent, healthy, elderly subjects with occlusal support classified as Eichner C (1,200 mm²),[26] suggesting that the present subjects had become thoroughly accustomed to their obturator prostheses. However, considerable individual variation was noted in masticatory performance (0 to 3,230 mm²), suggesting that postsurgical factors influenced masticatory performance. The authors performed multiple-regression analysis to investigate the magnitude of influence of these factors and to calculate predictive values of masticatory performance. Concerning the analysis, the study sample had certain limitations: *(1)* the small number of subjects and *(2)* the fact that soft palate resection was limited to the anterior margin. Surgical resection of the soft palate can impede velopharyngeal closure and cause dysfunction of speech and swallowing,[22] and the extent of a soft palate defect has been reported to be the most significant predictor of subjective obturator function.[4] Nonetheless, greater variation in the extent of soft palate defects is needed to investigate the influence of this factor on masticatory performance.

Category weights, as determined by quantification method type 1, identified the magnitude of influence of various explanatory factors: extent of hard palate resection > existence of posterior teeth in the mandible > maximum occlusal force > mouth-opening distance. This provided criteria for evaluating the potential of each patient during prosthodontic rehabilitation as well as evidence for the objective evaluation of obturator function. The extent of hard palate resection was found to be the strongest predictive factor of masticatory performance. When the category weights of each subgroup were compared, masticatory performance appeared to decline considerably when the maxillary defect extended to more than half the hard palate (HP-3). This finding agrees with subjective measures of quality of life[4,5] and a subjective evaluation (via questionnaire) of food acceptance.[12] This might be because resection of more than half the hard palate leads to a reduction in prosthesis stability and difficulty in retaining the obturator prosthesis.

The finding that the presence of posterior teeth in the mandible and maximal occlusal force were moderately related to masticatory performance is noteworthy. It was suggested that posterior teeth in the nonresected side in mandible might assist in mastication, which places special emphasis on maintaining such teeth in maxillectomy patients. Stability of the obturator in the edentulous maxilla might be influenced by the morphology of the remaining residual ridge and hard palate, as well as the extent and location of the surgical defect. However, clinical evaluation of the morphology of remaining tissues is difficult. Therefore, measurement of maximal occlusal force could be useful in the rehabilitation of obturator prosthesis wearers, because it might be a quantitative parameter indicating integrated performance of obturator stability and jaw-closing muscle activity. Additionally, category weights concerning mouth-opening distance suggested that limitation of mouth opening resulted in stepwise decreases in masticatory performance for mouth-opening distances smaller than 30 mm, suggesting that particular emphasis is needed during operative rehabilitation to ensure that the mouth-opening distance exceeds 30 mm.

Although goodness of fit for the predictive value was demonstrated by a relatively high coefficient of determination ($R^2 = 0.78$, $P < .01$), there were varying differences between actual and predicted masticatory performance. Masticatory performance would be anticipated as highest (2,510.2 mm^2) for a patient with a defect encompassing less than half the hard palate (category weight: 386.0), with posterior teeth in the nonresected side of the mandible (category weight: 459.5), with maximal occlusal force above 100 N (category weight: 268.1), and with a mouth-opening distance exceeding 30 to 40 mm (category weight: 108.8). However, this predicted highest value of masticatory performance was much smaller than the actual maximum, which was similar to the average value seen in healthy young dentate subjects (3,330 mm^2)[14] and exceeded the average value in healthy elderly subjects with occlusal support classified as Eichner A (4 units of occlusal support) (2.130 mm^2).[26] It should be noted that the small number of subjects and the categorization methods used limited the accuracy of prediction using quantification method type 1. In contrast, masticatory performance was predicted to be nearly 0 or less than 0 when patients had a defect that covered more than half the hard palate (category weight: -1,065.4), and no mandibular teeth (category weight: -297.3), maximal occlusal force under 100 N (category weight: -333.9), or a mouth-opening distance smaller than 30 mm (category weight: -218.8 when mouth-opening distance was 20 to 30 mm, -283.4 when mouth-opening distance was < 20 mm). This means that patients who demonstrate these conditions postoperatively cannot comminute a gummy jelly with 20 masticatory strokes. In 3 subjects, masticatory performance was predicted to be less than 0 mm^2, which also suggested that this analysis was limited in the small number of subjects and the present categorization.

The present results suggest that rehabilitation goals for obturator prosthesis wearers can be quantitatively predicted, and that treatment outcome associated with obturator prostheses can be evaluated by comparing masticatory performance measured using a gummy jelly with the predicted value. Predictive accuracy is expected to improve with the investigation of more subjects and categories.

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Literature Abstract

Simple device for the direct visualization of oral-cavity tissue fluorescence

A simple handheld device was introduced that employs a co-axial optical pathway to facilitate the direct visualization of the oral cavity for the detection of high-risk precancerous and early cancerous lesions. Blue excitation light (400 to 460 nm wavelength) is used to excite green-red fluorescence from fluorophores in the oral tissues. The purpose of this clinical study was to test this device for direct fluorescence visualization (FV) and its use for discrimination of high-risk oral premalignant lesions (POLs) and invasive squamous cell carcinoma (SCC) from normal oral mucosa. Under direct FV, normal oral tissue is seen as normal green autofluorescence and is classified as FV retention. Tissues that show a distinct reduction in the normal pale green appearance are classified as FV loss. Patients with a history of biopsy-confirmed oral dysplasia or SCC were recruited for this study. Each visit involved visual assessment of the oral cavity under white light to identify either new clinical lesions or alterations to previously identified clinical lesions. The light was then turned off, and the oral cavity was viewed with direct FV. The clinician then decided if the patient required a biopsy based on standard clinical features, including patient history, clinical appearance, and toluidine blue staining results, but not based on direct FV examination. If the lesion required a biopsy, a histologic diagnosis was assigned to the lesion. A total of 50 biopsies were obtained from 44 patients. All 6 samples that had a histologic diagnosis of normal showed FV retention. A total of 91% (10 of 11) of severe dysplasia lesions and 100% (33 of 33) of invasive SCC lesions showed FV loss. Using histology as the gold standard, the device obtained a sensitivity of 98% and a specificity of 100% for viewers to discriminate normal lesions from high-risk OPLs and invasive SCC.

Lane PM, Gilhuly T, Whitehead P, et al. *J Biomed Opt* 2006;11:024006. **References:** 34. **Reprints:** Pierre M. Lane, British Columbia Research Center, Cancer Imaging Department, 675 West 10th Ave, Vancouver, BC V5Z 1L3, Canada. E-mail: plane@bccrc.ca—*Alvin G. Wee, OSU College of Dentistry, Columbus, OH*