

Original Article

## Evaluations of Masticatory Performance of Complete Denture Wearers Using Color-Changeable Chewing Gum and Other Evaluating Methods

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**We have been investigating and developing a color-changeable chewing gum, that tends not to adhere to dentures. The aim of this study was to investigate the color change of the chewing gum comparing to other methods while evaluating post-insertion changes of masticatory performance of complete denture wearers.**

**Color-changeable chewing gum, the peanuts sieve test, a patient satisfaction questionnaire and a food questionnaire were applied to 26 edentulous subjects. The subjects were tested on two occasions: with previous dentures, with new dentures when they had no symptoms after finishing denture adjustment.**

**In comparison between the differences of previous and new dentures, significant correlations were found between the color change of the chewing gum and the scores of patient satisfaction questionnaires and food questionnaire. It was suggested that this chewing gum was useful for an objective masticatory evaluation of the denture wearers and could contribute to prosthetic treatments according to patients' satisfaction for dentures, which is clinically important information for both patients and dentists.**

**Key words:** complete denture, masticatory performance, chewing gum, sieve test, patient satisfaction

### Introduction

Evaluations of dental prosthesis in the clinic have depended largely on patients' subjective reports<sup>1-4</sup>. Judgment of a need for replacing with new dentures has been a reflection of the knowledge, experience, and skill of each individual dentist. It has also been uncertain whether patients actually seek for the treatment after understanding and giving their consent to replacement<sup>5</sup>. Though a number of objective methods of evaluating masticatory performance have been attempted, they require specific instruments, materials, or complicated procedures<sup>5-12</sup>. As a consequence, it is still desired to develop an objective method, which is used easily by the dentist at the chair side in the clinic with better compliance from patient.

We have chosen chewing gums as a test food for evaluating masticatory performance and have been investigating and developing a chewing gum that changes its color as it is chewed<sup>13-16</sup>. It is possible to produce a chewing gum of uniform hardness, weight, cohesiveness, adhesiveness, and composition, and easy to devise uniform measurement conditions. Unlike specific test foods such as alginate, wax and so on, there are frequent opportunities to use chewing gum as a part of the ordinary diet and it can be used safely as a test food<sup>17</sup>. We have already reported that it was possible to measure a masticatory performance<sup>16</sup> for both dentate subjects and denture wearers.

We investigated the chewing gum with normal

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Received October 13; Accepted December 1, 2006



**Fig. 1.** Color-Changeable Chewing Gum. XYLITOL® (LOTTE Co., Ltd. Saitama, Japan)

adults, indicating the validity of our method measuring the  $a^*$  values (CIE-L\*a\*b\* color system) which reflect the redness of chewed gum<sup>15</sup>. We developed a new chewing gum (Masticatory Performance Evaluating gum XYLITOL® 《30×20×1mm, 3.0g》) for denture wearers with the LOTTE Co., Ltd. (Saitama, Japan) (Fig.1). The gum base of new color-changeable chewing gum that hardly adheres to dentures, so that it is easily applied to denture wearers.

The aim of this study was to investigate the color change of the chewing gum comparing to other methods while evaluating post-insertion changes of masticatory performance of complete denture wearers.

## Materials and Methods

### 1. Subjects

This study comprised twenty-six edentulous patients, nine males and seventeen females, with an average age of 75.0 years (range 63 to 92), who were wearing complete dentures and referred to the Dental Hospital of Tokyo Medical and Dental University for new complete dentures. They were normal both mentally and physically except edentulism and had no signs of craniofacial dysfunction. Some of their previous dentures were fabricated in our hospital (10 out of 26 cases) and others were in private practitioners.

The informed consent has been obtained from all the subjects prior to the experiment. This study was followed by the declaration of Helsinki and approved by the Ethical Review Board of the Dental Hospital of

Tokyo Medical and Dental University.

### 2. Timing of the measurements

The procedures for making new dentures followed conventional methods<sup>18,19</sup> and the subjects were treated by eighteen dentists who belonged to the Department of Complete Denture Prosthodontics at Dental Hospital of Tokyo Medical and Dental University.

Before insertion of the new dentures, the subjects' previous dentures were examined and were performed a series of tests and inquiries; chewing gum test, the peanut sieve test, patient satisfaction questionnaire, and food questionnaire for evaluation of masticatory function<sup>4</sup>. After the insertion of new dentures with an average of one month (a range of two weeks to two months) interval, when the subjects showed no pain with them, same examinations and the subjects performed again.

### 3. Color changeable chewing gum

A newly developed chewing gum was available as a stick-type gum. The gum base contains red, yellow, and blue dyes, citric acid, and xylitol. The red dye is pH-sensitive that loses its color under the acid condition. The pH inside the chewing gum is maintained low by the citric acid while the chewing gum appears yellowish-green before mastication. However, when the chewing gum is mixed with saliva as mastication proceeds, the increase of pH inside the chewing gum as a result of elution of the citric acid makes the color of the chewing gum to change from yellowish-green to red.

The hardness of the chewing gum is adjusted so that it does not adhere to the denture materials and it is easily chewed even by complete denture wearers who have reduced occlusal force, based on a report by Takahashi *et al.*<sup>20</sup>.

### 4. Measurement of masticatory performance

#### 1) Measurement of masticatory performance using color changeable chewing gum

The subjects were instructed to, "Please chew the chewing gum well", without being given any instructions with regard to chewing side or chewing frequency. The numbers of chewing strokes were stipulated as 100 times, and this sequence was repeated three times with 10 minutes intervals. After each trial the subjects were asked to rinse their mouth with water.

The chewing gum was picked immediately after chewing and compressed to a thickness of 1.5mm in a

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polyethylene film with two glass plates. The chewing gum was then removed from the glass plates, and its color was measured through the polyethylene film with a colorimeter (CR-13; Konica-Minolta, Tokyo, Japan) (Fig.2). The CIE-L\*a\*b\* color system was used for color recording and the a\* values, which express redness, was used for the evaluations<sup>21</sup>. The color reading was performed at five sites on a single side; at the center of the compressed gum, approximately 3mm above, below and to the right and left and a mean value of a\* values represents each trial. All of color reading was performed by a same examiner. A mean value of three trials was used in analysis.

### 2) Measurement of masticatory performance by sieve test

Masticatory performance was measured according to the method described by Manly<sup>6</sup> and Manly and Braley<sup>7</sup> using peanuts. After asking the subjects to chew approximately 3.0g of peanuts with 20 chewing strokes, the material was collected and passed through a 10-mesh sieve (openings: 1700  $\mu\text{m}$ ). The peanuts remaining on the sieve were then dried at 80 °C for 24 hours and weighed. Their weight was subtracted from the original weight and it was expressed as a percentage. The procedure was performed five times and a mean value was used as the Manly's mastication performance(MMP) score in the analysis.

### 3) Patient satisfaction questionnaire

Another masticatory performance was subjectively evaluated by a questionnaire. Using a visual analogue scale (VAS) of 100mm long, the subject was asked thirty questions to assess the satisfaction of the previous

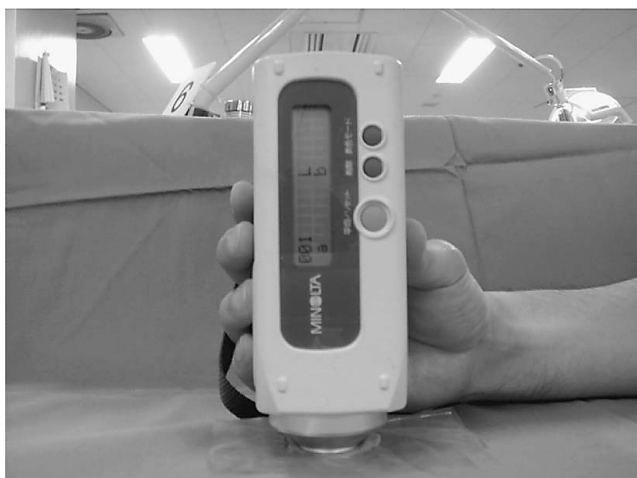


Fig. 2. Compressed gum and Colorimeter.

and new dentures. Following two questions “ Are you able to chew well?” and “How much are you satisfied with your dentures?” were picked for the evaluation and converted to scores ranging from 0 to 100 points (PS1 and PS2, respectively). The left end of the scales was indicated as “I cannot chew at all.” and “I am not satisfied with my dentures at all”, while the other end was referred to “I can chew very well.” and “I am totally satisfied with my dentures.”, respectively.

### 4) Subjective experience of masticatory performance<sup>8</sup>

Subjective experience was collected according to the method of Uchida *et al.*<sup>4</sup> based on the chewing experience of eating twenty different kinds of foods. A score of five points was allocated to each of the twenty items to which the subject replied, “I can eat it”. Scores of twenty items were summed up and the total point was used in the analysis of subjective experience of masticatory performance (SE).

### 5. Statistical analysis

The differences between previous and new dentures of each methods ( $\Delta a^*$ ,  $\Delta\text{MMP}$ ,  $\Delta\text{PS1}$ ,  $\Delta\text{PS2}$  and  $\Delta\text{SE}$ ) were analyzed each other by a paired *t*-test.

A paired *t*-test was used to analyze the difference between the values at the time of wearing previous and new dentures. To calibrate individual difference of the subjects' masticatory performance and to compare the detecting character of each method, the differences between previous and new dentures of each method ( $\Delta a^*$ ,  $\Delta\text{MMP}$ ,  $\Delta\text{PS1}$ ,  $\Delta\text{PS2}$  and  $\Delta\text{SE}$ ) were analyzed each other by Pearson's correlations.

Statistical analysis was performed using SPSS statistical processing software (SPSS 11.5J for Windows). The criterion for significance in all the analysis was 0.05.

## Results

Table 1 and 2 showed mean and Standard Deviation (S.D.) of the values of each method and the differences between previous and new dentures. PS2 showed a significant difference between previous and new dentures ( $p < 0.05$ ). Other methods except MMP showed a tendency to be higher in new dentures than previous dentures but did not show significant difference ( $p > 0.05$ ).

Significant positive correlations were found at the combinations of  $\Delta a^*$  and  $\Delta\text{PS1}$ ,  $\Delta a^*$  and  $\Delta\text{SE}$  and

**Table 1.** The evaluation of previous and new dentures.

		a*	MMP	PS1	PS2	SE
<b>old dentures</b>	Mean	8.17	40.88	64.50	70.08	63.46
	S.D.	9.21	17.30	24.09	25.74	20.65
<b>new dentures</b>	Mean	9.31	37.38	68.62	83.69	65.38
	S.D.	8.12	15.83	18.17	13.52	19.85

a\*: The a\* values of gum after 100 chewing

MMP: Manly's masticatory performance by sieve test

PS1: Patient satisfaction questionnaire "Are you able to chew well?"

PS2: Patient satisfaction questionnaire "How much are you satisfied with your dentures?"

SE: Subjective experience of masticatory performance

**Table 2.** The difference of previous and new dentures.

	$\Delta a^*$	$\Delta$ MMP	$\Delta$ PS1	$\Delta$ PS2	$\Delta$ SE
Mean	1.14	-3.50	4.12	13.62	1.92
S.D.	6.41	12.04	26.04	23.87	22.83

" $\Delta$ " indicates the differences of each item in previous and new dentures

**Table 3.** Correlation coefficients of each differences in previous and new dentures.

	$\Delta a^*$	$\Delta$ MMP	$\Delta$ PS1	$\Delta$ PS2	$\Delta$ SE
$\Delta a^*$		-0.027	0.435*	0.217	0.538 *
$\Delta$ MMP			-0.446*	-0.516*	-0.103
$\Delta$ PS1				0.788*	0.248
$\Delta$ PS2					0.037
$\Delta$ SE					

\* :  $p < 0.05$

$\Delta$ PS1 and  $\Delta$ PS2 (Table 3) ( $p < 0.05$ ). The differences of MMP ( $\Delta$ MMP) showed no significant correlations with the  $\Delta a^*$  values ( $p > 0.05$ ), and showed negative correlations with  $\Delta$ PS1 and  $\Delta$ PS2 scores ( $p < 0.05$ ).

## Discussion

Other all parameters except PS2 score did not show significant difference between new and previous dentures. Thus, it was indicated that although the subjects of this study were satisfied with new dentures, their masticatory performance was not necessarily improved. In many cases, previous dentures were

also fabricated in our hospital and others were in private practitioners. Because of a broad range of dental experiences among private and hospital dentists, there were differences in quality among fabricated dentures. Therefore, the quality of previous dentures as control was largely different among the subjects.

The  $\Delta$ MMP scores had no correlation with scores by other methods and showed negative correlations to subjective methods ( $\Delta$ PS1 and  $\Delta$ PS2). According to the reports from Maeda<sup>22</sup> and Kurimoto<sup>23</sup>, the scores of masticatory performance from the sieve test using peanuts are in proportion to occlusal contact area of subjects' dentures. In this study, because of larger occlusal contact area of previous dentures due to

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attrition of the artificial teeth than that of new dentures, peanuts may have been relatively easy to be chewed, and there was no significant correlation between the  $\Delta$ MMP scores and other methods. Although the sieve test is established as an objective method for dentate patients, it was reported that the lower the modulus of elasticity of test foods, the higher the masticatory performances<sup>24</sup>. It is suggested that since peanuts have a relatively low modulus of elasticity, their masticatory performance tended to be high even on the denture with severe attrition.

van der Bilt and Fontijn-Tekamp FA<sup>11</sup> compared the results of obtained masticatory performance by a single and a multiple sieve method, concluding that the single sieve method was less reliable than the multiple sieve method if an appropriate sieve mesh was not selected. Hirai *et al.*<sup>12</sup> also reported that there was a significant correlation between the outcomes of multiple sieve method and food questionnaire for evaluating masticatory function. However, the subjects had similar mandibular residual ridge height in the latter study and a multiple sieve method might be too complicated for clinical use.

Gunne<sup>8</sup> reported that there was no significant difference between new and previous dentures in the masticatory efficiency index using gelatin, and there was no significant correlation between the masticatory efficiency index and the subjective experience of the masticatory performance. Garrett *et al.*<sup>9</sup> evaluated masticatory performance of identical subjects with previous and newly fabricated dentures after using them for 3 months. They found that their satisfaction with new dentures increased, but masticatory performance from the sieve test using peanuts showed a tendency to decrease. Therefore, it was supported that measurement of masticatory performance for the complete denture wearers by the sieve test is not associated with other testing methods and may not be enough to evaluate the masticatory function in the clinic comprehensively.

In this study, significant positive correlations were found at the combinations of  $\Delta a^*$  and  $\Delta$ PS1,  $\Delta a^*$  and  $\Delta$ SE and  $\Delta$ PS1 and  $\Delta$ PS2. Therefore, the post-insertion change of masticatory performance using chewing gum is more associated with the subjective evaluating methods than the masticatory performance using peanuts. Patients who were able to chew the gum better than before were started to feel mastication to be more effective with the new dentures rather than using the previous one. It was also suggested that patients who were able to chew the gum effectively

could eat larger variety of foods than before. Uchida *et al.*<sup>4</sup> reported that the subjects whose SE scores were less than 50 with previous dentures improved their SE scores by having new dentures. Consequently, a proper timing for the denture refabrication might be decided by the chewing gum test in further studies.

By using an appropriate color scale with the chewing gum, dentists in their office or patients in home will be able to easily evaluate their dentures in use in the future. The accuracy of visual evaluation of color change by clinicians was similar to that of the image processing techniques<sup>10,13</sup>. By visually observing the color change of the chewing gum, denture wearers themselves may be able to easily evaluate their dentures in use and to understand a time for new denture fabrication and their necessity of visiting dental offices. It is clinically meaningful for both dentists and patients to make quality assessment of their prosthesis instantly at chair side without using special equipments. Nevertheless, it was not clearly revealed how the chewing gum used in this study changes its color among patients with different levels of masticatory ability. In order to apply this chewing gum to not only complete denture wearers but removable partial denture wearers and implant patients, further investigations will be needed.

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