Clinical significance
A new gel-type denture adhesive was evaluated for denture retention and ease of removal from oral mucosa. It was suggested that the new denture adhesive increased denture retention and was removed from oral mucosa easily.

Abstract
Purpose: The purpose of this study was to evaluate the effect of a new gel-type denture adhesive on denture retention and ease of removal from the oral mucosa after use.
Methods: Eleven complete denture wearing patients (3 males and 8 females; age range, 58-84 years; mean age, 73.7 years) with compromised maxillary denture-bearing tissues were included in the study. Denture retention and ease of removal were evaluated for a new gel-type denture adhesive. The results were compared with those obtained with and without a cream-type denture adhesive. Retention was evaluated by measuring unilateral bite force until these dentures were dislodged on the balancing side. Ease of removal was evaluated by scoring the remaining area of colored denture adhesives on the oral mucosa. Denture retention and ease of removal were also subjectively evaluated using questionnaires.
Results: A significant improvement in objective denture retention was observed when either the cream-type or gel-type denture adhesive was used ($p < 0.05$). A significant difference in objective ease of removal was observed between cream-type and gel-type denture adhesive when subjects had rinsed their mouth once ($p < 0.05$). Subjective assessment showed no significant differences in either retention or ease of removal between gel-type and cream-type denture adhesives ($p = 0.26, 0.24$).

Conclusions: Objectively, denture retention was higher with the cream-type than with the gel-type denture adhesive. Removal of the gel-type denture adhesive from the oral mucosa was easier than that of the cream-type. Subjectively, there were no differences in either retention or ease of removal.

Key words: complete denture, denture adhesive, denture retention, removal from denture.

Introduction
Many denture wearers use denture adhesives to improve retention and stability of dentures. Traditionally, most dentists have taken a critical attitude toward denture adhesives. Dentists have thought that denture adhesives had been used with poor clinical skills, and a lack of prosthetic expertise from dentists. In the past, denture adhesives were regarded as useful for patients with ill-fitting dentures. Today, such a conventional viewpoint is being challenged. It is recognized that dentists should use denture adhesives for well-fitting dentures. Furthermore, denture adhesives might be effective adjuncts in situations when the retention of the trial base is less than desirable when jaw relation records are performed or when a new arrangement of teeth is tested.

Many studies have recently been conducted on the effects of denture adhesives. The most popular, successful products consist of a mixture of carboxymethyl cellulose sodium salt. These denture adhesives first demonstrate low viscosity. With initial intraoral use, denture adhesives swell, and become viscous and sticky in the presence of saliva. As denture adhesives hydrate, free carboxyl groups form ionic adherence between the denture and the oral mucosa. It has been shown that the use of denture adhesives significantly increase retention and stability of dentures and biting force, providing patients with a greater feeling of satis-
fraction. Furthermore, denture adhesives are effective in providing psychological comfort to patients. Kapur reported that the use of denture adhesives did not significantly improve masticatory performance with the sieving method using peanuts. Fujimori et al. reported that masticatory performance significantly increased when using denture adhesives for denture wearers with compromised denture-bearing tissues. One of the methods used to objectively assess the retention of dentures involved the measurement of bite force until dislodgement of maxillary dentures. It has been reported that denture adhesives allowed patients to generate significantly greater incisal bite force. Fujimori et al. measured unilateral bite force in the first molar region. When the denture was dislodged, the maximum value measured before dislodging was recorded. They concluded that denture adhesives enhanced retention and stability of dentures, and unilateral bite force was increased.

Disadvantages of denture adhesives include difficult removal from the oral mucosa. One possible reason for this is that commercially available denture adhesives were developed for increased long-term viscosity. In addition, it is difficult for dentists to remove denture adhesives from patients’ oral mucosa, and often, this could be an obstacle in the fabrication of new dentures. Academic prosthodontists have agreed that denture adhesives might contribute to the development of denture stomatitis or imbalance in the oral flora due to microbial contamination. Furthermore, eluates from several commercially available products of denture adhesives have shown cytotoxicity against human gingival fibroblasts. In light of these findings, denture adhesives should be completely removed from the oral mucosa after use. However, to the best of our knowledge, there have been no reports on the removal of denture adhesives from the oral mucosa.

A new form of denture adhesive has been developed that is easier to remove from the oral mucosa than existing, commercially available products. This new gel-type denture adhesive includes carboxymethyl cellulose and distilled water as basic components. The purpose of this study was to objectively and subjectively evaluate denture retention and ease of removal between a new gel-type denture adhesive and a commercially available cream-type denture adhesive. Denture retention was evaluated objectively by measuring unilateral bite force when the dentures were dislodged on the balancing side. Ease of removal was evaluated objectively by measuring the remaining area of colored denture adhesives on the oral mucosa. Denture retention and ease of removal were also subjectively evaluated using a questionnaire format. Include difficult removal from the oral mucosa.

### Materials and Methods

A cream-type denture adhesive (Tough Grip cream, Kobayashi, Osaka, Japan) and a newly developed gel-type denture adhesive were evaluated in this study. The constitution of the new denture adhesive was decided by referring to commercially available cream-type denture adhesives. It included a large amount of distilled water to control adhesive force, and also included propylparaben, ethanol, and copolymers of methyl vinyl ether and maleic anhydride. Prior to this study, three trial gel-type denture adhesives were made. Table 1 shows the compositions of each trial denture adhesive.

#### Preliminary experiments

Preliminary experiments on consistency were performed because denture adhesives should have adequate fluidity not to change the occlusal relationship of dentures. Consistency tests were conducted to conform to the Japanese Industrial Standards (JIS) 6525-2. Denture adhesives (0.5 ml) were set between 2 acrylic pieces (50 mm square), and a 9.8 N load was applied using a loading machine (Instron 5544, Instron Corporation, Norwood, MA, USA) with 5 mm/min cross-head speed for 30 seconds. The resultant denture adhesives were measured across 4 directions at 45 degrees intervals. The mean values were compared. The three trial gel-types, a cushion-type (Tough Grip, Kobayashi, Osaka, Japan), and a cream-type (Tough Grip Cream, Kobayashi, Osaka, Japan) denture adhesives were examined (Fig. 1). Trial

<table>
<thead>
<tr>
<th>Table 1. Compositions of trial denture adhesives. T1, T2, and T3 represent trial denture adhesives nos. 1, 2, and 3.</th>
<th>Distilled water (%)</th>
<th>CMCNa (%)</th>
<th>Others (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>71.2</td>
<td>21.2</td>
<td>7.6</td>
</tr>
<tr>
<td>T2</td>
<td>75.6</td>
<td>18.0</td>
<td>6.4</td>
</tr>
<tr>
<td>T3</td>
<td>78.8</td>
<td>15.6</td>
<td>5.6</td>
</tr>
</tbody>
</table>
denture adhesive no. 1 showed low consistency similar to the cushion-type. This denture adhesive might change the occlusal relationship of the dentures because of low consistency. Trial denture adhesive no. 3 had the highest consistency. However, when fluidity was too high, the denture adhesive could flow out from the denture border, so it was decided to use trial denture adhesive no. 2 which had 75.6% distilled water and the same degree of consistency as the cream-type. Furthermore, each denture adhesive was colored with 0.4% indigo carmine to easily visually evaluate removal. Figure 2 shows the adhesive force of gel-type, colored gel-type, cream-type, and colored cream-type denture adhesives. Adhesive forces were measured 3 times, conforming to the JIS 6525-1. Denture adhesives were set in the round shape holes with 10 mm diameters and dipped into water at 37°C for one minute. A 9.8 N load was applied using the loading machine with 5 mm/min cross-head speed for 30 seconds. Then, tensile forces were measured with 5 mm/min cross-head speed as adhesive forces.

Subjects
Eleven complete denture wearers (3 males and 8 females; age range, 58-84 years; mean age, 73.7 years) who visited for treatment at the University Hospital, Faculty of Dentistry, Tokyo Medical and Dental University in Japan, volunteered to participate in this study. All subjects had compromised maxillary denture-bearing tissues. By using Kapur’s method, scores of maxillary denture-bearing tissues were less than 7 (mean score, 5.5; SD: 0.9). The scores of their maxillary denture were less than 4 (mean score, 3.0; SD: 0.5). No subject had medical problems that would contraindicate participation in the study. Approval from the Tokyo Dental and Medical University’s Human Assurance Committee was obtained for this study.

Retention
To evaluate denture retention with denture adhesives, maximum biting forces and maximal voluntary clenching were recorded unilaterally in the first molar region on the preferred chewing side, using an occlusal force meter (Model GM10, Naganokeiki). This occlusal force meter had a sensor chip of 9 mm thickness. When a denture was dislodged, the maximum value measured before dislodgment was recorded. At first, the occlusal force without denture adhesives were recorded, and repeated 3 times at 3-minute intervals. Next, the occlusal forces with each denture adhesive were recorded. Prior to evaluations, 0.8 g of denture adhesive were thinly and uniformly applied on the dentures. The dentures with denture adhesives were placed into subjects. Thirty minutes later, measurements were taken, and repeated 3 times at 3-minute intervals. This same procedure was carried out with another denture adhesive on the same day.

Ease of removal
Each denture adhesive was colored with 0.4% indigo carmine to easily visually evaluate removal. Prior to evaluations, 0.8 g of colored denture adhesive was thinly and uniformly applied on dentures. Thirty minutes later, examiners removed the dentures, and observed the oral mucosa of subjects. Then, conditions of oral mucosa were defined as baseline. Next, subjects removed denture adhesives in their mouth by following a standardized method including 5 stages. There are mouth rinses and the removal of the adhesive using cot...
ton gauzes, or hot water (70°C, 20 ml) for 2 minutes (Fig. 3). The evaluation was repeated for the 5 stages. For each stage, 3 examiners evaluated denture adhesive adherence to the oral mucosa according to 5 grades (Table 2). Water (20 ml) was used to rinse the mouth. Subjects were instructed to similarly gargle every time, and to practice before applying the denture adhesive. This same procedure was carried out with another denture adhesive on the same day. Three examiners evaluated the easiness of removal 110 times for 11 subjects, respectively; and inter-examiner reliability was measured using quadratic weighted kappa.

**Questionnaires**

Patient perceptions were assessed by a questionnaire on denture retention and the ease of removal for the denture adhesives from the oral mucosa after use. The subjects had used each denture adhesive for 3 consecutive days; they answered multiple choice questions. Table 3 shows questionnaire items and scales. Eleven subjects were randomly assigned to 2 groups for eliminating biases that may be evident with the order of application of the denture adhesives. Subjects initially used denture adhesives for 3 days, then answered the questionnaire, and stopped applying the denture adhesive. One week after they stopped using the denture adhesive, they used another denture adhesive for another 3 days, and answered the questionnaire (Fig. 4). Subjects were instructed how to apply the denture adhesive onto the tissue surface of dentures before use. When subjects used the cream-type denture adhesive, they followed the manufacturer’s directions. In addition, the subjects were instructed to thinly and uniformly apply 0.8 g of gel-type denture adhesive onto the tissue surface. The subjects applied denture adhesive the first time they used dentures in the morning. Furthermore, the subjects were instructed to rinse their dentures and mouths after meals, and to apply the new denture adhesive.

**Statistical analysis**

Median values of retention were statistically analyzed using a Wilcoxon signed ranks test with Bonferroni correction. Median values of removal scores and data of the questionnaire were statistically analyzed using a Wilcoxon signed ranks test. The significance level was set at 0.05 (SPSS 10.0J, SPSS Japan Inc.).

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**Table 2.** Scoring method used to evaluate the denture adhesive remaining on the oral mucosa.

<table>
<thead>
<tr>
<th>Score</th>
<th>Denture adhesive in the mouth</th>
</tr>
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<tbody>
<tr>
<td>4</td>
<td>Almost all of the denture adhesive remains</td>
</tr>
<tr>
<td>3</td>
<td>About three fourths of the denture adhesive remains</td>
</tr>
<tr>
<td>2</td>
<td>About half of the denture adhesive remains</td>
</tr>
<tr>
<td>1</td>
<td>About one fourth of the denture adhesive remains</td>
</tr>
<tr>
<td>0</td>
<td>Almost no denture adhesive remains</td>
</tr>
</tbody>
</table>

**Table 3.** Questionnaire items and scales.

<table>
<thead>
<tr>
<th>Did the denture adhesive enhance retention of the denture?</th>
</tr>
</thead>
<tbody>
<tr>
<td>5: strongly agree, 4: agree, 3: neither agree nor disagree, 2: disagree, 1: strongly disagree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Was the denture adhesive easy to remove from the oral mucosa after use?</th>
</tr>
</thead>
<tbody>
<tr>
<td>5: strongly agree, 4: agree, 3: neither agree nor disagree, 2: disagree, 1: strongly disagree</td>
</tr>
</tbody>
</table>
The Evaluation of a New Gel-Type Denture Adhesive

Results

Retention
A significant improvement in denture retention was observed when either the cream-type or gel-type denture adhesive was used ($p < 0.05$) (Fig. 5). A significant difference was observed between denture retention with the cream-type denture adhesive and with the gel-type denture adhesive ($p < 0.05$). Retention was higher with the cream-type denture adhesive than with the gel-type denture adhesive. Significant differences ($p < 0.05$) are marked with asterisk.

Ease of removal
Values of weighted kappa of the 3 pairs of 2 examiners were 0.936, 0.914, and 0.943, respectively with a mean value of 0.931.

Questionnaire
Figures 7 and 8 show results of subjective evaluations of retention and easiness of removal of the denture adhesive, using the questionnaires. There were no significant differences between the cream-type and gel-type denture adhesives on either denture retention or easiness of removal ($p = 0.26; 0.24$).

Figure 6 demonstrates the score of remaining denture adhesives on the oral mucosa. A significant difference was observed between ease of removal with the gel-type denture adhesive and with the cream-type denture adhesive when subjects had rinsed their mouth once. Significant differences ($p < 0.05$) are marked with asterisk.
**Discussion**

When denture adhesives were used, the retention of dentures was greatly increased, and large-scale devices were subsequently needed to directly measure retention force. Measurement of the bite force at chairside was a simple and practical method. Measurement of unilateral bite force can be used to clinically evaluate denture retention. Generally, incisal bite force has been used to examine the effects of denture adhesives on enhancement of denture retention. However, Psillakis et al. mentioned that the protrusive position was outside the range of chewing. Fløystrand and Ørstavik measured unilateral bite force when maxillary dentures were dislodged to evaluate denture retention. Fujimori et al. measured the unilateral bite force in the molar region with a cream-type denture adhesive, and observed that the force appeared to be more related to masticatory function than incisal bite force. Therefore, in this study, the unilateral maximum bite force was measured to evaluate retention of the maxillary denture. Both cream-type and gel-type denture adhesives significantly increased the unilateral bite force. Retention was higher with the cream-type denture adhesive than with the gel-type denture adhesive. The results of the questionnaire also showed that cream-type and gel-type denture adhesives enhanced denture retention. Patients subjectively found that retention with the cream-type denture adhesive was not different from with the gel-type denture adhesive.

Therefore, gel-type denture adhesives can enhance retention of dentures as much as cream-type denture adhesive, subjectively, although their adhesive force is less than the cream-type denture adhesive. Clinically, it has not been established how much adhesive force is needed for denture adhesives to be effective. Although an increase in denture retention is needed for denture adhesives, denture adhesives can contribute to patients not seeing dentists for recall, and mask underlying denture problems. Too much adhesive force that permits the use of ill-fitting dentures with denture adhesive should not be necessary. Additional studies of the appropriate adhesive force with a denture adhesive which is not effective for ill-fitting dentures are needed.

There has been no previously published, objective evaluation of the amount of denture adhesive that remains on oral mucosa after use. Although the remaining denture adhesive on the acrylic plate after washing in water was checked to evaluate removal in JIS, denture adhesives could show different actions in the mouth because of absorption of saliva or swelling. Therefore, denture adhesives were applied to edentulous patients in this study. The remaining denture adhesives on the oral mucosa, after washing, were scored to evaluate easiness of removal. The average of 3 examiners’ weighted kappa was 0.931. The inter-examiner reliability was very good.

The results showed that, in this study, it was difficult to remove the cream-type denture adhesive when using not only mouth rinses but also cotton gauze. It was easy to remove the gel-type denture adhesive with only mouth rinsing. In the presence of water, denture adhesives include carboxymethyl cellulose hydrates, and display ionic adherence to dentures and the mucosa. The gel-type denture adhesive included hydrated carboxymethyl cellulose with distilled water, decreasing adherence to the mucosa. Therefore, it was suggested that the removal of adhesives from the oral mucosa was easier with the gel-type compared to the cream-type denture adhesive, and that denture retention with gel-type denture adhesive was...
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less than that with cream-type denture adhesive. It appeared that the cream-type denture adhesive hydrated in the mouth, and new gel-type denture adhesive hydrated mainly outside of the mouth. This difference may affect the behavior of free carboxyl groups. Also, a difference between saliva and distilled water may have an influence on adherence. The advantages of hydrating with water beforehand are not only the ease of removal, but also the initial adhesive force in the mouth, or the intended adhesive force with little saliva. On the other hand, subjective evaluation of easiness of removal showed no significant difference between the cream-type and gel-type denture adhesives in the present study. Kulak et al reported that the cream-type denture adhesive based on carboxymethyl cellulose showed a peak of adhesive force at 3 to 5 hours after it had been applied. Therefore, when the subjects removed their dentures and rinsed their mouths after meals, removal of the denture adhesive from the oral mucosa must be difficult. Therefore, it is possible that subjects are not conscious of the remains of denture adhesive on the oral mucosa. In such situations, our instruction to maintain a clean oral mucosa may be ineffective because patients are not conscious of the conditions of their oral mucosa. It is an important aspect of a patient’s education. However, time between applying denture adhesives and evaluation was different between subjective and objective evaluation in this study. Objective evaluation was performed only thirty minutes after applying the two denture adhesives, because it was considered that waiting for a long time before examination would be a burden for patients. However, this might affect the result. Further research is needed with different evaluation periods.

Denture adhesives are classified into the following three types, namely, cream-type, powder-type, and cushion-type. Although cushion-type denture adhesive is popular among patients, dentists should not allow its use because it changes the occlusal relationship and can be a cause of ridge absorption. In this study, a commercially available cream-type denture adhesive, which can be used by dentists and is popular among patients, was compared with a newly developed gel-type denture adhesive. Moreover, powder-type denture adhesives should also be evaluated in future studies. Although powder-type denture adhesives are not more popular than the cream-type denture adhesive, it may be easy to remove them from the oral mucosa. In addition, a more subjective study on gel-type denture adhesives with a large number of subjects is needed.

Conclusion

Within the confines of this study, the following conclusions were established. Each of the gel-type and cream-type denture adhesives significantly improved denture retention. Denture retention was higher with the cream-type denture adhesive than with the gel-type denture adhesive. Removal from the oral mucosa was easier with the gel-type denture adhesive than with the cream-type denture adhesive. A significant difference was observed in ease of removal between cream-type denture adhesive and gel-type denture adhesive when subjects had rinsed their mouth once. The gel-type denture adhesive could be removed by only rinsing the mouth; it was difficult to remove the cream-type denture adhesive by using cotton gauze or rinsing the mouth with hot water.

Subjective assessment showed no significant differences in either retention or ease of removal between gel-type and cream-type denture adhesives.

References


