Clinical significance
Covering the palate with dentures can disrupt the timing of swallowing. To determine the cause of this phenomenon, we investigated whether covering the palate with a denture base altered tongue pressure. The results suggest that use of a denture base has little effect on tongue pressure during swallowing.

Abstract
Purpose: The purpose of this study was to clarify the effects of covering the palate with a palatal plate on tongue pressure during swallowing.
Methods: We investigated 21 subjects (12 males and 9 females; mean age: 25±2 years). Maximum voluntary tongue pressure and tongue pressure during swallowing were measured with and without the application of an experimental palatal plate. The subjects were asked to compress a pressure probe with a small balloon between the tongue and anterior area of the palate with maximum force, and the peak pressure recorded was regarded as the maximum voluntary tongue pressure. They were also asked to swallow a gelatin drink, and the maximum pressure recorded was regarded as tongue pressure during swallowing. Maximum voluntary tongue pressure and tongue pressure during swallowing recorded with and without the palatal plate were compared. Statistical analysis was performed with the paired-sample t-test. Perceived difficulty in swallowing with the palatal plate was evaluated using a 100-mm visual analog scale (VAS).
Results: No significant difference was noted in maximum voluntary tongue pressure or tongue pressure during swallowing between with and without the palatal plate. The mean ± SD of the VAS score for difficulty in swallowing with the palatal plate was 49.3±26.5.
Conclusion: Perceived difficulty in swallowing with a palatal plate showed wide individual variation. Covering the palate with a denture showed no effect on tongue pressure.

Key words: denture, tongue pressure, palatal plate, swallowing, palatal sensation

Introduction
Covering the palate with a denture base can cause a variety of physiologic or functional disturbances such as an unpleasant sensation in the mouth, the gag reflex and poor tongue recognition. It has also been reported to reduce the ability to distinguish food properties. However, the control mechanism of mastication and swallowing, which changes depending on the size and properties of the bolus or oral environment, has yet to be fully explained, and the detailed effects of covering the palate with a denture base remain to be determined. In two earlier studies, Ishizaki et al investigated the effects of covering the palate with a denture base on ingestion, and reported that continuous compression of the palatal mucosa by the denture base impaired mechanoreceptors in the palatal mucosa. In a previous study, we found that the use of a palatal plate affected the time required to propel the bolus into the pharynx (bolus-propulsion time) in about half of the subjects investigated. This indicates that covering the palate with a denture base disrupts the timing of swallowing, perhaps through the blocking of mechanoreceptors in the palatal mucosa. However, determining the underlying mechanism of such disruption was beyond the scope of this study.

As tongue pressure during food transport is controlled by palatal mechanical sensation, we hypothesized that attachment of a palatal plate might interfere with palatal sensation and consequently alter tongue pressure.
Materials and methods

Subjects
The 21 subjects who participated in this study (12 males and 9 females; mean age: 25±2 years) were selected from 25 healthy, dentulous volunteers. The remaining four volunteers showed hyperactive gag reflexes subjectively and objectively, and were, therefore, excluded from the study. All subjects gave their written informed consent to participate in this study prior to the experiments.

Experimental ethics
The study was approved by the Ethics Committee of Tokyo Dental College (#0034). All experiments were performed in accordance with the Edinburgh Revision of the Helsinki Declaration.

Fabrication of experimental palatal plate
A 0.5 mm-thick palatal plate cast in cobalt-chromium alloy (WIRONIUM®, BEGO) was used to cover the palate. The plate was designed to be supported by the palatal surface of the teeth to prevent it sinking into the mucosa (Fig. 1).

Tongue pressure measurement
Subjects were required to sit upright in a dental chair in order to measure the maximum voluntary tongue pressure and tongue pressure during swallowing based on the method described by Hayashi et al.6,7 A tongue pressure probe was assembled from three simple parts: a small balloon, a stainless pipe (length 8 mm, bore 5 mm, diameter 6 mm) and a 1 ml disposable tuberculin-test syringe cylinder. Before taking measurements, the probe was pressurized with air to 19.6 kPa (200 gf/cm²), and the balloon’s diameter was set to approximately 18 mm with a volume of 3.7 ml (Fig. 2). Pressures were recorded 3 times, both with and without the palatal plate. For maximum voluntary tongue pressure recordings, the subjects were instructed to compress a small, specially designed balloon between the tongue and anterior part of the hard palate for 7 seconds with maximum voluntary effort. To record tongue pressure during swallowing, the subjects were instructed to swallow 5 ml gelatin (Gokkun Jelly, Sanwa Kagaku Kenkyusho, Co., Ltd.) as naturally as possible, with the balloon pre-placed between the tongue and anterior part of the palate, and peak value of tongue pressure during swallowing was recorded. Statistical analysis was performed with the paired t-test (α=0.05) using the SPSS statistical software for Windows 11.0J (SPSS, Illinois, USA).

Measurement of difficulty in swallowing
On measuring tongue pressure with the palatal covering, difficulty in swallowing gelatin was evaluated by using a 100-mm visual analog scale (VAS). On the VAS, “same as the condition without palatal covering on measuring tongue pressure” was rated as zero, and “very difficult to swallow” as 100.

Results
The results for maximum voluntary tongue pressure and tongue pressure during swallowing with and without the palatal plate are shown in Table 1. No significant difference was seen between maximum voluntary tongue pressure values for with and without the palatal plate. No significant difference was seen between tongue pressures during swallowing for with and without the palatal plate.

The VAS value was 49.3±26.5 (median: 48.0, range: 3 to 94) (Fig. 3).
Discussion

No significant difference was found in maximum voluntary tongue pressure or tongue pressure during swallowing for with and without the palatal plate. This suggests that covering the palate with a denture base has no effect on tongue pressure during swallowing.

When we ingest food, we compress it against the anterior area of the palate to perceive its texture. The bolus formed by mastication is then transported from the anterior to the posterior area of the palate, sent to the pharynx, and swallowed. Hiiemae et al. also reported that the bolus is sent to the pharynx by bringing the tongue into contact with this part of the palate. There are a large number of sensory receptors in the palate, and it is characterized by palatal folds sensitive to mechanical stimuli, which function in the smooth execution of mastication and swallowing.

In edentulous patients with dentures, most of the palatal mucosa is often covered with a denture base. Ishizaki et al. reported that continuous compression of the palatal mucosa by a denture base induced a decrease in Merkel cells in the palatal mucosa. They also suggested that covering the palatal mucosa with a denture base might damage mechanoreceptors in the palatal mucosa, reducing its sensitivity to mechanical stimulation. In an earlier study, we showed that use of dentures covering the palate can affect bolus-propulsion time in some cases, and that there was an association between sensitivity of the posterior area of the palate and bolus-propulsion time. Lower tongue pressure during swallowing also contributed to changes in propulsion time. Therefore, swallowing function was suggested to be affected by the covering of the palatal mucosa by denture bases in some patients. On the basis of these studies, in the present study, we hypothesized that covering the palate with a denture base would affect tongue pressure during swallowing. However, our results showed no significant difference in maximum voluntary tongue pressure or tongue pressure during swallowing for with and without a palatal plate. Blocking of palatal sensation by a palatal plate may have been compensated for by tongue sensation, or tongue pressure may not have received feedback from palatal sensation. The VAS values demonstrated that the subjects felt difficulty in swallowing with the palatal plate, suggesting that coverage of the palate does not alter tongue pressure, but changes the timing of loading tongue pressure on the palate. This hypothesis was drawn from our previous study results, in which the attachment of a palatal plate changed the timing of swallowing. Unfortunately, this study could not substantiate this hypothesis. We used a balloon-type probe for tongue pressure measurement, but a palatal plate equipped with a pressure sensor should have been used to simultaneously measure tongue pressure and the timing of loading of the tongue pressure.

A 5 ml gelatin drink was selected as the test food. As it could be swallowed without mastication, its morphology would remain constant from the time of entry into the mouth to the beginning of the measurements, and it could be swallowed in a single motion. A 0.5 mm-thick palatal plate was used to eliminate the effect of discomfort, as the tongue feels little sensation regarding the presence of a foreign body of this size. The plate was designed to be supported by the teeth to avoid the stimulation of mechanoreceptors through the sinking of the plate due to tongue pressure.

In the present study, our results indicate no

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Mean (kPa)</th>
<th>SD (kPa)</th>
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<tbody>
<tr>
<td>Maximum voluntary tongue pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With the palatal plate</td>
<td>48.6</td>
<td>8.5</td>
</tr>
<tr>
<td>Without the palatal plate</td>
<td>50.4</td>
<td>8.9</td>
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<tr>
<td>Tongue pressure during swallowing</td>
<td></td>
<td></td>
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<tr>
<td>With the palatal plate</td>
<td>16.1</td>
<td>6.6</td>
</tr>
<tr>
<td>Without the palatal plate</td>
<td>16.1</td>
<td>6.4</td>
</tr>
</tbody>
</table>

Fig. 3 Histogram of perceived difficulty in swallowing (VAS scores) with palatal plate.
significant difference in maximum voluntary tongue pressure or tongue pressure during swallowing for with and without a palatal plate. This suggests that palatal covering by a denture base has no effect on tongue pressure during swallowing. However, all subjects experienced greater difficulty in swallowing with the palatal plate.

It has been reported that elderly persons who frequently wear dentures require large amounts of energy to produce adequate tongue pressure due to a decrease in muscle activity during swallowing. Decreased tongue pressure associated with aging has been also reported. The subjects of this study were young, but oral function is reduced with aging in elderly persons, and tongue pressure for compression of foods during swallowing is reduced, disrupting muscle coordination and reducing palatal and tongue sensations. These conditions may affect tongue pressure during swallowing when the palate is covered with a denture. Therefore, consideration of the shape of palatal coverage by dentures is important in elderly people.

Conclusion

The results suggest that maximum voluntary tongue pressure and tongue pressure during swallowing are not influenced by covering the palate with a palatal plate, although perceived difficulty in swallowing with the palatal plate was larger than that without the palatal plate.

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References