Use of a Tongue-Pressure Measurement System to Assist Fabrication of Palatal Augmentation Prostheses

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Purpose: The purpose of this study was to determine a baseline value of tongue pressure on the palatal region in normal subjects that could then be used to assist in fabrication of a palatal augmentation prosthesis (PAP). ***Materials and Methods:*** A tongue-pressure measurement system with 36 rubber pressure sensors was constructed for this study. This system was applied to 16 normal subjects, and the tongue pressure on the palatal region was measured when they were swallowing. ***Results:*** The maximum tongue pressures seen during swallowing were 85.0 g/cm^2 in the early stage, 95.0 g/cm^2 in the middle stage, and 93.0 g/cm^2 in the late stage. The average maximum tongue pressure throughout swallowing was 91.0 g/cm^2. The tongue pressure in the early stage ranged from 3.37 g/cm^2 to 8.74 g/cm^2. A significant difference was found between the anterior and the posterior regions and between the central and the posterior regions. The value in the middle stage ranged from 5.32 g/cm^2 to 10.22 g/cm^2. Significant differences were found between the anterior and the posterior regions and between the central and the posterior regions. Values in the late stage ranged from 6.80 g/cm^2 to 7.91 g/cm^2. ***Conclusion:*** The average maximum tongue pressure against the palate of approximately 90 g/cm^2 suggests that a PAP sufficient for swallowing should be strong enough to withstand this amount of pressure. The device is also useful to check for variations in the tongue contact area during trial of the prosthesis. *Int J Prosthodont 2005;18:471–474.*

Swallowing begins by placing the tongue against the palate. A palatal augmentation prosthesis (PAP) is designed to assist dysphagic patients in swallowing by making it possible for the tongue to be in contact with the palate. PAP has been defined as a palatal prosthesis that allows reshaping of the hard palate to improve tongue/palate contact during speech and swallowing if tongue mobility has been impaired as a result of surgery, trauma, or neurologic/motor deficits.[1] However, the shape or thickness of a PAP has been obtained via clinical experience, which often involves trial and error and incremental alterations.[2–4] Therefore, it is important to measure tongue pressure before fabricating a PAP. Many methods for measuring tongue pressure have been developed. Although x-ray cinematography, ultrasound, and dynamic palatograms are suitable to observe tongue motion, it is difficult to measure tongue pressure by these means. Further, videofluorography requires special equipment and carries the risk of radiation exposure.[5] Some studies have measured the distribution and range of tongue pressure using fine pressure transducers[6–10] or bulb-like and other devices.[11–16] However, the technical complexity of making such fine devices and restricted access to some of the special materials presents difficulties for extensive measurement. A measuring system that does not require any specific preparation would be convenient for clinicians who fabricate PAPs for their patients.

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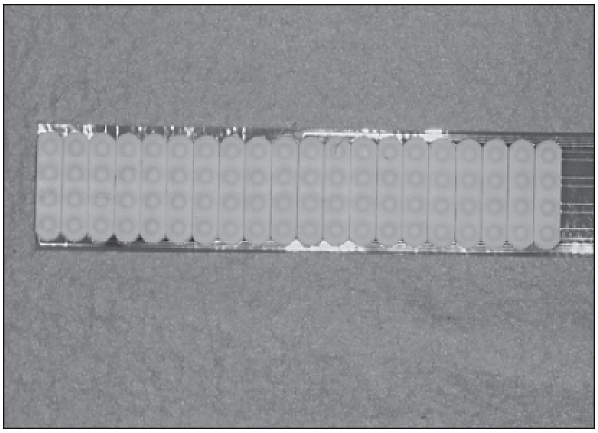

Fig 1 Rubber sensor sheets.

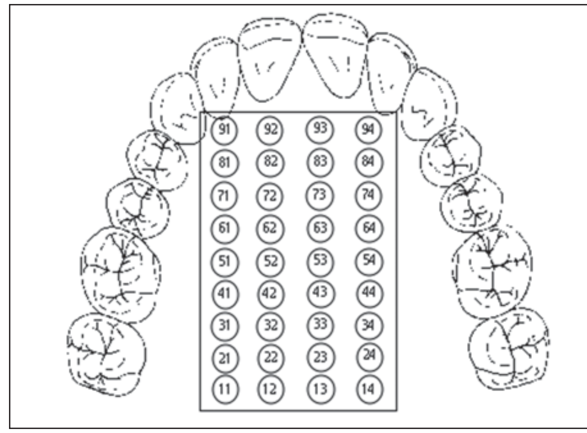

Fig 2 Sensor position of palatal region.

The purpose of this study was to use a new tongue-pressure measurement system to measure tongue pressure against the palate in normal subjects when swallowing saliva to provide a standard value for fabricating a suitable PAP.

Materials and Methods

Subjects

Sixteen healthy volunteers without problems related to mastication or dysphagia (10 men and 6 women; mean age 26.0 ± 6.9 years) were enrolled in this study. All had a complete set of natural dentition, except third molars, with normal occlusion. They were postgraduate students and clinicians at Kyushu Dental College Hospital; they understood the purpose of this study and agreed to participate in the experiment.

Protocol

The sensor part of the tongue-pressure measurement system consists of a 4 cm × 20 cm rubber sheet, 0.5 mm thick, that incorporated 80 rubber pressure sensors (Inaba Rubber) (Fig 1). The signals from each sensor were collected onto a computer via specialized software (INASTOMER-PX80, Inaba Rubber). The resistance value (Ω) from the sensors was converted into load (g/cm^2) with the same software. The numeric and 3-dimensional data from each sensor were shown on a display in real time, and the collected data were saved automatically as a Microsoft Excel file.

With consideration of the typical size of an adult's palate, 36 (4 × 9) of the 80 rubber pressure sensors were used for obtaining measurements in this study (Fig 2). A polycarbonate palatal plate, 0.5 mm thick, was fabricated for all subjects to which a rubber sensor sheet was attached. This sheet was able to fit tightly against a palatal plate, since the rubber sheet was flexible. Tongue pressure in the palatal region was measured while the subjects were swallowing. Measurements were taken 3 times for each subject.

Data Analysis

We evaluated the distribution of the tongue pressure area, the maximum tongue pressure value, and the average tongue pressure value. Swallowing was divided into 3 stages—the early stage, the middle stage, and the late stage—according to the time that is required in natural swallowing. We also divided the area of the sensor sheet into 3 regions—anterior, central, and posterior—with 12 sensors in each region. Statistical analysis was performed for each stage and region using 1-way repeated-measures analysis of variance and Fisher's PLSD as a post hoc test.

Results

The average distribution of the maximum tongue pressure of the 16 subjects is shown in Fig 3. In the early stage of swallowing, the tongue pressed against the center part of the anterior region, and the maximum tongue pressure was 85.0 g/cm^2. In the middle stage, the tongue pressed against the center and lateral parts of the central region and the lateral part of the posterior region, and the maximum tongue pressure was 95.0 g/cm^2. In the late stage of swallowing, the tongue-pressed area was the same as the middle stage, and the maximum tongue pressure was 93.0 g/cm^2. These values for maximum tongue pressure were the maximum values found on the 12 sensors in each region.

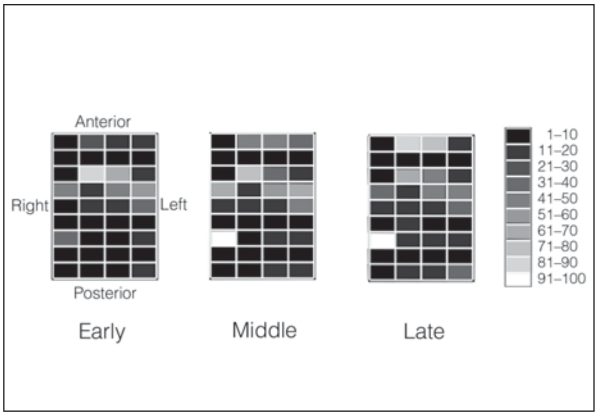

Fig 3 Distribution of maximum tongue pressure (g/cm²) when swallowing.

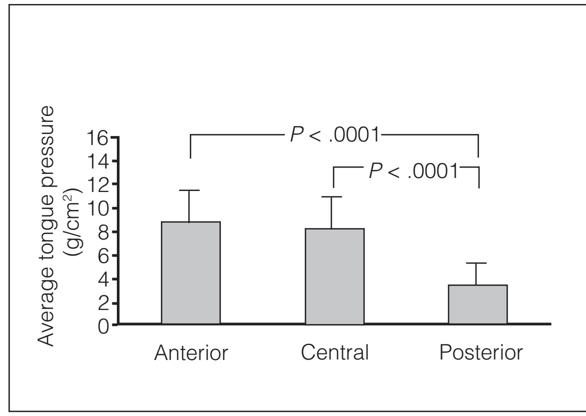

Fig 4 Average tongue pressure (g/cm²) when swallowing in the early stage.

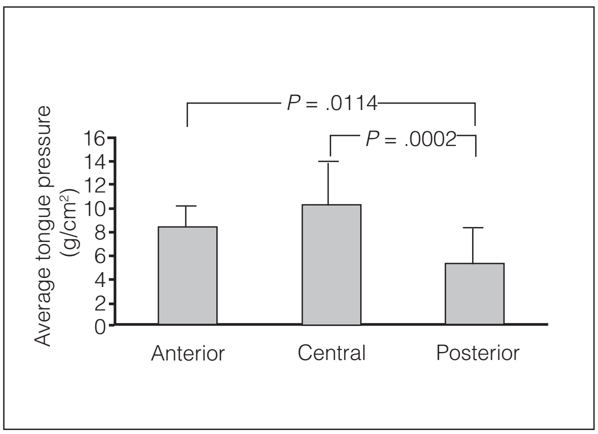

Fig 5 Average tongue pressure (g/cm²) when swallowing in the middle stage.

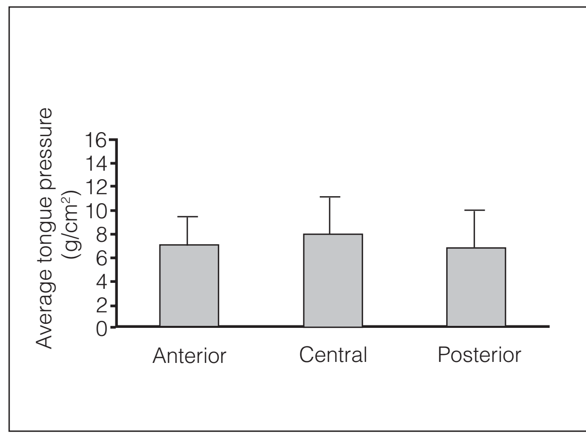

Fig 6 Average tongue pressure (g/cm²) when swallowing in the late stage.

The average maximum tongue pressure throughout swallowing was 91.0 g/cm^2.

The distribution of the average tongue pressure of the 16 subjects is shown in Figs 4 to 6. Average tongue pressure was calculated by the total tongue pressure of each sensor divided by the number of sensors. The value of the average tongue pressure was much lower than the maximum tongue pressure, because some sensors were in very little contact with the tongue. In the early stage, the average tongue pressure was 8.74 $\pm$ 2.64 g/cm^2 in the anterior region, 8.11 $\pm$ 2.64 g/cm^2 in the central region, and 3.37 $\pm$ 2.02 g/cm^2 in the posterior region. A significant difference was found between the anterior and the posterior region ($P < .0001$) and between the central and the posterior region ($P < .0001$) (Fig 4). During the middle stage of swallowing, the average tongue pressure average was 8.38 $\pm$ 2.59 g/cm^2 in the anterior region, 10.22 $\pm$ 2.64 g/cm^2 in the central region, and 5.32 $\pm$ 2.35 g/cm^2 in the posterior region. A significant difference was found between the anterior and the posterior region ($P = .0114$) and between the central and the posterior region ($P = .0002$) (Fig 5). In the late stage of swallowing, the average tongue pressure was 7.04 $\pm$ 2.79 g/cm^2 in the anterior region, 7.91 $\pm$ 3.77 g/cm^2 in the central region, and 6.80 $\pm$ 3.59 g/cm^2 in the posterior region. There were no significant differences in these 3 regions (Fig 6).

Discussion

During the oral stage of swallowing, the tongue plays a vital role in forming a bolus and transferring it to the pharynx.[17] Because swallowing begins with contact between the tongue and the palate, it is important to know the tongue pressure before fabricating a PAP. The tongue-pressure measurement system that we have developed is able to observe not only tongue pressure but also the tongue contact motion against the palate. Furthermore, because it consists of a rubber sensor sheet that is only 0.5 mm thick, it is easy to evaluate the appropriate thickness of a PAP by measuring tongue pressure with the sheet bonded to the base plate of a wax denture. For these reasons, this system is useful for measuring tongue pressure when fabricating a PAP. Because the rubber sensor sheet used in this study was a ready-made rectangular sheet, it was not able to measure tongue pressure in the entire region of the palatal portion of the teeth. To measure the tongue pressure of a whole palatal region, a specially shaped rubber sensor sheet would be required.

In this study, maximum tongue pressure during natural swallowing in the 16 subjects was 85.0 g/cm^2 in the early stage, 95.0 g/cm^2 in the middle stage, and 93.0 g/cm^2 in the late stage, giving an overall average maximum tongue pressure of 91.0 g/cm^2. Maruyama[8] reported that the peak tongue pressure was 63.5 g/cm^2 at the maxillary anterior teeth, 83.9 g/cm^2 at the first premolars, and 121.7 g/cm^2 at the first molars, with an average of 89.7 g/cm^2. This is in agreement with our findings. On the other hand, Kitaoka et al[9] reported that maximum tongue pressure during swallowing of young subjects was 15.6 kPa (159.1 g/cm^2), which is a much larger value than that seen in our study. It is thought that one of the reasons for this difference is the thickness of the maxillary plate of the measurement device. The thickness of their plate was 2 mm, and the thickness of our plate was 0.5 mm. It is important to define the thickness of the measuring device when the tongue pressure is measured because the value of the tongue pressure is changed by the thickness.

Because it is believed that the maximum tongue pressure against the palate of approximately 90g/cm^2 is sufficient for swallowing, this value has been adopted as a standard with our measuring device. It is a fact that some patients undergoing glossectomy are unable to produce this amount of tongue pressure.[18] Therefore, the fabrication of a PAP in such patients is still done by trial and error.

To evaluate the area of tongue contact with the palate, the oral stage of swallowing was divided into 3 stages, and the palatal area was divided into 3 regions in this study. The areas receiving the most pressure when swallowing were the anterior region in the early stage and the central region in the middle and late stages. These results suggested that there is a rhythmic variation in the area of tongue contact with the palate during swallowing from the anterior region, via the central region, and finishing with the whole region in the late stage, but pressure is especially concentrated in the central region.

Conclusion

It is thought that an average maximum recorded tongue pressure against the palate of approximately 90 g/cm^2 is sufficient for swallowing. Therefore, a PAP should be fabricated to allow for the production of this amount of tongue pressure. The described device permits the measurement of tongue pressure and is also useful to check for variations in tongue contact area during swallowing during try-in of the prosthesis.

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