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Original article

Development of *in vivo* measuring system of the pressure distribution under the denture base of removable partial denture

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Abstract

Purpose: To develop a system to measure the pressure distribution under the base of a removable partial denture (RPD) and to apply it *in vivo*.
Methods: A tactile sensor sheet with 100 sensing points and a measuring system (I-SCAN™, Nitta, Osaka, Japan) were used. The sensor was calibrated before being applied *in vivo*. A subject with a mandibular RPD (Kennedy class II, division 1) participated in this study, and the RPD was duplicated as the experimental denture. The basal surface at distal extension was accommodated to the sensor in a manner similar to direct relining. Measurements were performed with three patterns of occlusal rest design (mesial and distal rests, mesial rest only, and without a rest) during maximal voluntary clenching (MVC) and gum chewing.
Results: The calibration measurements showed that the output value from each sensing point and total output of sensing points were positively correlated with the applied load. The pressures recorded *in vivo* varied depending on the locations of sensing points on the basal surface of the denture. During MVC the pressure distribution changed with the clenching level, and the highest pressure was registered near the residual ridge crest. The pressure distribution also changed according to the number of occlusal rests. The load center shifted about 2 mm during MVC and about 4 mm during gum chewing.
Conclusion: The measuring system developed here enabled us to measure the pressure distribution under the denture base of RPD. The pressure distribution varied along with the design of the occlusal rest.

Keywords: Removable partial denture; Pressure distribution; *In vivo* measurement; Tactile sensor

1. Introduction

The pressure under the denture base of a removable partial denture (RPD) during function should be distributed uniformly in order to avoid pressure concentrations that may cause pain and inflammation in the tissues supporting the denture. This distribution is therefore taken into account in the modern principles of RPD design [1]. Pressures under denture bases have usually been evaluated by using simulation models on the bench [2–11], or the finite element method [12–14]. Although a few researchers measured the pressures under the denture bases of RPDs *in vivo* [15–23], the number of points at which pressures were measured was too small to clarify the pressure distribution. We therefore developed a system using tactile sensors to measure the pressure distribution under the denture base of a removable partial denture *in vivo*.

2. Materials and methods

2.1. Pressure measuring devices

A tactile sensor sheet (0.1-mm thick) with 100 sensing points in a 12 mm × 12 mm region (Fig. 1) and a pressure measuring system (I-SCAN™, Nitta, Osaka, Japan) were used. The sensor sheet comprised two PET (polyethylene terrephterate) film sheets. On each sheet, longitudinal and latitudinal electrodes are placed at even intervals. Special ink is formed into a film over the electrode. Intersecting points of longitudinal and latitudinal electrodes form separate force detection points

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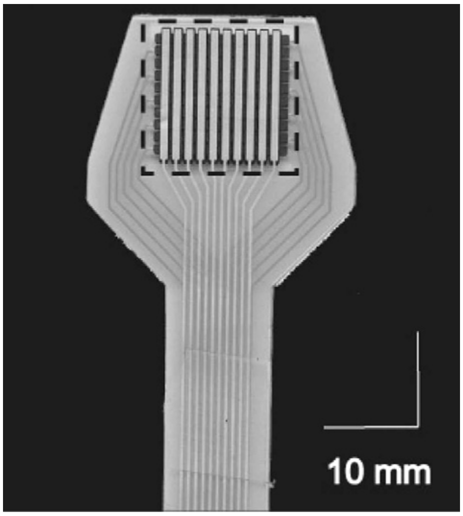

Fig. 1. The tactile sensor sheet (dashed line surrounds the sensing area).

(sensor cells). Electrical resistance of sensor cells under no load is almost infinite, while it decreases inversely proportional to applied force. Thus, the sensor sheet permits real time measurement of pressure distributions. The I-SCAN^{TM} have been applied widely to the industrial, medical, health and welfare, and dental fields for measuring pressure distributions.

Calibration apparatus was used to clarify the following characteristics of the sensor sheet under the assumed oral conditions: (1) the relation between the sensor output and the actual load; (2) the effect of hysteresis on sensor output; and (3) the effect of temperature on sensor output. Loading was done by placing sash weights on a ball spline embedded in the calibration apparatus, and the load was transferred to the sensor sheet in contact with a quadrate probe attached at the bottom end of the spline.

The load when the probe contacted the sensor was defined as zero. To evaluate the relation between the applied load and the sensor output, loads from 0 to 90 N were applied sequentially in each of 10 trials. To measure the effect of hysteresis on sensor output, in each of 10 trials loads from 0 to 60 N were applied sequentially and then they were removed sequentially. The room temperature was 27 °C when the load–output relation was evaluated and the effects of hysteresis were measured. To measure the effect of temperature on sensor output, the room temperature were changed and loads up to 80 N were applied sequentially in 10 trials at each of the following temperatures: 27, 30, 33, and 37 °C.

2.2. *In vivo measurement*

The subject was a 65-year-old woman with a satisfactory mandibular RPD (Kennedy class II division 1) fabricated at the prosthodontic clinic of Tohoku University Hospital (Fig. 2). Informed consent was obtained. A RPD that was a duplicate of the one worn daily by the subject was used as the experimental denture (Fig. 3a).

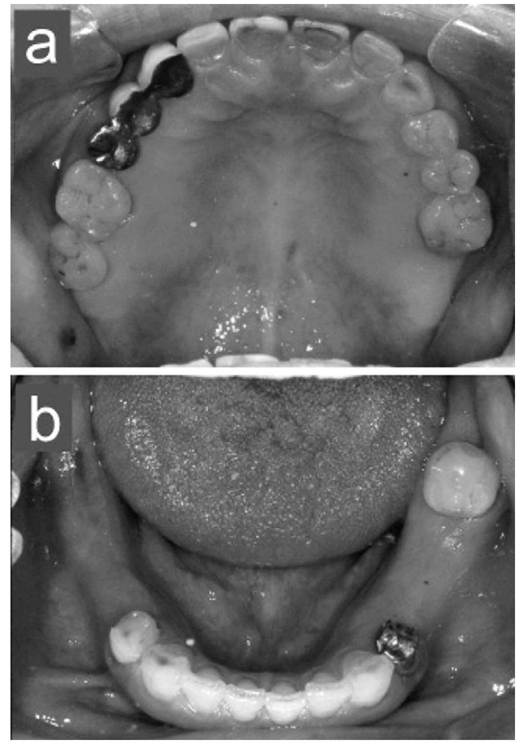

Fig. 2. Intraoral views of the subject. (a) The maxillary arch had been restored with a fixed partial denture. (b) Resorption of residual bone was moderate, and inflammation of the mucosa on residual ridge was not observed.

After the basal surface of the distal extension of the experimental denture was accommodated to the sensor sheet placed on the residual ridge in much the same way as direct relining using an autopolymerizing resin (Tokuyama Rebase II Normal, Tokuyama Dental Co., Tokyo, Japan), the sensor sheet was bonded to the basal surface by using an alpha-cyanoacrylate adhesive (Aronalpha, Toagosei Co., Tokyo, Japan). The conformation of the sensor sheet to the residual ridge was checked on the basis of the pressure distribution measured when the experimental denture was placed and the adaptability test using a white silicone rubber material (Fit checker, GC Co., Tokyo, Japan). The adaptations of all the occlusal rests, including those on indirect abutment tooth, were also checked using white silicone. Occlusal contact was adjusted before measurement so that the occlusal contact points were distributed symmetrically within the dental arch when the subject tapped her upper and lower teeth gently. Fig. 3b shows the occlusal contact pattern after the adjustment recorded with silicone rubber material (Flexicon [injection type], GC Co.). Measurements were performed at maximal voluntary clenching and during gum chewing with three different occlusal rest designs for the right first premolar (Fig. 3c): MD (mesial and distal rests); M (mesial rest only); and none (without a rest). The latter two situations were brought out by cutting the distal rest and mesial rest off in order. Muscle fatigue was minimized by allowing 2 min to elapse between successive measurements. The data obtained were analyzed in a PC.

This research was reviewed and approved by the Ethics Committee of Tohoku University Graduate School of Dentistry.