

RESEARCH ARTICLE

Effect of Relief at the Median Palatal Plate on Denture-supporting Ability

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ABSTRACT

Aim: A new maxillary palatal plate-form device that simultaneously measures clenching force and subsidence of the palatal mucosa at the onset of jaw clenching pain was developed to ascertain the effect of median palatal plate relief on denture-bearing ability.

Materials and methods: In 15 dentulous subjects, pseudo-palatal plates were affixed to the palatal mucosa; anterior splints were affixed as maxillary references for measuring subsidence upon transmission of the clenching force through a pressurizing splint affixed to the mandible. The relief at the median palatal plate was categorized as: No-relief, 0.23 mm relief, and 0.46 mm relief. Subjects clenched their jaws until they experienced pain. The clenching force and subsidence of the palatal mucosa were simultaneously measured and compared across relief categories, and their relationship to the extent of relief at the onset of pain was evaluated.

Results: At the onset of pain, both clenching force and subsidence of the palatal mucosa in the relief conditions were significantly greater than those in the no-relief condition ($p < 0.05$). In some patients, both clenching force and subsidence of the palatal mucosa decreased with increase in relief.

Conclusion: Relief at the median palatal plate effectively increases the bearing ability of the palatal part. However, the range and extent of relief might vary, depending on oral conditions.

Clinical significance: Using this approach, the relief area of maxillary full dentures suitable for individual patients was determined in an objective and convenient manner and the accuracy of denture treatments was improved. This could improve the quality of life of patients wearing dentures.

Keywords: Denture-supporting tissue, Mucosal thickness, Pain threshold, Relief, Subsidence of the palatal mucosa.

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Conflict of interest: None

INTRODUCTION

The increase in Japan's aging population is expected to result in an increase in the number of people wearing complete dentures.¹ Good-quality plate denture treatment is essential for improving the quality of life of denture wearers. To this end, it is important to evaluate the characteristics of denture-supporting tissues objectively during the diagnostic workup for plate denture treatment.

Previous studies have analyzed the characteristics of denture-supporting tissues under local pressure, which differs significantly from the conditions extant while wearing actual removable plate dentures.²⁻¹² Therefore, measurement with a device suited to the actual form of the denture base is essential for clinical applications.

Previously, a system was developed that allowed the simultaneous measurement of the applied load, up to onset of pain, and the corresponding changes in mucosal thickness.² The authors also analyzed the relationship between the characteristics of denture-supporting tissues (thickness and elasticity modulus of the palatal mucosa) and pain threshold (pressure, subsidence, and compressibility) in dentulous³ and edentulous subjects.⁴ However, these previous studies also evaluated local pressure conditions, which differ from the situation when actual dentures are worn.

At present, plate dentures composed of a cobalt-chromium alloy and zirconia framework for the palate are increasingly being used for improving the strength and compatibility of plate dentures.¹³⁻¹⁶ Because of problems, such as allergy to cobalt-chromium alloy and titanium,¹⁶⁻²⁰ plate dentures with a zirconia framework for the palate are gaining attention. However, it is difficult to adjust these types of dentures by cutting after fabrication; therefore, during palate plate fabrication, it is important to identify the appropriate site that requires relief as well as the degree of relief that is required. However, there have been few studies on this topic.

Therefore, in this study, a newly developed maxillary palatal plate-form device was used to analyze the

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relationship between clenching force and subsidence of the palate mucosa at the onset of pain in dentulous subjects, with the aim of clarifying the effect of relief at the palate on the denture-bearing ability of the palatal plate.

MATERIALS AND METHODS

Simultaneous Measurement Device

A system previously developed in this department² allows simultaneous measurement of the applied load and mucosal thickness. To date, a great deal of research has been conducted using this system to investigate the characteristics of denture-supporting tissues and the pressure–pain threshold.^{2–4} However, these previous studies only evaluated local pressure conditions, which differ from the situation when the dentures are actually worn.

Simultaneous measurement device incorporates the previous system into palatal plates, allowing simultaneous measurement of the clenching force and the changes in palatal mucosal thickness up to the onset of pain when clenching the jaws. This device comprises an oral device, a small compression load cell, a small ultrasonic thickness-gauge (Figs 1A to C), and a simultaneous measurement system.

In this study, pseudo-palatal plates were fabricated using room temperature-curing resin (Orthocrystal[®], NISSIN, Kyoto, Japan). These plates were affixed to the palatal mucosa, where they were subjected to subsidence under clenching force to approximate the conditions during denture wearing. The pseudo-palatal plate extended from the mesial side of the first molar to the distal side of the second molar, on both the left and right sides (Fig. 1D). This site is an important occlusal-supporting area for complete maxillary dentures; it excludes the rugae palatinae, which vary greatly among individuals and, consequently, make it challenging to determine the range of relief. A 0.65-mm-thick thermoplastic resin sheet (Duran PLUS[®], Rocky Mountain Morita Corporation, Tokyo, Japan) was used as a stopper; it was placed bilaterally on the first and second premolars to define the horizontal position of the pseudo-palatal plate.

The median part of the pseudo-palatal plate on its basal side corresponded with the thinnest region of the palatal mucosa.^{3,4,21,22} Relief sites for complete maxillary dentures²² had a relief width of 10 mm. Three types of relief were defined: No-relief, 0.23 mm relief, and 0.46 mm relief. The extent of relief was determined in accordance with the proposal of Ishinabe,²² using sheet wax (SHEET WAX # 32[®], GC, Tokyo, Japan), which allowed quantitative variation of the extent of relief.

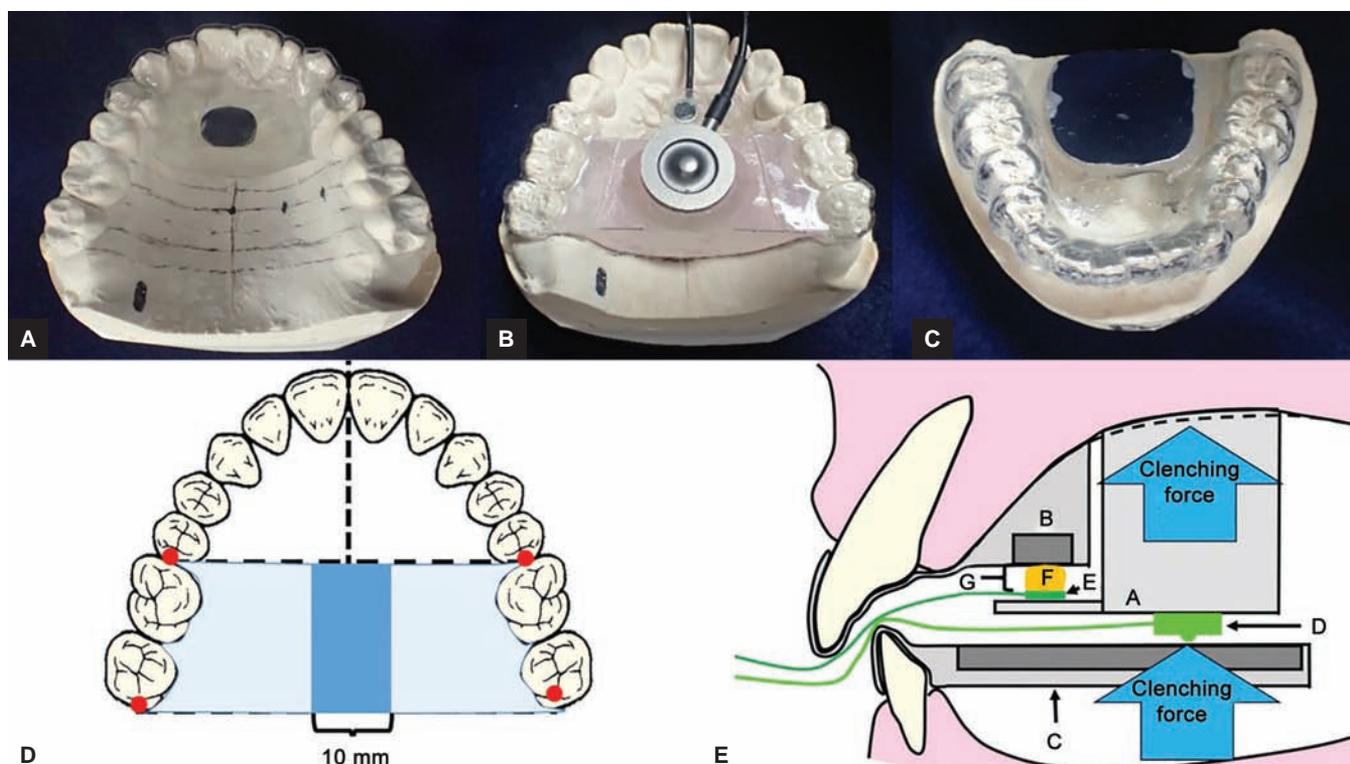
A small compression load cell (LMB-A-2KN[®], KYOWA, Tokyo, Japan), 7-mm high and 16-mm wide, was incorporated into the pressure side of the pseudo-palatal

plate to measure the clenching force. An ultrasonic thickness gauge was fitted onto the wings extending out from the body of the plate; this probe was used to measure the subsidence of the pseudo-palatal plate. Anterior splints, which were intended to serve as reference points for the maxilla during measurement of subsidence, were fabricated from a 1.0-mm-thick thermoplastic resin sheet (Duran PLUS[®], Rocky Mountain Morita Corporation, Germany) and a 0.8-mm-thick metal plate (MESH VENEER PLATE[®], Dentsply Sirona, Tokyo, Japan). Pressurizing splints, for transferring the clenching force to the pseudo-palatal plate through the small compression load cell, were manufactured from a 2.0-mm-thick thermoplastic resin sheet (Duran PLUS[®], Rocky Mountain Morita Corporation, Germany) and a 1-mm-thick metal plate (18/8 stainless steel).

The ultrasonic thickness gauge comprised a body display (25DL PLUS[®], Olympus NDT JAPAN Inc., Tokyo, Japan) and a probe. Thickness measurements were displayed on the body display as echo waveforms. The probe used in this study was an ultra-slim water-immersion probe (Pechakosan[®], KGK, Kanagawa, Japan) of 1-mm height, 5-mm diameter, 0.01-mm resolution, and a measurement range of 0.08 to 508 mm. The sampling frequency and ultrasonic wave speed were set at 10 Hz and 1973.9 m/s respectively. A couplant (Refrecare-H[®], EN Otsuka Pharmaceutical Co., Iwate, Japan) was placed between the ultrasonic thickness gauge and the metal plate of the anterior splints to ensure transmission of ultrasonic waves.

Figure 1E presents the schematic diagram of the oral device at the onset of pain. The metal plate of the pressurizing splint pressurizes the load cell during jaw clenching, causing subsidence of the pseudo-palatal plate. Before commencing measurement, the subjects were instructed to press the button on the signal generator when they first perceived pain. In this way, the subjects signaled the onset of pain using a light-emitting diode (LED) and an electronic buzzer. The clenching force at the onset of pain was measured by the load cell. The ultrasonic thickness gauge measured the couplant thickness before loading and at the onset of pain; the difference between these two values was set as the subsidence of the palatal mucosa at the onset of pain.

The load cell signal was amplified by a sensor system (PCD-300A[®], Kyowa, Tokyo, Japan) and displayed as a waveform of the clenching force on a computer screen (LATITUDE E5500[®], DELL Japan, Kanagawa, Japan). Live thickness readings, displayed on the ultrasonic thickness gauge, were photographed using a web camera (HD Pro Webcam C920[®], Tokyo, Japan) to allow simultaneous monitoring with the waveforms of the clenching forces. On-screen images were captured using video-capture



Figs 1A to E: 1A: Anterior splint 1B: Pseudo-palatal plate 1C: Pressurizing splint 1D: Range of Pseudo-palatal plate 1E: Schematic diagram of the oral device (A) Pseudo - palatal plate (B) Anterior splint (C) Pressurizing splint (D) Load cell (E) Ultrasonic thickness-gauge (F) Couplant (G) Thickness of the couplant

software (HyperCam3[®], Oddie Soft, Nakano, Japan) and used for analysis.

Furthermore, given that the simultaneous measurement device was newly developed, its measurement reliability was verified. The possibility of rotation or subversion of the pseudo-palatal plate was a concern,²² to prevent this, the pressure side of the pseudo-palatal plate and the metal plate side of the pressurizing splint were fabricated to run parallel to the occlusal plane. Additionally, as a preliminary experiment, subsidence of the pseudo-palatal plate was compared under conditions where the ultrasonic thickness gauge was affixed to the anterior and posterior parts of the pseudo-palatal plate wings in order to determine the possibility of rotation or subversion of the simultaneous measurement device during clenching. The findings of a t-test for comparison of the measurements obtained under the two conditions revealed no significant differences, which indicated that error due to rotation or subversion of the pseudo-palatal plate was minimal or absent.

Effect of Relief at the Median Palatal Plate on Clenching Force and Subsidence of the Palatal Mucosa at the Onset of Pain Subjects

This study was approved by the Ethics Committee of Showa University (approval number 2014-036). All subjects provided informed consent for participation.

This study included young dentulous subjects with little variability in characteristics, such as age and

oral conditions. Fifteen subjects (8 males; 7 females; mean age 28.9 years) without any palatal mucosal abnormalities or marked torus palatinus were recruited from among dentists at the Department of Geriatric Dentistry.

Measurement Conditions

Three types of pseudo-palatal plates were affixed in each subject to create three different categories of relief: No relief, 0.23 mm relief, and 0.46 mm relief; the clenching force and subsidence of the palatal mucosa at the onset of pain were measured for each relief category. The subjects were first trained in the required clenching speed using visual feedback. They were then instructed to increase the clenching force by 100 N every second and to press the signal generator button at the onset of pain, at which point they were required to hold that level of clenching for 3 seconds and thereafter gradually reduce the clenching force. Taking into account the difference in reaction time between perception of pain and pressing of the button, the mean value of the clenching forces at 0.5 seconds before and after LED emission was set as the clenching force at the onset of pain. Similarly, the mean value of the subsidence at 0.5 seconds before and after LED emission was set as the subsidence of the palatal mucosa at the onset of pain. The measurements were recorded at 5-minute intervals to allow for recovery of the palatal mucosa deformation; the number of measurements per relief category was set at three.

Statistical Analysis

The normality of data regarding the clenching force and subsidence of the palatal mucosa at the onset of pain for each type of pseudo-palatal plate in the 15 subjects was confirmed using the Shapiro–Wilk test. The mean values of the clenching force and subsidence of the palatal mucosa at the onset of pain for each category of relief were compared by two-way factorial analysis of variance (ANOVA) with replication, followed by multiple comparison correction. The level of significance (risk ratio) was set at 5%. Statistical analysis was performed using PASW Statistics 19 (SPSS, Tokyo, Japan).

Fit Testing of Pseudo-palatal Plates at Onset of Pain

A silicone fit testing material (FIT CHECKER®, GC, Tokyo, Japan) was used to test the goodness of fit of each pseudo-palatal plate at the onset of pain. In order to visualize the fit, red caries-detection dye (NISHIKA Caries Check®, Nippon Shika Yakuhin Co., Yamaguchi, Japan) was mixed into the silicone fit material.

RESULTS

Effect of Relief at the Median Palatal Plate on Clenching Force and Subsidence of the Palatal Mucosa at Onset of Pain

Data regarding the clenching force and subsidence of the palatal mucosa at the onset of pain for each type of pseudo-palatal plate were found to be normally distributed and were, therefore, evaluated by two-way ANOVA with replication and multiple comparison correction. The mean values of the clenching force and subsidence of the palatal mucosa at the onset of pain for each relief category are presented in Graph 1. At the onset of pain, both clenching force and subsidence of the palatal mucosa in the 0.23

and 0.46-mm relief conditions were greater than those under the no-relief condition (two-way ANOVA, $p < 0.05$). However, there was no significant difference in the two variables between the 0.23 and 0.46 mm relief conditions.

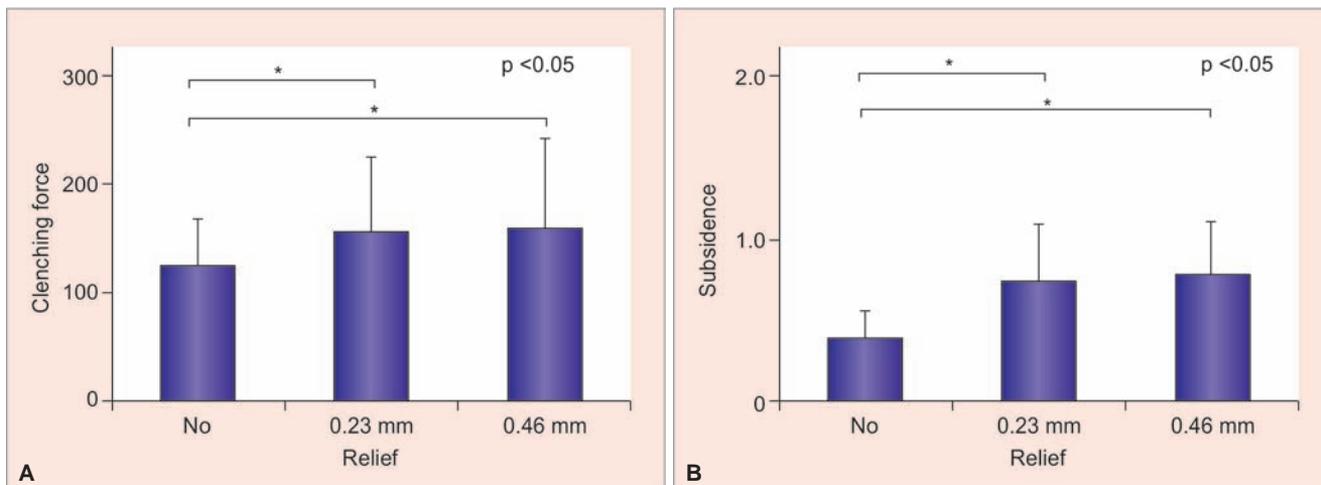
The clenching force and subsidence of the palatal mucosa at the onset of pain varied with the extent of relief. Graph 2 presents the subsidence measurements of the palatal mucosa in each subject. In the overall study sample of 15 subjects, an increase in relief resulted in significant increases in the mean values of the clenching force and subsidence of the palatal mucosa at the onset of pain. However, in some patients, the clenching force and subsidence of the palatal mucosa decreased with the increase in relief. Therefore, the subjects were categorized into two groups based on whether (gain group) or not (other group) the clenching force and subsidence of the palatal mucosa at the onset of pain increased with the increase in relief.

Relationship between Clenching Force and Subsidence of the Palatal Mucosa at Onset of Pain

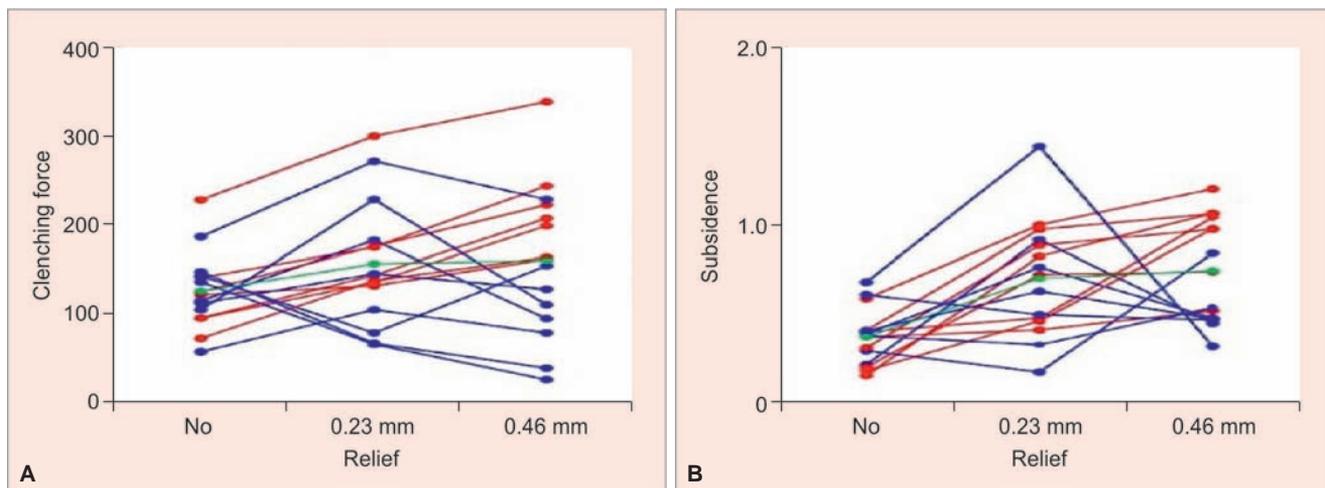
Graph 3 presents the findings of Pearson’s correlation analysis of the relationship between the clenching force and subsidence of the palatal mucosa at the onset of pain for each relief category. Although there was no correlation between the clenching force and subsidence of the palatal mucosa at the onset of pain in the no-relief category, the two variables exhibited a negative correlation in the 0.23 mm relief category ($r = -0.585$) and a positive correlation in the 0.46 mm relief category ($r = 0.605$).

Pseudo-palatal Plate Fit at Onset of Pain

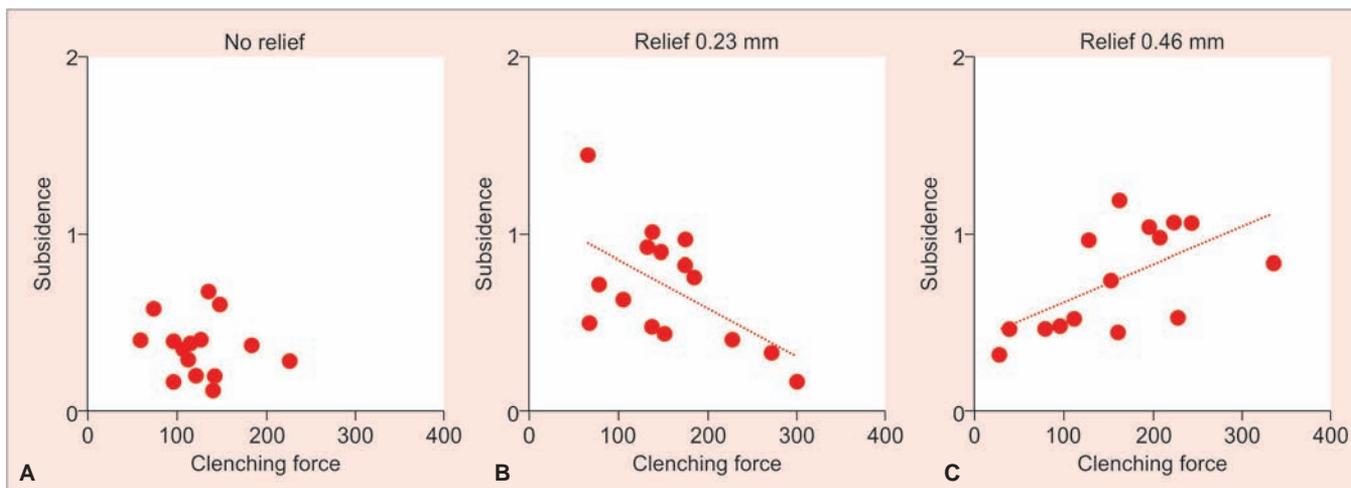
Figure 2 presents typical results of the fit evaluation of the pseudo-palatal plate using the silicone fit testing material. In the gain group, the palatal mucosal surface



Graphs 1A and B: Average values of clenching force and subsidence of palatal mucosa at the onset of pain



Graphs 2A and B: Transition of clenching force and subsidence of palatal mucosa at the onset of pain



Graphs 3A to C: Relationship between clenching force and subsidence of palatal mucosa

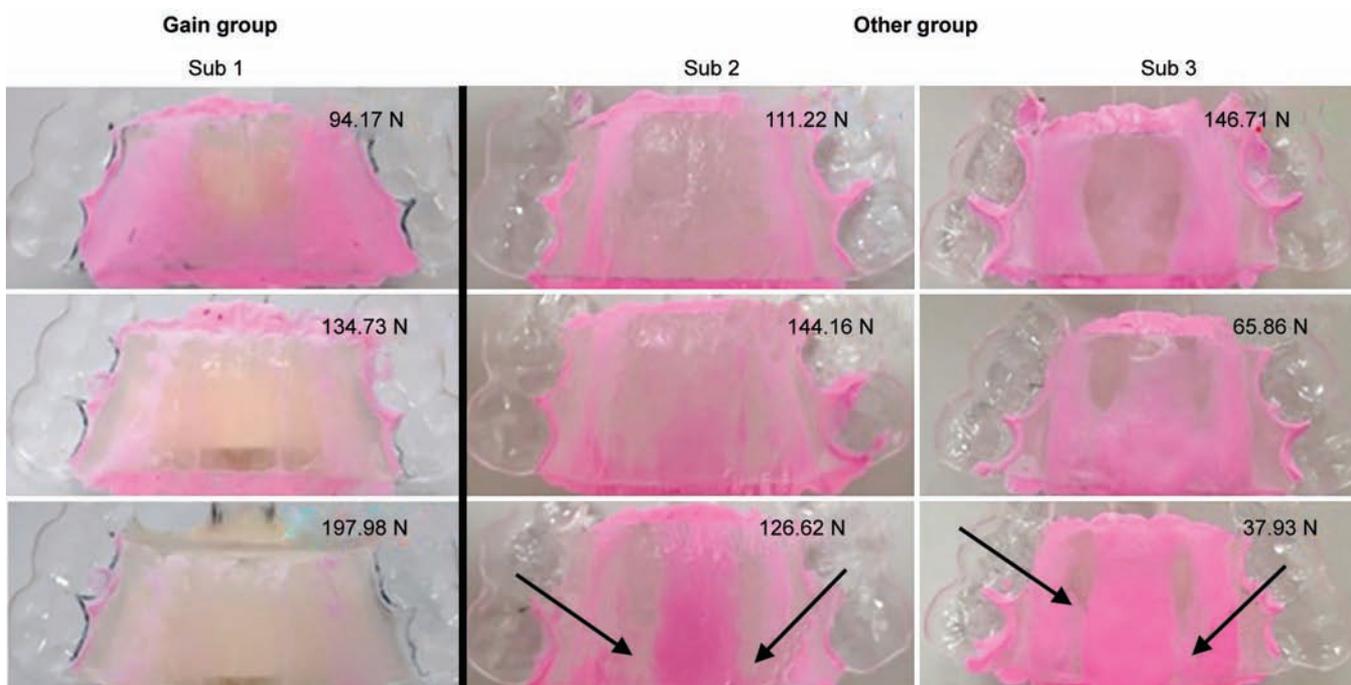


Fig. 2: Evaluation of fit using silicone fit testing material

fit improved with the extent of relief. In contrast, in the other group, application of relief created pressure outside the range of the relief, as indicated by arrows.

DISCUSSION

Reliability of the Simultaneous Measurement Device

Given that pain is a subjective parameter, it was essential to confirm the reliability of the proposed simultaneous measurement device by performing multiple measurements in the same subject. Therefore, the clenching force and subsidence of the palatal mucosa at the onset of pain were measured in 15 subjects. The findings demonstrated differences in both parameters among the subjects; however, intrasubject variations in the first, second, and third measurements were small. The intraexaminer reliability of the measurements was verified by intraclass correlation coefficient analysis; the intraexaminer reproducibility index values for clenching force and subsidence of the palatal mucosa at the onset of pain were both ≥ 0.90 (0.97 and 0.90 respectively), which indicated high reproducibility and intraexaminer reliability of the measurements obtained with this device.

Effect of Relief in the Median Palatal Plate on the Clenching Force and Subsidence of the Palatal Mucosa at Onset of Pain

The median palatal plate is considered to be a relief site for complete maxillary dentures.¹⁷⁻¹⁹ In the present study, there were significant increases in both clenching force and subsidence of the palatal mucosa at the onset of pain with the increase in relief at the median palatal plate, which proves that relief at this part of the palatal plate of maxillary dentures can enhance their bearing ability.

According to Ishinabe,²² the appropriate extent of relief at the median palatal plate, in the absence of the torus palatinus, is approximately 0.25 mm. Additionally, Sakai²³ reported that depending on their classification of the torus palatinus, the appropriate extent of relief for moderate and severe tori palatinus is 0.25 to 0.5 mm and approximately 0.50 mm respectively. In the present study, only subjects with less than moderate torus palatinus were included, in accordance with the classification system reported by Sakai²³ (torus palatinus absent or not apparent upon visual inspection, but the presence of a palpable ridge). Consequently, significant increases in the mean clenching force and subsidence of the palatal mucosa at the onset of pain were observed with increased relief. However, some of the subjects exhibited decreases in the clenching force and subsidence of the palatal mucosa at the onset of pain with the increase in relief. This is thought to be attributable to the influence

of oral characteristics, such as the thickness and elasticity modulus of the palatal mucosa, form and position of the torus palatinus, and palatal form, including the width and depth of the palate. Given the popularity of plate dentures—including metal- and zirconia-frame dentures—which are difficult to adjust after fabrication, it is essential to establish methods for determining the appropriate range and extent of relief at the time of denture design.

Relationship between the Clenching Force and Subsidence of the Palatal Mucosa at Onset of Pain

It was hypothesized that subjects who demonstrate high clenching forces at the onset of pain would also exhibit greater degrees of subsidence of the palatal mucosa. However, no correlation was found between the clenching force and subsidence of the palatal mucosa at the onset of pain in the no-relief category.

In contrast, the two variables exhibited negative and positive correlations respectively, in the 0.23 and 0.46 mm relief categories. The authors believe that these differences in results are related to variations in individual characteristics, such as the thickness and elasticity modulus of the palatal mucosa, form and position of the torus palatinus, and palatal form, including the width and depth of the palate.

Fit Assessment of Pseudo-palatal Plates at Onset of Pain

In the gain group, the palatal mucosal surface fit improved with an increase in relief. In contrast, in the other group, increase in relief caused the pressure to increase outside the range of relief. Individual conditions, such as those described above, are thought to influence the appropriate range and extent of relief.

LIMITATIONS

In this study, the authors evaluated whether complete maxillary dentures require relief at the median palatal plate for increased support. Our results demonstrated that it was possible to improve the denture-bearing ability of the palatal plate by applying relief at the median palatal plate. However, the appropriate range and extent of relief vary based on the individual characteristics, such as the palatal structure, mucosal thickness, and elasticity modulus, which makes it challenging to determine the optimal range and extent of relief for each individual. Future studies should focus on identifying simple and noninvasive methods for optimizing these parameters in each patient. It was difficult to clarify the relationship between the clenching force and subsidence of the

palatal mucosa at the onset of pain in this study—this aspect should be addressed in further studies. Additionally, in the present study, only young dentulous subjects were included. In future, the simultaneous measurement device should be improved to allow measurements in elderly edentulous subjects.

CONCLUSION

In conclusion, this study analyzed the relationship between the clenching force and subsidence of the palatal mucosa at the onset of pain in dentulous subjects using a newly developed maxillary palatal plate-form device. The effect of relief at the palatal region of the denture on its denture-bearing ability was also investigated. Our results indicated that relief at the median palatal plate is required to improve denture-bearing ability. The appropriate range and extent of relief might vary based on the individual oral characteristics, including the thickness and elasticity modulus of the palatal mucosa, form and position of the torus palatinus, and palatal form, including the width and depth of the palate.

CLINICAL SIGNIFICANCE

Using the approach described in this study, it was possible to determine the relief area of maxillary full dentures that was suitable for individual patients, in an objective and convenient manner. In this way, it is possible to improve the accuracy of denture treatments, which has varied greatly in terms of completion accuracy among practitioners to date. This can therefore lead directly to improvement of the quality of life of patients wearing dentures.

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