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Application of zirconia to palatal plate of removable denture
-Evaluation of subjective comfort and taste threshold with zirconia plate-

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Abstract

Objective: Zirconia can withstand the commensurate load as cobalt-chromium alloy. Therefore, use of a zirconia base could allow the thickness of the palatal area to be decreased as metal base dentures. Metal base removable dentures are not appropriate for patients who are allergic to denture base metals. We hypothesized that applying zirconia to the palatal area of removable dentures would result in a more satisfactory outcome for patients. The aim of this study was to compare the subjective comfort and taste thresholds of a zirconia plate with those of a resin plate and a metal plate.

Methods: Palatal plates fabricated using acrylic resin, zirconia, and cobalt-chromium alloy were inserted into healthy individuals. Taste thresholds were investigated using the whole-mouth gustatory test, and subjective comfort was evaluated using the 100-mm visual analog scale to assess ease of pronunciation; ease of swallowing; sensation of temperature; metallic taste; sensation of foreign body; subjective sensory about weight; adhesiveness of chewing gum; and general satisfaction.

Results: For detection and recognition thresholds, no significant differences were noted in sweet, salty, sour, bitter, or umami tastes among subjects wearing no plate, a resin plate, a zirconia plate, or a metal plate. Speech was easier and foreign body sensation was lower with a zirconia plate than with a resin plate, and the comprehensive
subjective comfort of the zirconia plate was evaluated as being superior to the resin plate.

**Conclusion:** Zirconia plate provides a high level of subjective comfort without influencing taste thresholds.

**Keywords:** Dentures, Taste, Palate, Zirconium oxide, Ce-TZP-Al₂O₃, Patient satisfaction,
**Introduction**

Conventional ceramics have been used for fixed prostheses; however, because the flexural strength and fracture toughness of ceramics were low [1], ceramics were frequently used in combination with metals. Recently, high-strength ceramics such as zirconia have been applied clinically with the advance of CAD/CAM techniques. Zirconia has excellent mechanical characteristics and stability, and without water absorbency or dissolution; therefore it is used for fixed prostheses by itself [2].

Metal base removable dentures are selected rather than resin base removable dentures to improve subjective comfort and to increase patient satisfaction. Because metal base removable dentures have greater mechanical strength than resin base removable dentures, the thickness of the palatal area of the metal base can be decreased, leading to a reduction in the sensation of foreign body. A further advantage is that because the thermal conductivity of metals is higher than acrylic resin, denture wearers can readily sense the temperature of food or drinks. It has been reported that thicker palatal plate like resin base removable denture increases taste thresholds [3]. However, it has also been reported that removable dentures do not interfere with taste [4]. Therefore, the influence of dentures on taste thresholds has not been clarified.

Although metal base removable dentures contribute to greater patient satisfaction
than resin base removable dentures, the cobalt-chromium alloy frequently used in metal base removable dentures has been reported to induce metal allergy [5] [6] [7], as also has titanium [8] [9]. For patients allergic to denture-base metals, and patients who are hesitant about the use of metals in the mouth, an alternative to metal base removable dentures is required.

We hypothesized that we can provide more satisfactory dentures for patients by applying zirconia to the palatal area of removable dentures, instead of acrylic resin and metals. The purpose of this study was to compare the subjective comfort and taste thresholds of a zirconia plate with those of a resin plate and a metal plate.

**Methods**

Sixteen healthy dentulous subjects (10 men and 6 women, mean age: 23±2 years), without missing teeth, salient malocclusion, taste disorders or speech disorders were investigated. Informed consent was obtained from all the subjects. The experimental protocol was approved by the Ethics Committee of Tokyo Dental College (#407).

Three types of palatal plate were fabricated: (a) a resin plate (RP), 1.5-mm-thick acrylic resin (Acron No.3; GC Corporation, Tokyo, Japan); (b) a zirconia plate (ZP), 0.5-mm-thick Ce-TZP/Al₂O₃ nanocomposite (P-Nano ZR; Panasonic Healthcare Co.,
Ltd, Tokyo, Japan); and (c) a metal plate (MP), 0.5-mm-thick cobalt-chromium alloy (Wironium; BEGO, Bremen, Germany). RP was fabricated by wax-up on the working cast, investing, and polymerization. ZP was fabricated using CAD/CAM. MP was fabricated by production of a refractory cast and wax-up, investing, and casting. The posterior border was set on the vibrating line (Figure 1).

Subjects were required to refrain from eating, drinking (alcohol or caffeine), taking medication and exercising within 2 hours prior to the commencement of experiments. The experiments were conducted in a quiet room with a temperature of 20±2 °C and a humidity of 50±10 %.

The palatal plates were inserted in random order while the subjects were blindfolded, so that the type of palatal plate could not be recognized. Each palatal plate was carefully inserted into the oral cavity to avoid touching the teeth of the subject. Thirty minutes after the plate was inserted, we confirmed that the subject did not feel nauseous, and initiated the experiments. Subjects wore the palatal plate for the duration of the following evaluations.

*Evaluation of taste thresholds*

The taste test solutions used were sucrose to test sweet taste, salt to test salty taste,
tartaric acid to test sour taste, quinine hydrochloride to test bitter taste, and a mixed solution of glutamic and inosinic acids to test umami taste. Test solutions were produced according to the method proposed by Yamauchi et al., and 13 solutions with differing concentrations were produced [10] (Table 1).

Taste thresholds were investigated using the whole-mouth gustatory test [10] while wearing no plate (NP), and wearing RP, ZP, and MP. A pipette was used to dispense 1 mL of solution into the oral cavity, and the solution was swallowed. The subject was asked to report if they could detect the taste, and then to describe the quality of taste. Distilled water was sprayed into the oral cavity before another taste was tested and the subject confirmed that it was tasteless. The concentration of each taste was gradually increased from the most dilute (C1). The lowest concentration at which the subject declared the presence of the taste was set as the detection threshold, and the lowest concentration at which the subject correctly reported the quality of the taste was set as the recognition threshold. The time required for completion of evaluation of taste thresholds was approximately 10 min per palatal plate.

Evaluation of subjective comfort

The evaluated items were ease of pronunciation, ease of swallowing, sensation of
temperature, metallic taste, sensation of foreign body, subjective sensory about weight, adhesiveness of chewing gum, and general satisfaction. The subject was instructed to perform individual evaluations by marking a 100-mm visual analog scale (VAS), as shown in Figure 2. To assess ease of pronunciation, the subject and experimenter performed daily conversation and then performed the evaluation. To assess ease of swallowing and sensation of temperature, the subject drank soup (Ajinomoto KK consomme, Ajinomoto Co., Inc, Tokyo, Japan) set to a temperature of 70°C. To assess the adhesiveness of chewing gum, the subject chewed gum (Xylitol; Lotte Co., Ltd, Tokyo, Japan) for 5 min. The time required for completion of evaluation of subjective comfort was approximately 10 min per palatal plate.

Statistical analysis

Statistical analysis was performed using the Wilcoxon signed rank test after the Friedman test ($\alpha = 0.05$). Corrections for multiple comparisons were made according to Bonferroni correction. Statistical software (SPSS version 22; International Business Machines Corporation, Chicago, USA) was used for analysis.

Results
Evaluation of taste thresholds

The results of the evaluation of taste thresholds using the whole-mouth gustatory test were shown in Figure 3. For the detection and recognition thresholds, no significant differences were noted among NP, RP, ZP, and MP in sweet, salty, sour, bitter, or umami, respectively.

Evaluation of subjective comfort

The results of the evaluation of subjective comfort using the 100-mm VAS were shown in Figure 4. There were no significant differences among the types of palatal plate in relation to ease of swallowing and subjective sensory about weight. On the ease of pronunciation, there were significant differences between RP and ZP, and RP and MP. On the sensation of temperature, there was a significant difference between RP and MP. On the metallic taste, there was a significant difference between RP and MP. On the sensation of foreign body, there were significant differences between RP and ZP, and RP and MP. On the adhesiveness of chewing gum, there was a significant difference between ZP and MP. On the general satisfaction, there was a significant difference between RP and ZP.
Discussion

Yttria-stabilized zirconia (Y-TZP) can withstand the commensurate load as metals such as cobalt-chromium alloy [11], but may undergo low-temperature degradation in the mouth. However, Ceria-stabilized tetragonal zirconia polycrystals based nanostructured zirconia/alumina composite (Ce-TZP/Al₂O₃ nanocomposite) does not exhibit low-temperature degradation [12] [13], and shows higher flexural strength and fracture toughness than Y-TZP [1] [14]. Therefore, in this study, the zirconia plate was fabricated using the Ce-TZP/Al₂O₃ nanocomposite. Because the mechanical strength of the Ce-TZP/Al₂O₃ nanocomposite is equivalent to or better than that of the cobalt-chromium alloy [1] [11], a zirconia plate fabricated at the same thickness as a metal plate has sufficient strength. Therefore, in the present study, we set the thickness of ZP at 0.5 mm, the same thickness as MP.

To evaluate taste thresholds, the filter paper disk method, electrogustometry, and the whole-mouth gustatory test are available. In the filter paper disk method, filter paper infiltrated with a reagent is placed on the tongue in a sequence of concentrations starting with the lowest concentration, and the taste threshold is measured. Although this method is simple and widely used, only the area on which the filter paper is placed can be examined. Electrogustometry is a method in which the tongue is electrified, and
the electrical stimulation is increased until the subject experiences a taste similar to a metallic taste or an acidic taste. This method can only examine the area in which the electricity is distributed, and examination regarding the quality of taste cannot be performed [15]. The whole-mouth gustatory test allows the subject to taste the test solutions in the whole mouth. Furthermore, it can discriminate according to the quality of taste. Because the purpose of the present study was to evaluate the influence of the insertion of a palatal plate on taste thresholds, we decided that the whole-mouth gustatory test was the most appropriate method.

Previous studies reported that the 100-mm VAS is a reliable and appropriate method to evaluate the subjective comfort of dentures [16] [17]. Therefore, in the present study, this method was used to investigate subjective evaluation during the insertion of each palatal plate.

Almost denture wearers were elderly patients. However, elderly persons were difficult to standardize definitions of condition, because most of them have missing teeth or continuously take some medicines. Therefore we chose young subjects for this experiment.

The insertion of each palatal plate did not affect the taste thresholds, nevertheless we supposed that wearing palatal plate would increase taste thresholds because of feeling
sensation of foreign body or metallic taste etc. Taste buds are present in the tongue and soft palate, and taste is sensed in these areas [18]. The palatal plate only covered the hard palate, without covering the tongue and soft palate. Therefore, the insertion of the palatal plate did not increase the detection and recognition thresholds.

Sensation of foreign body was lower and ease of pronunciation was greater in ZP and MP than in RP. It has been reported that 0.3mm and 0.8mm palatal plates don't make negative effects compared to 1.5mm palatal plate and dentulous individuals can adapt to palatal plates less than 0.8 mm in thickness [19]. Because the thickness of ZP and MP was 0.5 mm, foreign-body sensation was low and speech was easy.

There were no differences in ease of swallowing among the three types of palatal plate. It was reported that the insertion of a palatal plate did not change tongue pressure [20], and when the thickness of the palatal plate was not exceeding 1.5 mm, it did not influence tongue movement during swallowing [21] [22]. These findings suggest that the insertion of the palatal plates did not influence the ease of swallowing, because the thickness of the palatal plate was not exceeding 1.5 mm.

Although temperature was sensed more with MP than with RP because the thermal conductivity of cobalt-chromium alloy is higher than that of acrylic resin, there was no significant difference between MP and ZP. However, although the thermal conductivity
of zirconia is lower than that of metals, because the thickness of ZP was equal to that of MP, at only 0.5 mm, there was no difference in the sensation of temperature between ZP and MP.

When cobalt-chromium base dentures are inserted into the oral cavity, a small amount of metal elutes into the mouth [7], which causes not only metal allergy, but also a metallic taste [23]. In the present experiment, a metallic taste was experienced more with MP than with RP. Although the presence of this metallic taste did not influence the taste threshold, it might influence the evaluation of subjective comfort.

The weight of the palatal plates used in our experiment was 3.67±0.40 g in RP, 6.94±0.92 g in ZP, and 8.33±0.98 g in MP, showing significant differences among them. However, no significant difference in the experience of weight during insertion was noted among RP, ZP, and MP. It has been reported that when complete dentures fit adequately, patients cannot recognize an increase of 60 g in the weight of dentures [24] [25]. Therefore, because differences in the weight of the palatal plates were small in the present experiment, the subjective sensory about weight was not influenced.

Evaluation of the adhesiveness of chewing gum showed that chewing gum does not readily adhere to ZP in comparison with MP. Considering a previous report on an objective test of the adhesiveness of chewing gum to dental restorative materials [26],
we previously performed an objective test in which chewing gum was shown to adhere less to zirconia than to acrylic resin and cobalt-chromium alloy [27]. Because chewing gum did not readily adhere to zirconia in both the subjective and the objective evaluations, it is considered that zirconia is a material to which food does not readily adhere. Furthermore, zirconia is a material to which bacteria do not readily adhere [28] [29] [30]. These findings suggest that zirconia base removable denture would discourage adhesion of bacteria and food, facilitating the maintenance of denture hygiene.

ZP was reported to be more comfortable than RP. We suggest that, because speech was easier and foreign-body sensation was lower in ZP than in RP, the comprehensive comfort of ZP was evaluated as being greater. Although in MP speech was easier, foreign-body sensation was lower, and sensation of temperature was higher than in RP, the comprehensive comfort of MP was rarely different from that of RP because of the presence of a metallic taste compared with RP, and greater adhesiveness of chewing gum compared with ZP. Previous studies have reported that the subjective comfort of removable dentures markedly influences the level of patient satisfaction [31] [32]. Therefore, we consider that the application of zirconia to the palatal area of removable dentures will produce dentures with greater patient satisfaction.
Conclusions

Zirconia plate provides a high level of subjective comfort without influencing taste thresholds.

Acknowledgments

The author is grateful to the subjects for their kind cooperation in this study and also thanks Panasonic Healthcare Co., Ltd, for kind support in the design of the zirconia plates. Finally, the author thanks Professor Kaoru Sakurai, Associate Professor Takayuki Ueda, Senior Assistant Professor Akinori Tasaka, and Assistant Professor Tomofumi Takano for their mentorship.

Disclosure

The author declares that there is no conflict of interest.
[References]


Table 1. Concentrations of solution used for the whole-mouth gustatory test

Concentrations were chosen so that C6 would approximate the median value of the recognition threshold for healthy individuals. C0 corresponds to distilled water.

Figure 1. Types of palatal plates: (a) resin plate, (b) zirconia plate, (c) metal plate.

Figure 2. Questionnaire using a 100-mm visual analog scale.

The worst condition was set at the left, and the best condition was set at right. The subject was instructed to perform individual evaluations by marking. The distance between the left end and the mark was measured, and the distance measured was set as the evaluation score.

Figure 3. Detection threshold (A) and recognition threshold (B) of experimental groups:

NP, no plate; RP, resin plate; ZP, zirconia plate; MP, metal plate. For the detection and recognition thresholds, there were no significant differences among NP, RP, ZP, and MP in sweet, salty, sour, bitter, or umami, respectively.

NS : no significant, ⋆ : extreme value, ◦ : outlier,
The horizontal line that forms the top of the box is the 75th percentile. The horizontal line that forms the bottom is the 25th percentile. The horizontal line that intersects the box is the median. Horizontal lines above and below the box, called whiskers, represent maximum and minimum values.

Figure 4. Result of Visual analog scale of subjective comfort with each palatal plate: RP, resin plate; ZP, zirconia plate; MP, metal plate. *p < 0.017

The worst condition was set at 0, and the best condition was set at 100.
<table>
<thead>
<tr>
<th>Concentration</th>
<th>Sweet (sucrose)</th>
<th>Salty (NaCl)</th>
<th>Sour (tartaric acid)</th>
<th>Bitter (quinine HCl)</th>
<th>Umami (glutamic acid + inosinic acid)</th>
</tr>
</thead>
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<tr>
<td>C0</td>
<td>0.00977</td>
<td>0.00488</td>
<td>0.000391</td>
<td>0.00000244</td>
<td>0.000938 (0.000469 + 0.000469)</td>
</tr>
<tr>
<td>C1</td>
<td>0.0195</td>
<td>0.00977</td>
<td>0.000781</td>
<td>0.0000488</td>
<td>0.00188 (0.000938 + 0.000938)</td>
</tr>
<tr>
<td>C2</td>
<td>0.0391</td>
<td>0.0195</td>
<td>0.00156</td>
<td>0.000977</td>
<td>0.00375 (0.00188 + 0.00188)</td>
</tr>
<tr>
<td>C3</td>
<td>0.0781</td>
<td>0.0391</td>
<td>0.00313</td>
<td>0.000195</td>
<td>0.0075 (0.00375 + 0.00375)</td>
</tr>
<tr>
<td>C4</td>
<td>0.156</td>
<td>0.0781</td>
<td>0.00625</td>
<td>0.00039</td>
<td>0.015 (0.0075 + 0.0075)</td>
</tr>
<tr>
<td>C5</td>
<td>0.313</td>
<td>0.156</td>
<td>0.0125</td>
<td>0.000781</td>
<td>0.03 (0.015 + 0.015)</td>
</tr>
<tr>
<td>C6</td>
<td>0.62</td>
<td>0.313</td>
<td>0.025</td>
<td>0.00156</td>
<td>0.06 (0.03 + 0.03)</td>
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<tr>
<td>C7</td>
<td>1.25</td>
<td>0.625</td>
<td>0.05</td>
<td>0.00313</td>
<td>0.12 (0.06 + 0.06)</td>
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<td>C8</td>
<td>2.5</td>
<td>1.25</td>
<td>0.1</td>
<td>0.00625</td>
<td>0.24 (0.12 + 0.12)</td>
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<tr>
<td>C9</td>
<td>5.</td>
<td>2.5</td>
<td>0.2</td>
<td>0.0125</td>
<td>0.48 (0.24 + 0.24)</td>
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<tr>
<td>C10</td>
<td>10.</td>
<td>5.</td>
<td>0.4</td>
<td>0.025</td>
<td>0.96 (0.48 + 0.48)</td>
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<tr>
<td>C11</td>
<td>20.</td>
<td>10.</td>
<td>0.8</td>
<td>0.05</td>
<td>1.92 (0.96 + 0.96)</td>
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<tr>
<td>C12</td>
<td>40.</td>
<td>20.</td>
<td>1.6</td>
<td>0.1</td>
<td>3.84 (1.92 + 1.92)</td>
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**Table 1**
Figure 1
<table>
<thead>
<tr>
<th>Ease of pronunciation</th>
<th>Very difficult</th>
<th>Same as before</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of swallowing</td>
<td>Very difficult</td>
<td>Same as before</td>
</tr>
<tr>
<td>Sensation of temperature</td>
<td>Very bad</td>
<td>Same as before</td>
</tr>
<tr>
<td>Metallic taste</td>
<td>Very strong</td>
<td>Not at all</td>
</tr>
<tr>
<td>Sensation of foreign body</td>
<td>Very strong</td>
<td>Not at all</td>
</tr>
<tr>
<td>Subjective sensory about weight</td>
<td>Very heavy</td>
<td>Not at all</td>
</tr>
<tr>
<td>Adhesiveness of chewing gum</td>
<td>Very much</td>
<td>Not at all</td>
</tr>
<tr>
<td>General satisfaction</td>
<td>Very low</td>
<td>Very high</td>
</tr>
</tbody>
</table>

**Figure 2**
Figure 3
Figure 4