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Evaluation of participants’ perception and taste thresholds with a zirconia palatal plate

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ABSTRACT

Purpose: Zirconia and cobalt-chromium can withstand a similar degree of loading. Therefore, using a zirconia base for removable dentures could allow the thickness of the palatal area to be reduced similarly to metal base dentures. We hypothesized that zirconia palatal plate for removable dentures provides a high level of participants’ perception without influencing taste thresholds. The purpose of this study was to evaluate the participants’ perception and taste thresholds of zirconia palatal 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 participants’ perception was evaluated using the 100-mm visual analog scale to assess the 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 the taste thresholds, no significant differences were
noted in sweet, salty, sour, bitter, or umami tastes among participants wearing no plate, or the resin, zirconia, and metal plates. Speech was easier and foreign body sensation was lower with the zirconia plate than with the resin plate. Evaluation of the adhesiveness of chewing gum showed that chewing gum does not readily adhere to the zirconia plate in comparison with the metal plate. The comprehensive participants’ perception of the zirconia plate was evaluated as being superior to the resin plate.

**Conclusions:** A zirconia palatal plate provides a high level of participants’ perception without influencing taste thresholds.
1. 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 metal copings. Recently, high-strength ceramics such as zirconia have been applied clinically with the advance of computer-aided design/computer-aided manufacturing (CAD/CAM) techniques. Zirconia has excellent mechanical characteristics and stability, along with a lack of water absorbency or dissolution, and can therefore be used for fixed prostheses without the need for metal copings [2].

Metal base removable dentures are usually selected to improve participants’ perception and to increase patient satisfaction in place of resin base removable dentures. Because metal base removable dentures have greater mechanical strength than resin base removable dentures, the thickness of the palatal area can be decreased, leading to a reduction in the sensation of foreign body for the patient. Furthermore, because the thermal conductivity of metals
is greater than acrylic resin, denture wearers can readily sense the temperature of food or drinks. It has been reported that a thicker palatal plate, such as that resulting from a resin base, 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 yet 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 allergies in some patients [5,6], and a similar problem has also been reported with titanium [7,8]. 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 zirconia palatal plate for removable dentures provides a high level of participants’ perception without influencing taste thresholds. The purpose of this study was to evaluate the wearing satisfaction of zirconia palatal plate for removable dentures
by comparing the participants’ perception and taste thresholds of a zirconia palatal plate with resin or metal palatal plates.

2. Materials and methods

Sixteen healthy, fully dentate participants (10 males and six females; mean age: 23±2 years), without obvious malocclusion, taste disorders, or speech disorders, were enrolled in this study. Informed consent was obtained from all participants. The experimental protocol was approved by the Ethics Committee of Tokyo Dental College (#407).

Three types of palatal plate were fabricated: (a) a 1.5-mm-thick acrylic resin (Acron MC No. 18, GC Corporation, Tokyo, Japan) plate (RP); (b) a 0.5-mm-thick Ce-TZP/Al₂O₃ nanocomposite (P-Nano ZR, Panasonic Healthcare Co., Ltd., Tokyo, Japan) plate (ZP); and (c) a 0.5-mm-thick cobalt-chromium alloy (Wironium, BEGO, Bremen, Germany) plate (MP). Final impression was taken by silicone rubber impression material (Fusion II, GC Co., Ltd., Tokyo, Japan) with individual tray. Three types of palatal plate were fabricated from
one working cast of each participant. The RP was fabricated by wax-up on the working cast, investing, and microwave-polymerization of the acrylic resin. The ZP was fabricated using CAD/CAM (C-Pro System, Panasonic Healthcare Co., Ltd., Tokyo, Japan). The 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).

The participants were instructed to refrain from eating, drinking (alcohol or caffeine), taking medication, and exercising within 2 hours prior to the commencement of the experiments.

An assistant, blinded to the aim of this study and type of palatal plates, used a random number table to select the order of palatal plate. Participants were asked to wear an eye mask while the experimenter inserted the palatal plate in participants’ mouth, so that the type of palatal plate inserted could not be recognized. Each palatal plate was carefully inserted into the oral cavity to avoid touching the teeth of the participant. All examinations were carried out after the good stabilization of the palatal plate in participant’s
mouth was confirmed. Thirty minutes after the plate was inserted, we confirmed that the participant did not feel nauseous, and we then initiated the experiments. The participants wore the palatal plate for the duration of the following evaluations and all palatal plates were maintained in their mouth with good stability.

2.1. **Evaluation of taste thresholds**

The taste test solutions used were as follows: sucrose, sodium chloride, tartaric acid, quinine hydrochloride, and a mixed solution of glutamic and inosinic acids for sweet, salty, sour, bitter, and umami tastes, respectively. The test solutions were produced according to the method proposed by Yamauchi et al., and 13 solutions with differing concentrations were produced (Table 1) [9].

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

2.2. *Evaluation of participants’ perception*

The evaluated items were as follows: 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. Each participant was instructed to perform individual evaluations by marking a 100-mm visual analog scale (VAS), as shown in Figure 2. To assess the ease of pronunciation, the participant and experimenter engaged in daily
conversation for 3 min and then the evaluation was performed. To assess the ease of swallowing and sensation of temperature, the participant 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 participant chewed gum (Xylitol, Lotte Co., Ltd., Tokyo, Japan) for 5 min. The time required for completion of evaluation of participants’ perception was approximately 10 min per palatal plate.

2.3. Statistical analysis

Statistical analysis was performed using the Mann-Whitney U test after the Kruskal-Wallis test ($\alpha=0.05$). Corrections for multiple comparisons were made according to the Bonferroni correction (evaluation of taste thresholds: $\alpha=0.0125$, evaluation of participants’ perception: $\alpha=0.017$). Statistical software (SPSS version 22, International Business Machines Corporation, Chicago, IL, USA) was used for the analysis.
3. Results

3.1. Evaluation of taste thresholds

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

3.2. Evaluation of participants’ perception

The results of the evaluation of participants’ perception using the 100-mm VAS are 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. For the ease of pronunciation, there were significant differences between the RP and ZP, and the RP and MP. ZP and MP showed high perspectives compare to RP. For the sensation of temperature, there was a significant difference between the RP and MP. MP showed high perspectives compare to RP. There was a significant difference
between the RP and MP in terms of metallic taste. RP showed high perspectives compare to MP. For the sensation of foreign body, there were significant differences between the RP and ZP, and the RP and MP. For the adhesiveness of chewing gum, there was a significant difference between the ZP and MP. ZP showed high perspectives compare to MP. For general satisfaction, there was a significant difference between the RP and ZP. ZP showed high perspectives compare to RP.

4. Discussion

Yttria-stabilized zirconia (Y-TZP) may undergo low-temperature degradation in the mouth. However, a Ce-TZP/Al₂O₃ nanocomposite does not exhibit low-temperature degradation [10], and shows higher flexural strength and fracture toughness than Y-TZP [1,11]. Therefore, in this study, the zirconia plate was fabricated using a Ce-TZP/Al₂O₃ nanocomposite. Because the mechanical strength of the Ce-TZP/Al₂O₃ nanocomposite is equivalent to or better than that of cobalt-chromium [1], 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 the ZP at 0.5 mm, which was the same thickness as the 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 metallic or acidic taste. This method can only examine the area in which the electricity is distributed, and evaluation of taste quality cannot be performed. The whole-mouth gustatory test allows the participant to taste the test solutions in the whole mouth. Furthermore, it can discriminate according to the quality of the 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 participants’ perception of dentures [12]. Therefore, in the present study, this method was used to investigate subjective evaluation during the insertion of each palatal plate. Young participants were included for this experiment although the majority of denture wearers are elder patients. It is because elder people are difficult to standardize for the experiment about, for example, the number of remaining teeth or medication intake. Elder people might have decreased senses of oral mucosa compared with young people. On this point, the difference of participants’ perception among RP, ZP and MP might be smaller than one of young participants shown in this study. The evaluation with elder people is necessary in future studies to clarify this limitation of this study.

The insertion of each palatal plate did not affect the taste thresholds; nevertheless, we presumed that wearing a palatal plate may increase the taste threshold because of factors such as a
sensation of foreign body or metallic taste. Taste buds are present on the tongue and soft palate, and therefore taste is sensed in these areas [13]. The palatal plate only covered the hard palate, and did not cover the tongue or soft palate. Therefore, the insertion of the palatal plate did not increase the detection and recognition thresholds.

The sensation of a foreign body was lower and the ease of pronunciation was greater for the ZP and MP than for the RP. It has been reported that 1.0-mm-thick palatal plate made speech awkward and indistinct [14]. Because the thickness of the ZP and MP used in this study was 0.5 mm, the degree of foreign body sensation was low and the ease of pronunciation was high.

There were no differences in the ease of swallowing among the three types of palatal plate. It has been reported that the insertion of a palatal plate does not change tongue pressure [15], and that when the thickness of a palatal plate does not exceed 1.5 mm, tongue movement is not influenced during swallowing [16]. These findings suggest that the insertion of the palatal plates did not influence the
ease of swallowing because the thickness of the palatal plate did not exceed 1.5 mm.

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

When cobalt-chromium-based dentures are inserted into the oral cavity, a small amount of metal leaches into the mouth [6], which may cause not only a metal allergy or hypersensitivity, but also the sensation of a metallic taste [17]. In the present study, a metallic taste was experienced more with the MP than with the RP. Although the presence of this metallic taste did not influence the taste threshold, it may influence the evaluation of overall participants’ perception.

The weight of the palatal plates used in our experiment was
3.67±0.40 g for the RP, 6.94±0.92 g for the ZP, and 8.33±0.98 g for the MP, showing significant differences among them. However, no significant difference in the subjective experience of weight during insertion was noted among the 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 [18]. 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 the ZP in comparison with the MP. Based on a previous report objectively testing the adhesiveness of chewing gum to dental restorative materials [19], we previously performed an objective test in which chewing gum was shown to adhere less to zirconia than to acrylic resin and cobalt-chromium [20]. Because chewing gum did not readily adhere to zirconia in both the subjective and 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 [21]. These findings suggest that a zirconia base removable denture would discourage the adhesion of bacteria and food, facilitating the maintenance of denture hygiene.

The ZP was reported to be more comfortable than the RP. We suggest that, because speech was easier and the foreign body sensation was lower with the ZP than the RP, the comprehensive comfort of the ZP was evaluated as being greater. Although with the MP, speech was easier, the foreign body sensation was lower, and the sensation of temperature was higher than with the RP, the comprehensive comfort of the MP was rarely different from that of the RP. This could be because of the presence of a metallic taste when compared with the RP, and a greater adhesiveness of chewing gum when compared with the ZP. Previous studies have reported that the participants’ perception of removable dentures markedly influences the level of patient satisfaction [22]. Therefore, we consider that the application of zirconia to the palatal area of removable dentures will produce dentures with greater patient satisfaction.
5. Conclusions

Within the limitations of this study, the insertion of palatal plate does not affect the taste thresholds and participants’ perception of the Ce-TZP/Al₂O₃ nanocomposite plate is equivalent or better than of the cobalt-chromium alloy plate. Therefore, a zirconia palatal plate for removable dentures provides a high level of participants’ perception without influencing taste thresholds.

Disclosure/Acknowledgments

The protocol for this study was approved by the Ethics Committee of Tokyo Dental College (#407). The zirconia plates were provided by Panasonic Healthcare Co., Ltd., Japan. The sponsor had no control over the interpretation, writing, or publication of this work. All authors declare that there is no conflict of interest related to this study.
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Figure and Table Legends

Table 1. Concentrations of solutions 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 the right. The participant was instructed to mark their subjective evaluation on each scale. 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 the 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 the NP, RP, ZP, and MP groups for sweet, salty, sour, bitter, or umami tastes.

Figure 4. Results from the visual analog scale of participants’ perception 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.

| Concentration | Sweet (sucrose) | Salty (sodium chloride) | Sour (tartaric acid) | Bitter (quinine hydrochloride) | Umami (glutamic acid + inosinic acid) |
|---------------|----------------|------------------------|---------------------|-------------------------------|--------------------------------------|
| C0            | 0              | 0                      | 0                   | 0                             | 0                                    |
| C1            | 0.00977        | 0.00488                | 0.000391            | 0.0000244                     | 0.000938 (0.0000469 + 0.0000469)     |
| C2            | 0.0195         | 0.00977                | 0.000781            | 0.0000486                     | 0.00188 (0.0000938 + 0.0000938)      |
| C3            | 0.0391         | 0.0195                 | 0.00156             | 0.000977                      | 0.00375 (0.00188 + 0.00188)          |
| C4            | 0.0781         | 0.0391                 | 0.00313             | 0.00195                       | 0.0075 (0.00375 + 0.00375)           |
| C5            | 0.156          | 0.0781                 | 0.00625             | 0.00391                       | 0.015 (0.0075 + 0.0075)              |
| C6            | 0.313          | 0.156                  | 0.0125              | 0.000781                      | 0.03 (0.015 + 0.015)                 |
| C7            | 0.62           | 0.313                  | 0.025               | 0.00156                       | 0.06 (0.03 + 0.03)                   |
| C8            | 1.25           | 0.625                  | 0.05                | 0.00313                       | 0.12 (0.06 + 0.06)                   |
| C9            | 2.5            | 1.25                   | 0.1                 | 0.00625                       | 0.24 (0.12 + 0.12)                   |
| C10           | 5              | 2.5                    | 0.2                 | 0.0125                        | 0.48 (0.24 + 0.24)                   |
| C11           | 10             | 5.0                    | 0.4                 | 0.025                         | 0.96 (0.48 + 0.48)                   |
| C12           | 20             | 10.0                   | 0.8                 | 0.05                          | 1.92 (0.96 + 0.96)                   |
| C13           | 40             | 20.0                   | 1.6                 | 0.1                           | 3.84 (1.92 + 1.92)                   |
| [Ease of pronunciation] | What change in the ease of pronunciation did you experience with the palatal plate? |
|------------------------|----------------------------------------------------------------------------------|
| Very difficult         | Same as before                                                                   |

| [Ease of swallowing]  | What change in the ease of swallowing did you experience with the palatal plate? |
|-----------------------|----------------------------------------------------------------------------------|
| Very difficult        | Same as before                                                                   |

| [Sensation of temperature] | What change in the sensation of temperature did you experience with the palatal plate? |
|---------------------------|---------------------------------------------------------------------------------------|
| Very bad                  | Same as before                                                                       |

| [Metallic taste]          | What sensation of a metallic taste did you experience with the palatal plate?        |
|---------------------------|---------------------------------------------------------------------------------------|
| Very strong               | Not at all                                                                            |

| [Sensation of foreign body] | What sensation of foreign body did you experience with the palatal plate? |
|-----------------------------|-------------------------------------------------------------------------------|
| Very strong                 | Not at all                                                                      |

| [Subjective sensory about weight] | How was the weight of wearing palatal plate? |
|-----------------------------------|---------------------------------------------|
| Very heavy                        | Not at all                                  |

| [Adhesiveness of chewing gum]    | What level of adhesiveness of chewing gum did you experience with the palatal plate? |
|----------------------------------|---------------------------------------------------------------------------------------|
| Very much                        | Not at all                                                                            |

| [General satisfaction]           | What is your general level of satisfaction with the palatal plate?                    |
|----------------------------------|---------------------------------------------------------------------------------------|
| Very low                         | Very high                                                                              |
