Vertical Displacement in Unilateral Extension Base Flexible Removable Dentures

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Abstract

The need for flexible thermoplastic denture base materials has increased due to patient demand for better esthetic outcomes. Designs aimed at improving esthetic outcomes can cause difficulties for prosthodontists, however, from the viewpoint of function and maintenance. Therefore, the purpose of this study was to investigate vertical displacement in unilateral extension base denture models, comparing that obtained by flexible removable dentures with that by conventional metal clasp dentures. Models of unilateral extension base flexible removable dentures for mandibular defects were prepared. Periodontal ligament and jaw mucosa were simulated using a silicone impression material. Four types of flexible removable denture, with or without a metal rest, and two metal clasp dentures made of acrylic resin as a conventional design were used as dental prostheses. The amount of vertical displacement in the defect areas was measured under a load of 50 N at the first and second molars. Among the 6 types of dentures investigated, the amount of vertical displacement was greater with flexible removable dentures than with metal clasp dentures. This vertical displacement tended to decrease significantly, however, with the use of a metal rest with the flexible removable dentures. Esteshot with a metal rest, in particular, showed the smallest amount of displacement in the flexible removable dentures (first molar, 0.265 ± 0.007 mm; second molar, 0.423 ± 0.008 mm). These results indicate the importance of the application of rests in unilateral extension base flexible removable dentures. It may be useful to employ a metal rest in conjunction with a flexible removable denture to reduce load on the underlying mucosa, as is done with conventional partial dentures.

Key words: Flexible removable denture — Vertical variation — Unilateral extension base

*These authors contributed equally to this work.
Introduction

The materials used to fabricate flexible removable dentures (FRDs) are softer than the acrylic resin used in the conventional type, and this softness promotes the healing of the oral mucosa. In the first few decades following their introduction, no metal rest was used with an FRD, which found favor with patients from an esthetic viewpoint, an issue that has received a lot of attention in the literature. Another issue which requires consideration, however, is mechanical stress. Many studies, including both basic research and case reports, have investigated how conventional metal clasp dentures (MCDs) exert mechanical stress on the oral mucosa or periodontal ligament of the abutment teeth; little has been done, however, on this issue with regard to FRDs.

The purpose of this study was to investigate differences in vertical displacement in unilateral extension base denture models, comparing that obtained with FRDs and MCDs.

Materials and Methods

1. Unilateral extension base models

The models comprised a unilateral extension base made of 2 kinds of resin (E50-520, Nissin, Kyoto, Japan). The thickness of the periodontal ligament estimated to be 1 mm at the root of the first and second premolars. The thickness of the mandibular oral mucosa was estimated to be 2 mm. An additive-type silicone impression material (EXAMIX FINE, GC Corporation, Tokyo, Japan) was used to simulate junctional oral mucosa and periodontal ligament (Fig. 1). These material settings were selected based on a previously reported protocol.

2. Flexible removable dentures

The FRD models were prepared with the following 4 types of resin: (A) Valplast (VAL), a component of polyamide resin (Univar, Tokyo, Japan) used to secure the neck of the premolar teeth; (B) a combination of Val and a metal rest (Rest) on the distal area of the left mandibular second premolar; (C) Esteshot (ES), a component made of polyester resin (i-CAST, Kyoto, Japan) used to secure the neck of the premolar teeth; and (D) a combination of ES and Rest on the distal area of the left mandibular second premolar. The two following patterns of classical clasps were also prepared as conventional partial MCDs: (E) an Akers Clasp (AC) in the areas of the first premolar mesial and second premolar distal corners; and (F) a Double Akers Clasp (DAC) in the first and second premolars. Figure 2 shows all the settings.

3. Measurement of vertical displacement

Measurements were performed using a precision force measurement machine (SV-950 N, Marubishi Kagaku Seisakusho, Tokyo, Japan) according to the method previously established by Sugiyama. The occlusal surface of the prosthesis was set on a plane parallel to the surface of the base of the model. The machine vertically loaded 50 N each onto the first and second molars. The amount of vertical displacement at the loading point when the load was applied to 2 areas corresponding to each defect in the prosthesis was determined. Each prosthesis was digitally converted (PCD-320A, Kyowa Electronics, Tokyo, Japan) and the output recorded on a personal computer (Fig. 3A–B). These material settings were applied as previously described.

4. Statistical analysis

Each measurement was made 5 times at each of the 2 loading sites in each prosthesis. An ANOVA and Bonferroni correction were performed for multiple comparisons.

Results

Vertical displacement under mechanical loading was analyzed in the FRD groups (with or without a rest). Significant differences were observed among the following subgroups among the FRDs: Val-Val (Rest), Val-ES, Val-ES (Rest), Val (Rest)-ES (Rest), and
ES-ES (Rest) in the first molar (Fig. 4A). No significant difference was observed in Val (Rest)-ES, however (p = 0.1373). Significant differences were observed in all FRD subgroups in the second molar (Fig. 4B). The results showed that the amount of vertical
displacement with ES was significantly smaller than that with Val for loading at both the first and second molars. In addition, ES (Rest) showed the smallest amount of displacement among the FRDs (first molar, 0.265 ± 0.007 mm; second molar, 0.423 ± 0.008 mm) (Fig. 4A–B, Table 1). A two-way ANOVA with two factors, “resin material” and “near zone metal rest”, was used, resulting in two alternating factors. An effect was recognized at p = 0.0123 with loading on the first molar and at p<0.01 with that on the second molar, so multiple comparisons were performed for all groups.

To evaluate differences in the amount of vertical displacement between the FRDs and MCDs, that in the MCD groups was determined as well. The MCDs tended to show a smaller amount of vertical displacement than any of the 1 FRDs at both the first and second molars (Table 1). The displacement shown by DAC, however, was comparable with that shown by ES (rest) in the first molar (Table 1).

A comparison of the FRDs and MCDs revealed that ES (Rest)-DAC showed no significant difference in the amount of displacement in the first molar (Table 2A). On the other hand, all comparisons between FRDs and MCDs revealed significant differences in the second molar (Table 2B).

Discussion

In the 1950s, various types of stress-absorbing design were employed aimed at relieving pressure on the abutment teeth in favor of placing it on the periodontal ligament. Since the 1960s, some groups have studied the possibility of employing a rigid design that would not cause any problems, even if the abutment tooth and denture base were tightly connected. The findings of these earlier studies established the principles underlying current partial denture design.

A unilateral extension base is useful in exploring the influence of loading position and the support system. In cases where there...
are two or more teeth defects on the unilateral extension base, it is important to set an indirect maintenance device on the contralateral tooth based on mechanical rigid maintenance\(^{1,9}\). However, in clinical practice at this institution, a unilateral extension base is often employed as patients feel uncomfortable with the need to maintain a single denture. In addition, these days, patients prefer to select metal-free materials as they offer better esthetic outcomes, and it is in answer to this demand that FRDs have become so widely applied. Much research has been done on the esthetics of such devices; little has been done on the mechanical stress they cause, however\(^{14,19}\). Therefore, the purpose of the present study was to investigate such stress under mechanical loading with unilateral FRDs using dental prosthesis models.

The AC and DAC were used as conventional dentures. The results revealed that AC showed the smallest vertical displacement at the loading site (0.178 ± 0.008 mm in the first molar and 0.228 ± 0.01 mm in the second molar). The AC is considered a standard clasp model from the viewpoint of mechanical properties in partial dentures\(^{13}\). The rest is an essential part of the framework in clasp design for extension-base removable partial dentures\(^{8}\). The present findings also support using an AC in partial dentures.

The MCDs had a tendency to show a smaller amount of vertical displacement than any of the FRDs at both the first and second molars. This suggests that FRDs lead to greater displacement than do MCDs. Usually, thermoplastic resin is used for FRDs. Thermoplastic resin is classified into the following 5 types from the viewpoint of material properties: polyamide, polyester, polycarbonate, acrylic, and polypropylene. Valplast\(^{®}\), which is classified as a polyamide resin, is the oldest material in the history of FRDs, and has been widely used in clinical practice\(^{3}\). It has the

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<th>Table 2</th>
<th>(A) Comparison of vertical variation at first molar. (B) Comparison at second molar.</th>
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<td>(A)</td>
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<td>First Molar</td>
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*: p < 0.01

| (B)    |                                                                                  |
|        | Second Molar                                                                    |
|        | Val | Val (Rest) | ES | ES (Rest) | AC | DAC |
| Val    |     | *         |    |          |    |     |
| Val (Rest) | * |           |    |          |    |     |
| ES     | *   |           |    |          |    |     |
| ES (Rest) | * | *         |    |          |    |     |
| AC     | *   | *         |    | *        |    |     |
| DAC    | *   | *         |    | *        |    | *   |

*: p < 0.01
highest elasticity among all thermoplastic resins, and its flexural strength is also twice that of a polymethylmethacrylate resin.\textsuperscript{16} 

Estheshot\textsuperscript{®}, which was used in this study, is classified as a polyester resin. The elasticity and bending strength of this type of resin are inferior to those of polyamide resins. However, polyester resin has high resistance against mechanical stress and has an excellent accuracy.\textsuperscript{18} The use of polyester resin has increased in clinical practice in recent years. The results of the present study revealed that Val resulted in the largest amount of vertical displacement, probably due to its elasticity. In addition, displacement is also caused by large polymerization shrinkage.\textsuperscript{16} 

In the present study, Val (Rest) and ES (Rest), which applies rests to the distal area in the abutment teeth, tended to show a significant decrease in vertical displacement, suggesting that a rest should be provided when using an FRD. 

Estheshot (Rest) showed vertical displacement comparable to that with DAC in the first molar, whereas it showed significantly larger vertical displacement than did DAC in the second molar. In the ES and ES (Rest) groups, the results showed a significant difference in the second molar. These results indicate that the metal rest controlled vertical variation in the distal area. Taken together, this indicates that additional measures to regulate vertical displacement against mechanical load are needed, even with use of a metal rest with an FRD. 

The focus of this study was on vertical displacement, and only experimental and artificial models were used. Further study using more optimized experimental models and oral tissues, including mucosa, teeth, and periodontal tissues, are planned by this group. 

**Conclusion** 

Within the limitations of the present study, a number of conclusions can be drawn. The FRDs showed a tendency to result in a greater amount of vertical displacement than a conventional MCD. These results suggest, however, that the concomitant use of a rest is useful in reducing vertical displacement. 

Even if a metal rest is set on the distal side, the amount of vertical displacement associated with an FRD is less than that with an MCD when a unilateral extension base is used. 

When applying an FRD, a design involving the application of rests and additional options for rigid supports should be considered. 

**Conflict of Interest** 

The authors declare no conflict of interest. 

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