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| Citation         | 北海道歯学雑誌, 33(2), 153-159  |
| Issue Date       | 2013-03  |
| Doc URL          | <a href="http://hdl.handle.net/2115/52453">http://hdl.handle.net/2115/52453</a>  |
| Type             | article  |
| File Information | 10-wada.pdf  |



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## ORIGINAL

# Influence of changes in denture-base fit and connecting rigidity on the load distribution of abutment teeth and the displacement of abutment teeth and denture base in mandibular distal-extension removable partial dentures.

Tatsunori Wada, Masayasu Saito, Yoshifumi Miura and Atsuro Yokoyama

**ABSTRACT** : The purpose of this study was to clarify the influence of denture-base fit and retainer design on the distribution of stress on abutment teeth, and the displacement of abutment teeth and the denture base. A mandibular model with a simulated periodontal ligament and mucosa was fabricated to simulate a partially edentulous case with the right first molar and second molar missing. The edentulous area was made flat to eliminate the influence of residual ridge forms. Two types of removable partial dentures with different direct retainers: 1, a cone crown telescope (CCT); and 2, a modified circumferential clasp with a distal guide plate, a buccal retentive arm and a lingual enlarged bracing arm (MCC), with an embrasure clasp as an indirect retainer, were designed. The following conditions of the denture-base conformity with the simulated mucosa were established: completely suitable (CS), mesial half unsuitable ( $M^-$ ), distal half unsuitable ( $D^-$ ), buccal half unsuitable ( $B^-$ ), lingual half unsuitable ( $L^-$ ), and completely unsuitable (CU). A  $200\mu\text{m}$  clearance area was made between the denture base and simulated mucosa on these unsuitable parts. The stresses at the apical, buccal and distal portions, the distal displacement of abutment teeth and the subsidence of the denture base were investigated.

Both the stress on and the displacement of abutment teeth for the partially unsuitable denture base were larger than those for the completely suitable denture bases for the CCT-retained denture. The distal stress and distal displacement of abutment teeth for the completely unsuitable denture base were larger than for the completely suitable denture base with the MCC-retained denture. The buccal stress distribution and the distal displacement of the abutment teeth with the CCT-retained denture were significantly larger than those with the MCC-retained denture under all conditions. When the denture base was completely unsuitable or the distal part was unsuitable, the subsidence of the denture base with the MCC-retained denture was larger than that with the CCT-retained denture.

These results showed that the denture base fit influenced the stress and displacement of the abutment teeth for the CCT-retained denture more than that for the MCC-retained denture, and the subsidence of the denture base of the MCC-retained denture was the same as that of the CCT-retained denture when the unsuitable parts of the denture base were only mesial and buccal. Thus, the MCC-retained denture does not cause overloading of abutment teeth and the residual ridge even if the fitness of the denture base decreases.

**Key Words** : Denture base fit, Connecting rigidity, Removable partial dentures, Stress distribution of abutment teeth, Displacement of denture-base.

## Introduction

Long-term wear of removable partial dentures (RPDs)

may unavoidably cause residual ridge resorption under the denture base, and consequently decrease the mucosal support. Rigid dentures, rigidly connected to abutment

teeth, are less likely to cause residual ridge resorption than nonrigid, flexible dentures<sup>1-2</sup>. Igarashi reported that relining was required within 3 years of wearing for 17% of rigid dentures<sup>3</sup>. Öwall reported that the RPDs with rigid-precision attachments hardly required relining in a clinical survey<sup>4</sup>. However, 26 of 27 RPDs retained by clasps required relining over a 10-year period in a study by Bergman et al<sup>5</sup>. Thus, it is advantageous that relining of rigid dentures is needed less frequently than flexible dentures.

On the other hand, the stress distribution on abutment teeth for rigid dentures is larger than that for nonrigid dentures<sup>6-8</sup>. Chou et al. reported that dentures using rigid precision attachments produced greater stresses and caused more movement of abutment teeth than dentures using clasps did, and they pointed out the risk of rigid dentures<sup>9</sup>. Saito et al. also reported that the incidence of failure of the abutment teeth increased when the connecting rigidity of retainers was strong<sup>10</sup>. Therefore, it seems that once the mucosal support decreases, it might cause larger stress on the abutment teeth of rigid dentures. However, there are no reports on the movement of abutment teeth and the denture base for the different denture designs when denture-base fitness decreases. The purpose of this study, therefore, was to investigate the influence of changes of denture-base fit and the retainer design on the stress distribution on abutment teeth and the displacement of the abutment teeth and denture base.

**Materials and methods**

A metal mandibular model with a partially edentulous arch having the right first and second molars missing was used for this study. The experimental model was fabricated according to the previous report<sup>7</sup>. Every tooth was made of stainless steel and the form was shown in 1. The form of the coronal part of the abutment tooth was used as the inner coping of the cone crown telescope (CCT). The metal cast crown for the clasp was joined to the coronal part of the abutment tooth by a screw. The roots were surrounded by 1-mm-thick addition-type silicone (DentsiliconeV, Shofu) to simulate the periodontal ligaments. The residual ridge was fabricated using autopolymerizing acrylic resin (Tray resin II, Shofu) and covered with a 3-mm-thick silicone rubber impression material (Remasil, Dentaurum) to simulate the mucosa. The edentulous area was made flat to eliminate the influence of the residual ridge forms. That

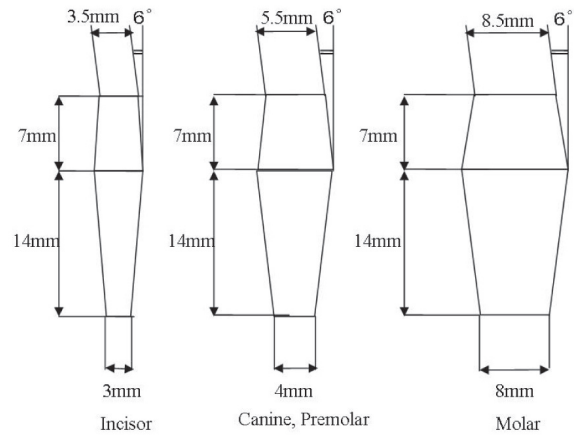


Fig. 1. A diagram of simulations of teeth

area was 20 mm in width and 30 mm in length shown in Fig. 2. The denture base was made with autopolymerizing acrylic resin (Tray resin II, Shofu). The following six conditions of the denture-base conformity with the simulated mucosa were used: completely suitable (CS), mesial half unsuitable (M<sup>-</sup>), distal half unsuitable (D<sup>-</sup>), buccal half unsuitable (B<sup>-</sup>), lingual half unsuitable (L<sup>-</sup>), and completely unsuitable (CU). A 200µm clearance was set between the denture base and simulated mucosa for the unsuitable parts (Fig. 3).

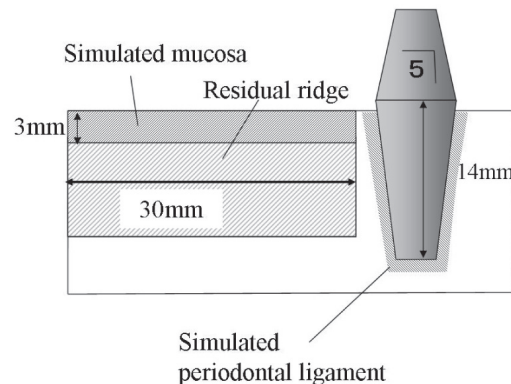


Fig. 2. A diagram of the experimental model

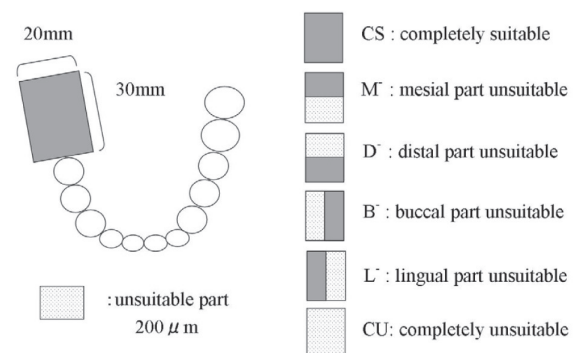


Fig. 3. The conditions of denture-base fitness

As direct retainers, a CCT and a modified circumferential clasp with a distal guide plate, a buccal retentive arm and a lingual enlarged bracing arm (MCC) were used for the mandibular right second premolar and an embrasure clasp was used for the mandibular left first premolar and second premolar as indirect retainers (Fig. 4). Five retainers of each design were manufactured.

All cone crown telescopes and clasps were made of dental gold platinum alloy (PGA-13, Ishifuku Metal Industry Co.). These retainers were firmly joined to the framework, which was cast with cobalt-chrome alloy, by screws and could be exchanged for each other.

A vertical static load of 50N was applied on a point 16 mm distal to the second premolar on the denture base, representing the position of the first molar, by using a load application device as shown in Fig. 5. The stresses of

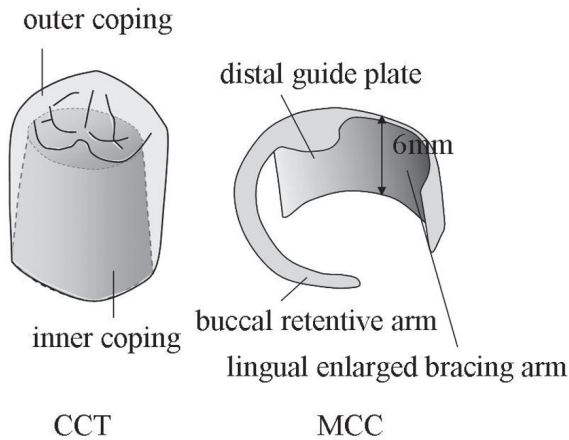


Fig. 4. A diagram of the direct retainers

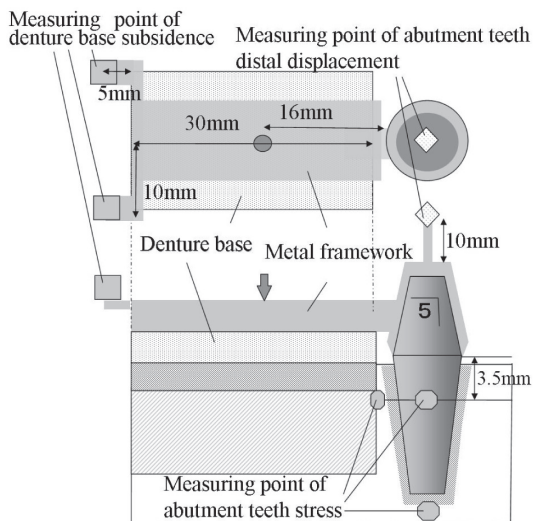


Fig. 5. A diagram showing the experimental dentures and measuring points

abutment teeth were measured with pressure sensors that were attached to the silicone periodontal ligaments at apical, distal and buccal portions of the second premolar. Each of these sensors consisted of a pressure sensor (PS-2KB advanced type, Kyowa Electronic Instruments Co.) at one end of an aluminum cylinder, a cap with a projection 1 mm in diameter at the other end, and silicone gel between the cap and the sensor. The signals from the sensors were amplified and recorded using a data logger (Loggermate DL1200, NEC San-ei Instruments, Inc.).

Subsidence of the denture base was measured at buccal and lingual points 5mm distal from the distal end of the denture base. Distal displacement of the second premolar was measured at a point 10 mm above the cusp. These displacements were measured with a laser measurement system (LK3000, Kyowa Electronic Instruments Co.). The experimental denture assemblies were illustrated in Fig. 6.

The values of stress distributions and displacements were statistically analyzed using two-way analysis of variance (ANOVA) and Scheffe analysis, with a significance level of 0.05.

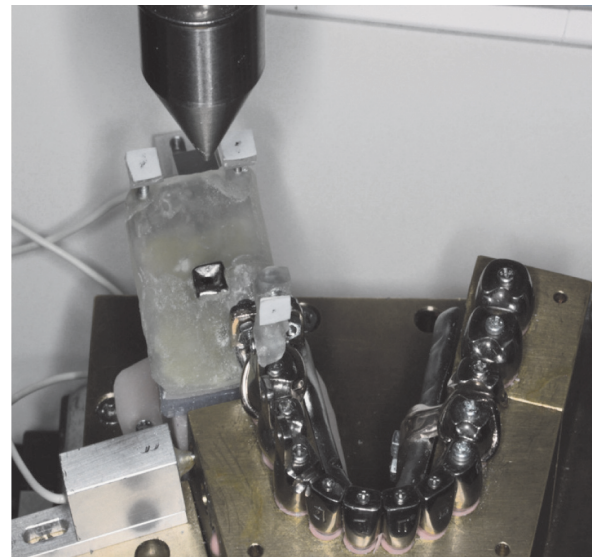


Fig. 6. A photograph showing the experimental denture assemblies

## Results

### *Stress distributions of abutment teeth*

The apical stress distributions of the abutment teeth were shown in Fig. 7. That for the CU condition was significantly larger than for the CS condition with the CCT-retained denture. There was no significant

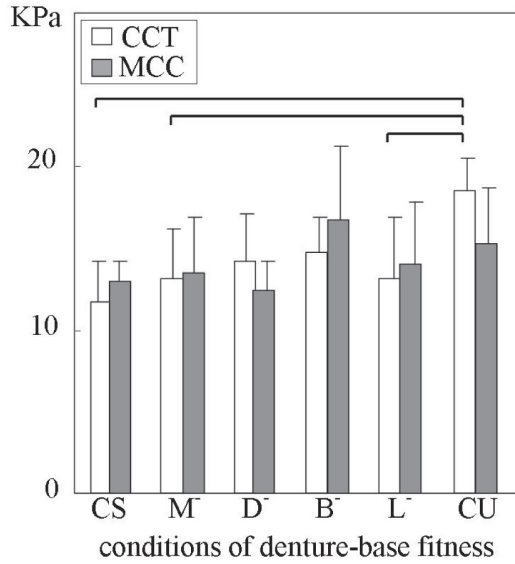


Fig. 7. Comparison of apical stresses on abutment teeth. Solid lines show significant differences ( $p < 0.05$ ; Scheffe analysis).

CS: completely suitable, M<sup>-</sup>: mesial half unsuitable, D<sup>-</sup>: distal half unsuitable, B<sup>-</sup>: buccal half unsuitable, L<sup>-</sup>: lingual half unsuitable, CU: completely unsuitable  
 CCT: cone crown telescope, MCC: modified circumferential clasp

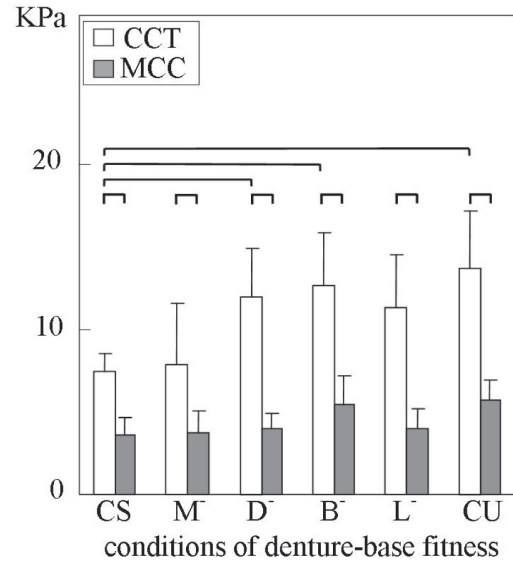


Fig. 8. Comparison of buccal stresses on abutment teeth. Solid lines show significant differences ( $p < 0.05$ ; Scheffe analysis).

CS: completely suitable, M<sup>-</sup>: mesial half unsuitable, D<sup>-</sup>: distal half unsuitable, B<sup>-</sup>: buccal half unsuitable, L<sup>-</sup>: lingual half unsuitable, CU: completely unsuitable  
 CCT: cone crown telescope, MCC: modified circumferential clasp

difference among the various conditions for the MCC-retained denture. Nor was there was any significant difference between those for the CCT- and MCC-retained dentures.

The buccal stress distributions of the abutment teeth were shown in Fig. 8. Those for the D<sup>-</sup>, B<sup>-</sup> and CU conditions were significantly larger than for the CS condition with the CCT-retained denture. There was no significant difference among the various conditions for the MCC-retained denture. However, the stress distributions for the CCT-retained denture were significantly larger than for the MCC-retained denture under all conditions.

The distal stress distributions for the abutment teeth were shown in Fig. 9. Those for conditions D<sup>-</sup>, B<sup>-</sup> and CU were significantly larger than for CS with the CCT-retained denture. For the CU condition the stress distribution was significantly larger than for CS with the MCC-retained denture. Those for D<sup>-</sup>, B<sup>-</sup> and CU with the CCT-retained denture were significantly larger than for the MCC-retained denture.

**Distal displacement of abutment teeth**

The distal displacement of abutment teeth was shown in Fig. 10. For D<sup>-</sup>, B<sup>-</sup>, L<sup>-</sup> and CU it was significantly larger than for CS with the CCT-retained denture. The

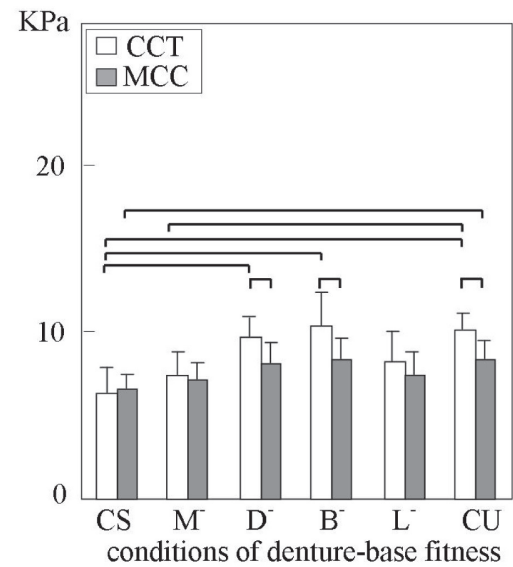
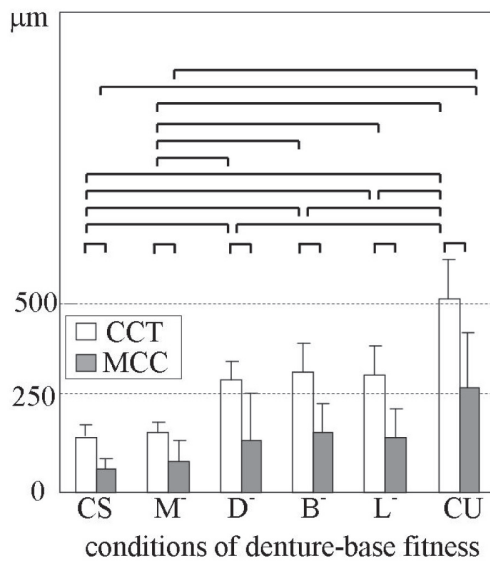
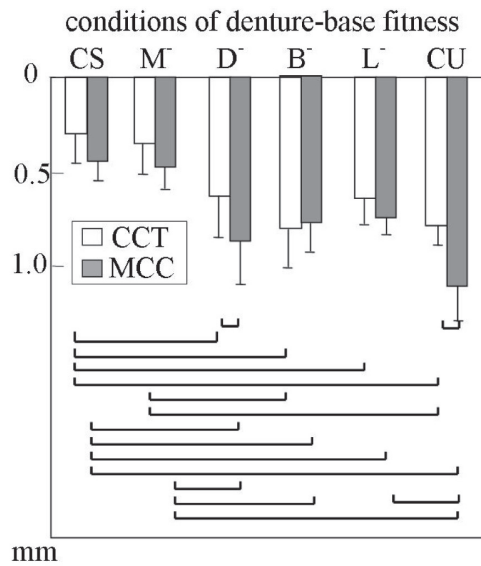


Fig. 9. Comparison of distal stresses on abutment teeth. Solid lines show significant differences ( $p < 0.05$ ; Scheffe analysis).

CS: completely suitable, M<sup>-</sup>: mesial half unsuitable, D<sup>-</sup>: distal half unsuitable, B<sup>-</sup>: buccal half unsuitable, L<sup>-</sup>: lingual half unsuitable, CU: completely unsuitable  
 CCT: cone crown telescope, MCC: modified circumferential clasp



**Fig. 10.** Comparison of distal displacement of abutment teeth. Solid lines show significant differences ( $p < 0.05$ ; Scheffe analysis).  
 CS: completely suitable, M<sup>-</sup>: mesial half unsuitable, D<sup>-</sup>: distal half unsuitable, B<sup>-</sup>: buccal half unsuitable, L<sup>-</sup>: lingual half unsuitable, CU: completely unsuitable  
 CCT: cone crown telescope, MCC: modified circumferential clasp



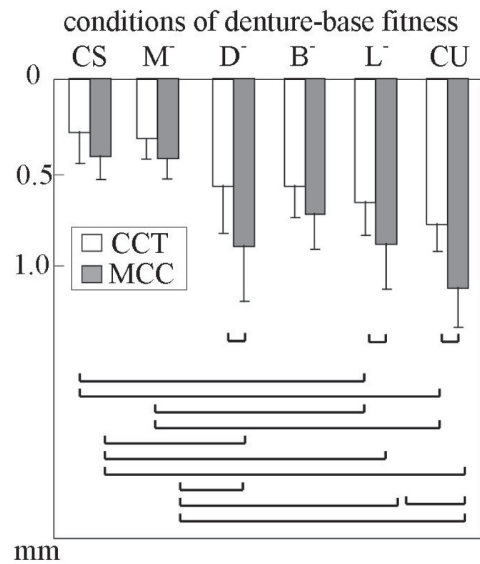
**Fig. 11.** Comparison of subsidence at buccal points of denture bases. Solid lines show differences ( $p < 0.05$ ; Scheffe analysis).  
 CS: completely suitable, M<sup>-</sup>: mesial half unsuitable, D<sup>-</sup>: distal half unsuitable, B<sup>-</sup>: buccal half unsuitable, L<sup>-</sup>: lingual half unsuitable, CU: completely unsuitable  
 CCT: cone crown telescope, MCC: modified circumferential clasp

distal displacement of abutment teeth for CU was significantly larger than for CS with the MCC-retained denture. For the CCT-retained denture, the distal displacement was significantly larger than with the MCC-retained denture under all conditions.

**Subsidence of denture base**

The subsidence at the buccal point of the denture base was shown in Fig. 11. For D<sup>-</sup>, B<sup>-</sup>, L<sup>-</sup> and CU it was significantly larger than for CS for both the CCT-retained denture and the MCC-retained denture. Subsidence under conditions D<sup>-</sup> and CU with the MCC-retained denture was significantly larger than with the CCT-retained denture.

The subsidence at the lingual point of the denture base was shown in Fig. 12. For L<sup>-</sup> and CU it was significantly larger than for CS with the CCT-retained denture. For D<sup>-</sup>, L<sup>-</sup> and CU, subsidence was significantly larger for CS with the MCC-retained denture. With the MCC-retained denture it was significantly larger for D<sup>-</sup>, L<sup>-</sup> and CU than with the CCT-retained denture.



**Fig. 12.** Comparison of subsidence at lingual points of denture bases. Solid lines show significant differences ( $p < 0.05$ ; Scheffe analysis).  
 CS: completely suitable, M<sup>-</sup>: mesial half unsuitable, D<sup>-</sup>: distal half unsuitable, B<sup>-</sup>: buccal half unsuitable, L<sup>-</sup>: lingual half unsuitable, CU: completely unsuitable  
 CCT: cone crown telescope, MCC: modified circumferential clasp.

## Discussion

In this study, a simulated model and experimental dentures were designed to clarify the influences of denture-base fitness and retainer design. Some authors reported that the residual ridge form influenced the movement of abutment teeth and the denture base<sup>11-13</sup>. The flat shape was used as the residual ridge form in order to eliminate the influence of that form and examine the effect of each retainer clearly. Rehm et al. reported that the distal rotation of a terminal abutment tooth was limited within the range of physiologic tooth mobility in conical crown-retained dentures with a mesiodistal length of the denture base of 40mm, which corresponded to the case in which the second premolar, first molar and second molar were missing<sup>14</sup>. On the other hand, Igarashi proposed that even when the first and second molars were missing, the RPD could be used with sufficient mucosa supportability<sup>15</sup>. In this study we set the mesiodistal length of the denture base to 30mm, which corresponded to the case in which the first and second molars were missing, in order to clarify the influence of denture-base fitness on the movement of abutment teeth and the denture base clearly.

In the CS condition, the apical stress on abutment teeth was larger than the distal and buccal stresses, as Kratochvil et al.<sup>16</sup> and Saito et al.<sup>7</sup> reported. In addition, when the denture-base fitness decreased, the apical stress was larger than the other stresses. This suggested that not only the cone crown telescope but also the modified circumferential clasp with a distal guide plate, a buccal retentive arm and a lingual enlarged bracing arm used in this study had sufficiently strong connecting rigidity. It is well known that great apical stress does not always cause damage to abutment teeth since teeth can withstand greater forces along the long axis than horizontal forces. Kimura reported that the center of rotation of the abutment tooth is transferred from the apical side to the cervical side following decreases of denture-base fitness<sup>17</sup>. Therefore, the risk of overloading of abutment teeth should be assessed by buccal and distal stresses and distal displacement of the abutment teeth. Under D<sup>-</sup>, B<sup>-</sup> and CU conditions, buccal and distal stresses in the CCT-retained denture were significantly larger than under the CS condition. Under the unsuitable conditions, except for the mesial one, distal displacement of abutment teeth in the CCT-retained denture was significantly larger than under the CS condition. Only

under the CU condition were the distal stress and displacement of abutment teeth in the MCC-retained denture significantly larger than under the CS and M<sup>-</sup> conditions. These results showed that buccal stress and distal displacement in the CCT-retained denture become larger than those in the MCC-retained denture, and buccal and apical stresses were not influenced with the MCC-retained denture when the denture-base fitness decreased. Therefore, the decrease of denture-base fitness would more greatly influence stress and displacement of abutment teeth with the CCT-retained denture than with the MCC-retained denture. Clinically, Saito et al. reported that troubles of abutment teeth such as fractures occurred more frequently with cone telescope dentures than with dentures having a conventional Akers clasp<sup>10</sup>. The finding in this study that abutment teeth of the CCT-retained denture suffered severe stress when the denture base was unsuitable might support their observation. It is thought that the risk of overloading of abutment teeth with the CCT-retained denture is higher when denture-base fitness decreases. Clinically, it is necessary to observe the denture-base fitness periodically, especially the buccal and distal parts.

There was no significant difference between the subsidence at the buccal and lingual points of the denture base in the CCT- and MCC-retained dentures under the CS condition, as Miura et al. reported<sup>18</sup>. For D<sup>-</sup> and CU, subsidence at the buccal point of the denture base of the MCC-retained denture was larger than with the CCT-retained denture. In addition, subsidence at the lingual point of the denture base of the MCC-retained denture was larger than for the CCT-retained denture under D<sup>-</sup>, L<sup>-</sup> and CU conditions. However, for M<sup>-</sup> and B<sup>-</sup>, there was no difference of subsidence of the denture base between the CCT- and MCC-retained dentures. These results showed that subsidence of the denture base of the MCC-retained denture was influenced more greatly by denture-base fitness than was that of the CCT-retained denture, and also that the lesser connecting rigidity caused ridge absorption, which might support the clinical report by Bergman et al.<sup>5</sup> However, the subsidence of the denture base of the MCC-retained denture was the same as that of the CCT-retained denture when the unsuitable parts of the denture base were limited to the mesial and buccal regions. This finding suggested that the circumferential clasp with the strong connecting rigidity could be more suitable than the conventional

Akers clasp<sup>10)</sup>.

While the residual ridge form was flat, the subsidence of the denture base showed different tendencies for the buccal and lingual points. It is thought that the rigid indirect retainers limited the lingual movement of the dentures.

### Conclusions

- The MCC-retained denture would not cause overloading of abutment teeth less than the CCT-retained denture even if the fitness of the denture base decreased.
- The MCC-retained denture might be suitable for residual ridge even if the fitness of the denture base decreased partially.

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