In prosthodontic treatment, reconstruction of a proper occlusal contact relationship is very important as well as reconstruction of a proper interproximal relationship and marginal fitness. Unfortunately, occlusal relationships are sometimes lost in the process of occlusal adjustment of crowns. The purpose of this study was to compare the occlusal contacts of single crown fabricated by two different types of impression techniques.

Nine subjects, whose molars required treatment with crown restoration, were enrolled in this study. Full cast crowns were fabricated using two types of impression techniques: the conventional impression method (CIM) and the bite impression method (BIM). The occlusal contacts of crowns were precisely evaluated at the following stages: after occlusal adjustment on the articulator (Step 0), before occlusal adjustment in the mouth (Step 1), after occlusal adjustment at the intercuspal position (Step 2), and after occlusal adjustment during lateral and protrusive excursions (Step 3).

The number of occlusal contacts of the crowns on the functional cusps fabricated with BIM was significantly greater than that with CIM after occlusal adjustment. For this reason, the crowns fabricated with BIM might have a more functionally desirable occlusal surface compared to the crowns fabricated with CIM.

Key words: bite impression method, functional cusp, occlusal adjustment, occlusal contact, tooth displacement

Introduction

In case of endodontically treated or extensively damaged teeth, the indirect method for crown fabrication is usually applied. In crown restorations, proper reconstruction of the occlusal, interproximal relationship and marginal fitness is very important. It has been reported that insufficient reconstruction of the occlusal relationship might cause inflammatory reactions because of disturbance of the blood circulation to periodontal and pulpal tissues. Therefore, the occlusal relationship, i.e., the occlusal contacts, of the crowns must be in functional harmony with the stomatognathic system, especially with the periodontal tissues. However, in the step of try-in, height of the crown fabricated by the conventional indirect method was usually approximately 300 µm higher than the ideal occlusal height before occlusal adjustment. Therefore, occlusal adjustment of the crown became necessary before cementation. Previous studies have reported that crown restorations have fewer occlusal contacts and the location of occlusal contacts differs compared with those intended or natural teeth after occlusal adjustment of the crown.

It has also been reported that casts fabricated with the bite impression method (Figure 1), which represents tooth displacement during clenching, have a higher reproducibility of occlusal contacts than those fabricated with the conventional indirect
impression method, which does not represent the tooth displacement during clenching.\textsuperscript{11} However, the difference in reproducibility of occlusal contacts after occlusal adjustment by these two impression techniques has not been quantitatively investigated. Previous studies have reported that the number and area of occlusal contacts were shown to be proportionally related to masticatory efficiency.\textsuperscript{12-16} It has also become clear that during mastication, food is crushed between functional cusps in the circumscribed region and these region were influenced by the location of occlusal contacts.\textsuperscript{17,18}

The aim of the present study was to compare and evaluate the occlusal contacts of crowns fabricated by these two types of impression techniques after occlusal adjustment.

![Figure 1. Bite impression method.](image)

**Materials and Methods**

Nine subjects (5 males and 4 females; mean age, 51.2 ± 16.8 years) were enrolled in this study according to the following criteria:
1) No experience of orthodontic treatment and no symptoms of stomatognathic disorder.
2) No missing teeth except for the third molar.
3) Presence of a first or second molar that needs to be restored with full cast crown.

All subjects’ teeth (Table 1) were endodontically treated and restored with cast post and core or composite resin core. Details of the study protocol were explained to all subjects and informed consent was obtained prior to the study. This research was approved by the Research Ethics Committee of Tokyo Medical and Dental University (Approval No. 489, 2010).

**Table 1. Experimental tooth in each subject.**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Subjects’ tooth</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>lower left first molar</td>
</tr>
<tr>
<td>B</td>
<td>lower left first molar</td>
</tr>
<tr>
<td>C</td>
<td>upper right first molar</td>
</tr>
<tr>
<td>D</td>
<td>upper left second molar</td>
</tr>
<tr>
<td>E</td>
<td>lower left first molar</td>
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<tr>
<td>F</td>
<td>lower left second molar</td>
</tr>
<tr>
<td>G</td>
<td>upper left first molar</td>
</tr>
<tr>
<td>H</td>
<td>lower right second molar</td>
</tr>
<tr>
<td>I</td>
<td>lower left second molar</td>
</tr>
</tbody>
</table>

1. **Tooth preparation**

Tooth preparation for full cast crown was performed and the subjects’ teeth were temporarily restored with provisional crowns made of acrylic resin (UNIFAST III, GC Corp., Tokyo, Japan). Occlusal adjustment of the provisional crown in the intercuspal position was performed using articulating paper. Adjustment was performed based on finger sensation during the tapping and pull-out test with articulating paper at the abutment tooth and the mesial adjacent tooth. The provisional crown was adjusted until the area and number of occlusal contacts were similar to those of the mesial adjacent tooth with and without the provisional crown. After 1 week, the periodontal tissue was checked for signs of inflammatory reactions and symptoms of stomatognathic disorder.

2. **Impression taking**

Two types of impression methods were used.

1) **Conventional impression method (CIM): control group**

Using this impression method, the impression of the dentition including abutment tooth and opposing teeth were taken separately. After the abutment tooth tray made of acrylic resin (UNIFAST III, GC Corp.) was adjusted, a tray adhesive (ADHESIVE, GC Corp.) was applied to the inside and outside of the abutment tooth tray. A moderate viscosity polyvinyl siloxane impression material (EXAMIXFINE CARTRIDGE REGULAR TYPE, GC Corp.) was injected into the abutment tooth tray and it was placed over the subject’s tooth. Then, a partially rotating impression tray (Rotating Tray Fusayama Type, YDM Corp., Tokyo, Japan) filled with the low viscosity polyvinyl siloxane impression material (EXAMIXFINE CARTRIDGE REGULAR HARD TYPE, GC Corp.) was also placed over the subject’s tooth and the adjacent teeth. The impression of the opposing teeth was also taken with hydrocolloid impression material (AROMA FINE, GC Corp.) using the partially rotating impression tray. The
Evaluation of the occlusal contact of crowns

occlusal relationship with moderate biting force at the intercuspal position was registered using occlusal registration materials (Correct Plus, Pentron Corp., Tokyo, Japan).

2) Bite impression method (BIM): experimental group

Using this impression method, the impression of the abutment tooth, adjacent and opposing teeth can be taken simultaneously during biting. After the abutment tooth tray made of acrylic resin (UNIFAST III, GC Corp.) was adjusted, a tray adhesive (ADHESIVE, GC Corp.) was applied to the inside and outside of the abutment tooth tray.

The moderate viscosity polyvinyl siloxane impression material (EXAMIXFINE CARTRIGE REGULAR TYPE, GC Corp.) was injected into the abutment tooth tray and was placed over the subject’s tooth. Then, the upper and lower sides of a bite impression tray (Bite tray K type, YDM Corp.) with a plastic film (NEW KUREWRAP, KUREHA Corp., Tokyo, Japan) as a separating sheet (thickness, 16 µm), were filled with low viscosity polyvinyl siloxane impression material (EXAMIXFINE CARTRIGE REGULAR HARD TYPE, GC Corp.). Afterwards, the bite impression tray was placed over the posterior mandibular teeth, and subjects were asked to bite in the intercuspal position with moderate biting force.

3. Die fabrication

1) CIM

Type IV die stone (GC New Fujirock, GC Corp.) was poured into the impression including the subjects’ teeth. Laboratory stone (New Plastone II LE, GC Corp.) was then poured into the impression of the antagonistic teeth.

The cast models were mounted on a plain-line articulator (Partial articulator type B, YDM Corp.) with plaster (SOFT PLASTER, SHOFU INC., Kyoto, Japan). Mounting of the cast models on the articulator was performed without holding the occlusal registration in reference to the perforation of occlusal registration which represented actual occlusal contacts in vivo.

2) BIM

In the same way as CIM, type IV die stone was poured into the impression trays. The cast models were removed from the tray after 1 hour and mounted on a plain-line articulator (Partial articulator type B, YDM Corp.) with plaster (SOFT PLASTER, SHOFU INC.). Mounting the cast models on the articulator was performed in the same way described for CIM.

4. Fabrication of full cast crowns with two different impression methods

All crowns were fabricated using the lost wax technique. Crown patterns were fabricated with inlay wax (Inlay Wax Medium, GC Corp.). The patterns were invested with an investment material (Cristobalite PF, SHOFU INC.) and cast with silver-palladium alloy (Castwell M.C. 12% Gold, GC Corp.). After casting, adjustment of the interproximal contact and occlusal relationship of the crowns was performed on the articulator. Adjustment of the occlusal relationships of these crowns was performed until the articulating paper (ARTICULATING PAPER, GC Corp.) was torn on the mesial adjacent tooth.

5. Registration of occlusal relationships on the articulator

After occlusal adjustment on the articulator, the occlusal relationships of the crowns and the adjacent teeth on the cast were registered with an occlusal contact checking material (BITE-CHECKER, GC Corp.) (Step 0).

6. Try-in and adjustment of the interproximal contacts of the crowns

The crowns were tried-in and the interproximal contacts were adjusted using 50-µm-thick contact gauge (CONTACT GAUGE, GC Corp.) until it could be inserted with slight resistance.

7. Occlusal adjustment

1) Occlusal adjustment in the intercuspal position

Occlusal adjustment in the intercuspal position was performed using articulating paper. It was performed based on finger sensation during tapping and pull-out test of the abutment tooth and the mesial adjacent tooth with articulating paper. If several excessive height of occlusal contacts on the crown were detected by articulating paper, all these occlusal contacts were removed until the area and number of occlusal contacts were similar to those of the mesial adjacent tooth without the crown.

2) Occlusal adjustment during lateral and protrusive excursions

The occlusal adjustments during lateral and protrusive mandibular movements were performed until all interferences were removed.

8. Registration of occlusal relationships in the intercuspal position

After adjustment of the interproximal contacts and
checking the fitness of the crown in the mouth, occlusal contacts of the crown with moderate biting force at the intercuspal position were registered using occlusal contact checking materials at the following stages:

- before occlusal adjustment in the mouth (Step 1)
- after occlusal adjustment at the intercuspal position (Step 2)
- after occlusal adjustment during lateral and protrusive excursions (Step 3)

9. Analysis of occlusal contact

The occlusal registration was trimmed to make it parallel to the occlusal plane. It was put on a lighting board parallel to a digital camera at a constant distance and digital images were taken. The occlusal contact area was analysed by means of light transmission. The thickness of the silicone interocclusal registration materials was calibrated using a steel ball of 101.6 mm diameter according to Nakao’s method. The occlusal contact regions below 10 µm were detected using image processing software (Win Roof, Mitani Corp., Fukui, Japan). The images of occlusal contact regions were superimposed on the images of the dentition.

10. Statistical analysis

1) The occlusal relationships of the crowns

Comparison of number of occlusal contacts of the crowns were analysed as follows:

(1) between CIM and BIM in each step
(2) among each step in CIM
(3) among each step in BIM
(4) between functional and non-functional cusps in CIM for each step
(5) between functional and non-functional cusps in BIM for each step
(6) between CIM and BIM on functional cusps for each step
(7) between CIM and BIM on non-functional cusps for each step

Friedman test used nonparametric two way factorial analysis variance for (1), (4)-(7). In addition, Wilcoxon signed-rank test with Bonferroni correction was used as a post-hoc test for multipul comparisons for (4)-(7).

On the other hand, Wilcoxon signed-rank test with a Bonferroni correction was performed for (2), (3).

2) The occlusal relationships of the adjacent teeth on the cast

Wilcoxon rank sum test was performed for the comparison of number of occlusal contacts as follows:

(1) between CIM and BIM at Step 0
(2) between functional and non-functional cusps in CIM at Step 0
(3) between functional and non-functional cusps in BIM at Step 0

These analyses were performed using a computerized statistical software package (SPSS for Windows 12.0J, SPSS Japan Inc., Tokyo, Japan) at a significance level of 0.05.

Results

1. The number of occlusal contacts of the crowns between CIM and BIM in each step

The number of occlusal contacts was compared between the CIM and BIM technique at several steps (Table 2).

The numbers of occlusal contacts of the crowns of CIM at Step 0, 1, 2 and 3 were 6.6±2.6, 4.1±1.6, 5.4±1.9, 4.4±1.7, respectively, and the numbers of occlusal contacts of BIM at Step 0, 1, 2 and 3 were 6.1±2.6, 4.0±2.9, 6.7±3.8, 6.4±2.4, respectively (Figure 2).

There was no significant difference in the number of occlusal contacts between CIM and BIM at all the steps.

2. The number of occlusal contacts of the crowns fabricated with the two different types of impression techniques at each step

1) CIM (Figure 3)

The number of occlusal contacts significantly decreased from Step 0 to Step 1, and from Step 0 to Step 3.

There were no significant differences among all other steps.

2) BIM (Figure 4)

The number of occlusal contacts significantly increased from Step 1 to Step 2, and from Step 1 to Step 3.

There were no significant differences among all other steps.

3. The number of occlusal contacts on the functional cusps and the non-functional cusps of the crowns fabricated with the two different impression techniques (Table 3, 4)

1) CIM (Figure 5)

The number of occlusal contacts on the functional cusps was significantly greater than that on the non-functional cusps at Step 1, Step 2 and Step 3.

There was no significant difference at Step 0.
Evaluation of the occlusal contact of crowns

Table 2. Number of occlusal contacts of crowns prepared with two types of impression techniques in each subject.

<table>
<thead>
<tr>
<th>Subject</th>
<th>CIM†</th>
<th>BIM‡</th>
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<tbody>
<tr>
<td></td>
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<td>Step</td>
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<td>Mean</td>
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<td>S.D.</td>
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</table>

† CIM: conventional impression method
‡ BIM: bite impression method

Table 3. Number of occlusal contacts of crowns on functional cusps and non-functional cusps in each subject (CIM).

<table>
<thead>
<tr>
<th>Subject</th>
<th>Functional cusps</th>
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<tr>
<td>Mean</td>
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<td>S.D.</td>
<td>2.6</td>
<td>1.6</td>
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</table>

Table 4. Number of occlusal contacts of crowns on functional cusps and non-functional cusps in each subject (BIM).

<table>
<thead>
<tr>
<th>Subject</th>
<th>Functional cusps</th>
<th>Non-functional cusps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Step</td>
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<td>2</td>
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<tr>
<td>Mean</td>
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<tr>
<td>S.D.</td>
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<td>1.1</td>
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</table>
2) BIM (Figure 6)
The number of occlusal contacts on the functional cusps was significantly greater than that on the non-functional cusps at all steps.

4. The difference of occlusal contacts of the crowns between functional and non-functional cusps
1) The functional cusps (Figure 7)
The number of occlusal contacts of the crowns fabricated with BIM was significantly higher than that of the crowns fabricated with CIM at Step 3. There were no significant differences among all other steps.

2) The non-functional cusps (Figure 8)
There were no significant differences among all other steps.
5. The difference of occlusal contacts of the adjacent teeth between functional and non-functional cusps at Step 0

The numbers of occlusal contacts of the adjacent teeth of CIM and BIM at Step 0 were 6.0±4.0, 9.3±2.7, respectively.

1) CIM and BIM (Figure 9)

There was no significant difference in the number of occlusal contacts of the adjacent teeth between CIM and BIM at Step 0.

2) CIM (Figure 10)

There was no significant difference in the number of occlusal contacts of the adjacent teeth between the functional cusps and the non-functional cusps at Step 0.

3) BIM (Figure 11)

The number of occlusal contacts on the functional cusps of the adjacent teeth was significantly greater than that on the non-functional cusps at Step 0.

Discussion

Previous studies have revealed that the numbers, locations and areas of the occlusal contacts on the molar regions have a close relationship with stomatognathic function, especially in the masticatory efficiency.\textsuperscript{12-16}

In addition, loading on the functional cusps of the molars was more comfortable than that on the non-functional cusps.\textsuperscript{20} Consequently, it was confirmed that an adequate number of occlusal contacts at the functional cusps was essential to achieve functional harmony with the stomatognathic system. Previous studies have reported the occlusal height or the number or area of occlusal contacts of crowns fabricated by CIM.\textsuperscript{9,10} On the other hand, few studies have evaluated the number and location of occlusal contacts of crowns fabricated by BIM, although distortion of periodontal tissues during clenching may influence the occlusal contacts. Therefore, it is necessary to investigate the effects of BIM on the number and location of occlusal contacts. In this study, there was no significant difference between the total number of occlusal contacts on the adjacent teeth on the cast with CIM and that with BIM (figure 9). On the other hand, in the
case of BIM, the number of occlusal contacts on the functional cusps of the adjacent teeth was significantly greater than that on the non-functional cusps (figure 11), though there was no significant difference in the number of functional and non-functional occlusal contacts on the adjacent teeth in CIM (figure 10). These differences implied there was a possibility the shape of occlusal surface of the cast with CIM was not the same as that with BIM.

The numbers of occlusal contacts of the crown fabricated using CIM were compared in terms of Step 0, 1, 2 and 3 (Figure 3). The number of occlusal contacts significantly decreased from Step 0 to Step 1. Some previous studies revealed that teeth were displaced during clenching.\(^\text{21,22}\) The load/tooth displacement curve (LDC) represented the relation between the amount of tooth displacement and load.\(^\text{23,24}\) There is a large difference between the LDC of the upper and lower molars.\(^\text{25}\) The LDC of the upper molar shows mainly two phases, and the lower molar shows one phase. In the case of upper molars, the first phase was mainly caused by distortion of the periodontal ligament showing displacement to the apical direction with a slight bite force and the second phase by distortion of the alveolar bone in addition to the periodontal ligament showing displacement to the apico-palatal direction and this displacement gradually increased in proportion to the bite force.\(^\text{23}\) In the case of the lower molars, the displacement occurs only to the lingual direction and the amount of the displacement gradually increased also in proportion to the bite force.\(^\text{23}\) Because of the difference in the amount and direction of the tooth displacement in the upper and lower molars, the occlusal relationship between the upper and lower molars during clenching might be quite different from that at rest. In the case of impression with CIM, the teeth were not displaced because the subjects were asked to open their mouth during impression, and consequently no functional force was applied on the surface of the teeth. That is, the location of the teeth on the cast with CIM was similar to that of teeth at rest in vivo. Therefore, the occlusal contacts of the crowns fabricated with CIM at try-in might be fewer than that on the cast. The number of occlusal contacts of the crown fabricated with CIM significantly decreased between Step 0 to Step 3. It has been reported that the amount and direction of tooth displacement of the upper molar depend on the loading points on the occlusal surface.\(^\text{25}\) When the occlusal contacts were located on the buccal cusps of the upper molars only, the upper molar was displaced largely towards the bucco-apical direction with slight rotation.\(^\text{25}\) On the other hand, when the occlusal contacts were located on the lingual cusps of the upper molars only, the upper molar was displaced towards the palato-apical direction with rotation.\(^\text{25}\) The amount of tooth displacement of the upper molar loading on the buccal cusp was greater than that loading on the lingual cusp.\(^\text{25}\) When only the height of occlusal contacts of the buccal cusps of the upper molars were higher than the ideal occlusal height, the occlusal contacts on the lingual cusps (functional cusps) might be removed mistakenly by the practitioner, because of the consequently bucco-apical slight rotation of the upper molar to obtain occlusal contact with the antagonist. This might explain the decrease in the number of occlusal contacts of crowns fabricated with CIM. Thus, the number of occlusal contacts was decreased and the occlusal contacts which were designed on the cast were lost after the occlusal adjustment. The number of occlusal contacts of the crowns fabricated with BIM in each step was compared (Figure 4). There was no significant difference in the number of occlusal contacts of the crowns between Step 0 and Step 1. The occlusal relationship between the upper and the lower molars of the cast with BIM was not so different from that in vivo. Therefore, the distribution of occlusal contacts on the cast was not so different from that at try-in. As for the number of occlusal contacts of the crowns with BIM, there was no significant difference between Step 0 and Step 3.

For this reason, the number of occlusal contacts of the crowns on the cast with BIM could be maintained throughout the process of occlusal adjustment. There was no significant difference in the number of occlusal contacts of the crowns between with CIM and BIM at Step 0 (Figure 2). This fact reflects that there was no difference in the quantity of the occlusal contacts of both crowns fabricated on the cast with CIM or BIM. There is a possibility that the relationship of the upper and lower molars on the casts with CIM are different from that with BIM by taking into consideration the difference of the distribution of occlusal contacts of the adjacent teeth between two kinds of impression methods. Though there was no significant difference between the total number of occlusal contacts of the adjacent teeth on the cast with CIM and that with BIM (figure 9), however, there was a significant difference in the number of occlusal contacts of the adjacent teeth between the functional and non-functional cusps only in BIM (figure 11). This fact might contribute to preserve occlusal contacts on the functional cusps of crowns fabricated with BIM, and, suggested that the
location of occlusal contacts of the crowns after occlusal adjustment can vary between CIM and BIM. The number of occlusal contacts on the functional cusps of the crowns fabricated with BIM was significantly greater than that with CIM in Step 3. These results suggested that the crowns fabricated with BIM had larger number of occlusal contacts around the functional cusps than those of the crowns with CIM. Therefore, the crowns fabricated with BIM might have more functional occlusal surface compared to the crowns fabricated with CIM.

References