Purpose: The purpose of this study was to clarify the influence of changes of occlusal contacts on adjacent tooth displacement during articulation.

Materials and Methods: The amount and direction of displacement of the maxillary left first molar and adjacent teeth were measured using a displacement transducer, Type M-3. Seven subjects were included in this study. On the maxillary left first molar, 8 experimental occlusal contact points were established using platinum foil and these were divided into 2 groups, the buccal and lingual groups, which corresponded to the buccal and lingual cusps, respectively.

Results: During clenching, the buccal group showed differences in the direction of the tooth displacement paths among the 3 teeth (second premolar, first and second molar), but there was no difference in the lingual group and the direction of displacement of these 3 teeth was similar to the natural teeth.

Conclusion: It is necessary to make at least one lingual occlusal contact point to obtain displacement of not only the abutment tooth but also the adjacent teeth.

Key words: Tooth displacement path, three-dimensional analysis, occlusal contact, interproximal contact relation.

Introduction

The occlusal form of prosthesis must be functionally harmonized with the stomatognathic system, especially the periodontal tissues. When the occlusal height of the prosthesis is excessive, it may cause occlusal trauma. In contrast, when it is too low, it may result in various disorders such as unstable centric occlusion and disuse atrophy. If the functional balance of the masticatory system is disturbed, mesial drift may contribute to crowding of the teeth. Many researchers have investigated tooth displacement, one of the indices, expressing the functional state of periodontal tissues. The occlusal contact area changes, as the clenching force becomes stronger. Also, it has been reported that the direction of the path of tooth displacement changed, depending on the position of occlusal contact. In addition, the interproximal contact relation plays an important role in...
maintaining the integrity of the dental arch. At rest, there was a space in the interproximal area, which disappeared during function. This was demonstrated using a CCD microscope. However, it is not yet clear how the occlusal force is dispersed from one tooth to the adjacent one.

The objective of this study was to clarify the influence of changes in the occlusal contact position on adjacent tooth displacement during clenching.

Materials and methods

Seven subjects (2 males, 5 females, average age 27.5 years) were included in this study. This study was approved by the declaration of Helsinki and informed consent was obtained from all the subjects prior to the experiment. All subjects had healthy periodontal tissues and stomatognathic system. The stability of articulation in the intercuspal position was also confirmed. Subjects A to E had normal interproximal contact relations, which was confirmed by resistance when inserting a 50μm thick stainless steel strip. In subjects F and G, a 110μm thick stainless steel strip could be easily inserted into the mesial and distal contact areas and had so-called loose interproximal contact relations.

The maxillary left second premolar and first and second molars were the experimental teeth.

Experimental occlusal contact point

On the maxillary left first molar, 8 experimental occlusal contact points were established using platinum foil (fig. 1). The experimental occlusal contact points were divided into 2 groups, a buccal group (BG) and a lingual group (LG). The BG comprised 4 experimental occlusal contact points, 2 on each buccal cusp designated as point 1 and point 2 for the mesio-buccal cusp, and point 3 and point 4 on the disto-buccal cusp. The LG was also divided into 4 designated experimental occlusal contact points, 5, 6, 7 and 8.

A platinum foil (Ishifuku Metal Industry CO., LTD.) was used to establish the 8 experimental occlusal contact points. The platinum foil was compressed on the model using a press machine to a minimum thickness of 200μm (fig. 2). The foil was then tested intraorally and the occlusal contact points were adjusted. For each fabricated platinum foil, there was only one occlusal contact point remaining after occlusal adjustment and this was confirmed by silicone impression material (Bite-Checker, GC, Japan).

Measurement

A three-dimensional tooth displacement transducer Type M-3 (Miura, 2000) was used to record the three dimensional tooth displacement paths of the test teeth (fig. 3). This measuring device consisted of three pairs of magnets and pickup-heads, universal joints, an aluminum plate for fixation and a measuring probe. The tooth displacement transducer was screwed to a paraocclusal splint. This splint was fixed to the labial surface of the anterior teeth. The linearity error of each transducer for bucco-lingual, mesio-distal and corono-apical directions was less than 2%, within a range of ±200μm. We measured the three dimensional movement of the central point of the buccal surface of the subject tooth with this displacement transducer.

Displacement paths of the maxillary left first molar and adjacent teeth were recorded during clenching at the intercuspal position as follows:
1) Natural teeth.
2) The teeth with experimental occlusal contact points 1-8.

Electromyogram recordings were taken simultaneously from the masseter muscles using bipolar surface electrodes for regulating the intensity of muscle contraction. All subjects were instructed to lightly clench, with a force approximately 15% of the maximal voluntary contraction (MVC). The output signals from the three transducers were amplified and the signals were monitored and recorded on data recorder (PC208Ax, SONY). The data were taken through an AD converter (PC-Scan II, SONY) at 2.5m/sec intervals, and the tooth displacement path was displayed in the horizontal, sagittal, and frontal planes. Measurement of the amount and direction of teeth displacements in the horizontal and frontal planes is shown in fig. 4.

Examination of the state of the adjacent teeth of subjects A to D.

To examine the state of mesial and distal interproximal contact relations of the first molar, the interproximal contact force was measured by pulling out registration strips of 12.5μm thickness (Occlusal registration strips, ARTUS) during clenching at the intercuspal position with natural teeth and the teeth having experimental occlusal contacts points (1-8).

Statistical Analysis

Data were analyzed using the Statistical Package for Medical Science (SPSS Ver.11 for Windows) with the average values of BG and LG. Five specimens were analyzed per group in the normal group and two specimens were analyzed per group in the loose interproximal group. The displacement data of the normal group were analyzed by one-way analysis of variance (paired test). Turkey HSD test at 95% confidence level was then performed. The angle data of the normal group were analyzed by the Hotelling test with Bonferroni’s correction

Results

Table 1 shows the means and standard deviations of the amount of tooth displacement with natural teeth and the teeth having experimental occlusal contact points. In the case of normal group, the amount of tooth displacement of BG and LG of the first molar was larger than the adjacent teeth. But in the case of natural teeth, the second molar showed the largest amount of tooth displacement. In the case of the loose interproximal contact group, BG and LG of the second molar showed the smallest amounts of displacement. During clenching with natural teeth, the first molar showed larger displacements than the adjacent teeth. One-way ANOVA revealed that the amount of the
tooth displacement during clenching with normal interproximal relations was influenced by the teeth (Table 2). The p values of Turkey’s HSD test are shown in Table 3. This test revealed significant differences between the second premolar and first molar of the BG and LG (p= 0.001; p= 0.002), between the first and second molars of the BG and LG (p= 0.0002; p= 0.005) and in the natural tooth (p= 0.011). There was no statistical difference between the second premolar and second molar except in the natural teeth (p=0.003).

Table 4 shows the mean angles and angular deviation of angle data. The mean angles and the results of Hotelling test are shown in Figure 5 and Table 5. The Hotelling test revealed significant differences between the second premolar and first molar of the BG in the horizontal plane (p= 0.003), and the second premolar and second molar of the BG in the horizontal and
frontal planes (p= 0.001; p= 0.015). In the case of LG, no significant differences existed among the 3 teeth except between the first and second molars in the horizontal plane (p=0.041). Figure 6 shows the mean angle of displacement of the subject with loose interproximal contact relations. Table 6 shows the results of the Hotelling test of the natural tooth in BG and LG. The Hotelling test revealed significant differences between the natural tooth and second premolar in the BG (p= 0.0001).

For most of the subjects with normal interproximal contact relations, there was resistance in the interproximal contact area when registration strips were pulled out during clenching with natural teeth. While clenching with the experimental occlusal contact points on the first molar, the resistance increased in the mesial interproximal contact area of all subjects. However, there was generally no resistance in the distal contacts of subject A, B and C.

### Discussion

When a tooth is restored with a crown, proper reconstruction of the occlusal contact points is necessary to maintain the balance of the masticatory system. The first molar was selected for this study because it is the first permanent tooth and a key to the establishment of proper occlusion and arch alignment.

During clenching with natural teeth, the amount of tooth displacement tended to increase from the second premolar to the second molar in the normal interproximal case. The contact position of the lower dental arch and occlusal force has been studied using dental prescale\(^{15}\). It indicated that the occlusal force increases from the anterior to posterior teeth and the maximal occlusal load appears in the second molar region. With occlusal force, the amount of displacement also tended to increase in the cases with normal interproximal contacts. These results revealed a relation between occlusal force and the displacement of the tooth. During clenching with teeth having experimental occlusal contact points, there was a difference between the first molar and adjacent teeth, but there was no difference between the adjacent teeth. In the loose interproximal contact cases, the amount of tooth displacement of the second molar tended to decrease in comparison to first molar in the case of the natural tooth and the teeth having experimental occlusal contact points.

It was found that during clenching with natural teeth, the first molar and the adjacent teeth were displaced in the disto-palatal and apical direction in the normal interproximal relation. It has been reported that the 3-dimensional displacement paths of the posterior teeth were in the disto-palatal and apical direction during function\(^{16,17}\). Our results showed a similar tendency. In the subjects with loose interproximal relations during

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### Table 5. Results of the Hotelling test of the 2nd premolar, 1st and 2nd molars

<table>
<thead>
<tr>
<th></th>
<th>HP</th>
<th>FP</th>
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<tbody>
<tr>
<td>BG</td>
<td>HP</td>
<td>FP</td>
</tr>
<tr>
<td>2nd Premolar and 1st Molar</td>
<td>16.82</td>
<td>0.003</td>
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<tr>
<td>1st Molar and 2nd Molar</td>
<td>7.30</td>
<td>0.02</td>
</tr>
<tr>
<td>2nd Premolar and 2nd Molar</td>
<td>23.41</td>
<td>0.001</td>
</tr>
<tr>
<td>LG</td>
<td>HP</td>
<td>FP</td>
</tr>
<tr>
<td>2nd Premolar and 1st Molar</td>
<td>1.64</td>
<td>0.23</td>
</tr>
<tr>
<td>1st Molar and 2nd Molar</td>
<td>5.90</td>
<td>0.041</td>
</tr>
<tr>
<td>2nd Premolar and 2nd Molar</td>
<td>0.27</td>
<td>0.61</td>
</tr>
</tbody>
</table>

### Table 6. Results of the Hotelling test of natural teeth with BG and LG

<table>
<thead>
<tr>
<th></th>
<th>HP</th>
<th>FP</th>
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<tbody>
<tr>
<td>BG</td>
<td>HP</td>
<td>FP</td>
</tr>
<tr>
<td>2nd Premolar NT and BG</td>
<td>56.31</td>
<td>0.0001</td>
</tr>
<tr>
<td>NT and LG</td>
<td>0.12</td>
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<td>1st Molar NT and BG</td>
<td>13.43</td>
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<td>NT and LG</td>
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<td>2nd Molar NT and BG</td>
<td>2.92</td>
<td>0.12</td>
</tr>
<tr>
<td>NT and LG</td>
<td>0.29</td>
<td>0.60</td>
</tr>
<tr>
<td>LG</td>
<td>HP</td>
<td>FP</td>
</tr>
<tr>
<td>2nd Premolar NT and BG</td>
<td>5.67</td>
<td>0.04</td>
</tr>
<tr>
<td>NT and LG</td>
<td>0.80</td>
<td>0.39</td>
</tr>
<tr>
<td>1st Molar NT and BG</td>
<td>4.26</td>
<td>0.07</td>
</tr>
<tr>
<td>NT and LG</td>
<td>0.76</td>
<td>0.40</td>
</tr>
<tr>
<td>2nd Molar NT and BG</td>
<td>1.68</td>
<td>0.23</td>
</tr>
<tr>
<td>NT and LG</td>
<td>0.92</td>
<td>0.36</td>
</tr>
</tbody>
</table>
clenching with natural teeth, the teeth were displaced mostly in the mesio-buccal and apical directions.

During clenching with the teeth having experimental occlusal contact points, the first molar in the BG had a greater influence on the second premolar than the second molar. In the case of the BG, the displacement path of the first molar was in the mesio-buccal and apical directions. This tendency may be due to the axial tooth inclination or the anatomical configuration of the buccal roots curving distally. There is proof that displacement in a mesio-buccal direction disturbs the harmony of dental arch. One occlusal contact on the buccal cusp cannot lead to physiological tooth displacement, that is, the dental arch may expand in a non-physiological direction.

In the case of the BG, the second premolar tended to displace more in a mesial direction compared with the first molar. This is because the occlusal force is transmitted directly through the interproximal contact in a mesial direction. As a result of distortion of the buccal alveolar bone of the first molar, the alveolar bone of the second premolar is also distorted in the buccal direction. Displacement of the teeth also occurs because of distortion of the periodontal ligament and alveolar bone. Therefore, in normal interproximal contact relations, the teeth are directly influenced by these contacts and distortion of periodontal tissues.

The displacement of the second molar in the BG was in a disto-buccal direction, in contrast to those of the first molar. When the state of contact pressure was
examined with registration strips, there was generally no resistance between the first and second molars. This indicates that the relation of interproximal contact was loose. Therefore, displacement in a distal direction might be an effect of distortion of the alveolar bone, rather than through the interproximal contact. In the case of the BG, displacement of the second molar was influenced by distortion of the buccal alveolar bone, similar to that of the second premolar.

There was no significant difference among the 3 teeth in the LG and these teeth tended to displace in a disto-palatal direction. These directions were similar to those of the displacement paths during clenching with natural teeth. When the tooth displaces in a palatal direction, the dental arch form tends to shorten and this effect results in displacement in the same direction. These occlusal contact points are most important when tracing the natural tooth displacement.

The subjects with loose interproximal contact relations revealed a tendency to displace in the mesial direction during clenching with teeth having experimental occlusal contact points. In this case, axial inclination occurred more often, particularly in the mesial direction, because the adjacent tooth did not restrain the displacement of the teeth.

**Conclusion**

After a thorough investigation on the influence of
experimental occlusal contacts on adjacent teeth, we drew the following conclusions:
1. The second premolar is easily influenced by occlusal contacts on the buccal cusps of adjacent teeth and the tooth displaced in what is considered to be an anti-physiological direction.
2. With occlusal contact on the lingual cusps of the adjacent teeth, the displacement path is similar as during clenching with natural teeth.
3. When it is possible to insert a stainless steel strip of 110 μm thickness in the interproximal region, the teeth will be displaced in the mesial direction and the occlusal force will be dispersed irregularly within the dental arch.
4. We suggest that at least one occlusal contact should be present on the lingual cusp to make natural tooth displacement possible; also the adjacent teeth will be displaced in the same direction in the same arch.

References