CHANGES IN BUCCAL ARCH SEGMENT DURING 
THE PERIOD OF CHANGE OF DENTITION

BY

Tadashi Noda*¹

ABSTRACT

The object of this study was to know what changes take place on the buccal segment during the period of change of dentition, and the following conclusions can be made from its result.

1) The space for the alignment of the permanent buccal teeth changes during the period of change of dentition in buccal segment. The main increase of this space occurs during the period of eruption of the permanent canine and some of the permanent first premolar. These kinds of increase make it possible for the permanent canine and the permanent first premolar to align normally. The main decrease of this space takes place through the replacement of the deciduous second molar by its predecessor.

2) As the permanent canine positions more mesially than its predecessor, the permanent first molar is able to migrate mesially more than the amount of the leeway space between the crown diameters of the deciduous buccal teeth and those of their permanent successors.

3) The leeway space is not always necessary for the permanent buccal teeth to align, and it is a part of available space for the alignment of the permanent buccal teeth.

INTRODUCTION

To guide the dentition from the deciduous to the permanent is one of the important objects in the dentistry for children. For this purpose, it is important to know the process of alignment of the permanent teeth. Based on this point of view, the present study was undertaken to know what changes take place on the buccal segment during the period of change of dentition.

The permanent buccal teeth erupt after the permanent incisors and first molars appear, and align on the space between the distal surface of the permanent lateral incisor and the mesial surface of the permanent first molar. It is unknown what changes take place on the buccal segment

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through the replacement of the deciduous buccal teeth by the permanent successors, especially the permanent canine which has a larger diameter than its predecessor and the permanent second molar with less diameter than its deciduous molar. Then, the changes in buccal segment during the period of change of dentition were studied by the observation of longitudinal materials.

**Materials**

A longitudinal study was made on 305 Japanese elementary school children in Tokyo. Study casts were made from alginate impressions semi-annually for 6 years. Fifty-one cases in maxilla and 38 cases in mandible were selected for this report. In these cases caries activity did not affect the interproximal surface of the deciduous buccal teeth and the alignment of the permanent buccal teeth was clinically normal. An evaluation of alignment was made according to the methods described by Massler\(^1\), Lundström\(^2\), and Kirk\(^3\).

Observations were made separately on each buccal segment, each side of both jaws. Table 1 presents the number of cases on each buccal segment. Eight different eruption orders of permanent buccal teeth were observed in maxilla and seven different eruption orders were noted in mandible (Table 2). The most frequent in maxilla was the (5,4) 5 order and the next the 3 4 5 order, these two orders appearing in approximately 53%. In mandible, the most frequent was the 3 4 5 order which appeared in about 61%.

**Methods**

For the observation of changes on the buccal segment during the period of change of dentition, the following measurements were taken from dental casts of the individual series.

1) Mesio-distal crown diameters of the deciduous and permanent buccal teeth.

2) Three dimensions on the dental arch shown in Fig. 1.

<table>
<thead>
<tr>
<th>Table 1. Number of observations on each buccal segment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Maxilla</td>
</tr>
<tr>
<td>Mandible</td>
</tr>
</tbody>
</table>
Table 2. Order of eruption

<table>
<thead>
<tr>
<th>Eruption order</th>
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<th>Mandible</th>
</tr>
</thead>
<tbody>
<tr>
<td>3—4—5</td>
<td>13</td>
<td>23</td>
</tr>
<tr>
<td>4—3—5</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>4—5—3</td>
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<td></td>
</tr>
<tr>
<td>5—4—3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>(3,4)—5</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>4—(3,5)</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>(4,5)—3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3—(4,5)</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>(3,4,5)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>51</td>
<td>38</td>
</tr>
</tbody>
</table>

Fig. 1. Measurements on the dental arch.

(1) **Buccal Arch Length**: The linear distance from the distal surface of the lateral permanent incisor to the mesial surface of the permanent first molar.

(2) **I.D.—2d.**: The linear distance from the lingual interdental papilla of the central incisors to the distal surface of the permanent lateral incisor.

(3) **I.D.—6m.**: The linear distance from the lingual interdental papilla
of the central incisors to the mesial surface of the permanent first molar. These measurements were made with a sliding caliper to an accuracy of 0.05 mm.

The described dimensions on dental casts of the individual series were observed from the time before changing of dentition in buccal segment to the time of the alignment of the permanent buccal teeth. Changes in three different dimensions were drawn on graphs of the line individually, and factors related to changes of these graphs were examined.

**FINDINGS**

1. Change in Buccal Arch Length

   The distance from the distal surface of the lateral permanent incisor to the mesial surface of the first permanent molar is called the buccal arch length. During the period of change of dentition, various dimensional changes, such as the increase and/or decrease, were observed on the buccal arch length of individuals according to the order, interval, and time of eruption of the permanent buccal teeth.

   In maxilla, 50 out of 51 cases, approximately 98%, showed an increasing change in length during this period, and 28 out of 38 cases, about 74% in mandible (Table 3).

   Table 3 presents the number of cases belonging to each of changing patterns of the buccal arch length. As shown in Table 4, in about 86% of cases in maxilla and about 58% of cases in mandible, the buccal arch length during the transitional dentition in buccal segment increased more

<table>
<thead>
<tr>
<th>Eruption order</th>
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<th></th>
<th></th>
<th></th>
<th>Mandible</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Increase</td>
<td>Decrease</td>
<td>Increase-decrease</td>
<td>Total</td>
<td>Increase</td>
</tr>
<tr>
<td>3—4—5</td>
<td>3</td>
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<td>3</td>
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<tr>
<td>4—3—5</td>
<td>4</td>
<td>7</td>
<td>7</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>4—5—3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>5—4—3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>(3,4)—5</td>
<td>1</td>
<td>13</td>
<td>14</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>4—(3,5)</td>
<td>2</td>
<td>6</td>
<td>8</td>
<td></td>
<td>1</td>
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<tr>
<td>(4,5)—3</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3—(4,5)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>(3,4,5)</td>
<td>4</td>
<td>1</td>
<td>46</td>
<td>51</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 3. Number of changing patterns of the buccal arch length
than that before the replacement of the buccal teeth. The average increment in these cases was 1.10 mm, with a maximum of 2.25 mm and a minimum of 0.15 mm in maxilla, and 0.55 mm, with a maximum of 1.10 mm and a minimum of 0.05 mm in mandible.

1) Maxilla

1) Changing Pattern of the Buccal Arch Length

As shown in Table 3, the increase-decrease type of changing pattern was noted in approximately 90% of cases. The increase type was observed in four cases and the decrease type in only one case.

a) Increase-Decrease Type of Changing Pattern

Fig. 2 illustrates examples of cases of the increase-decrease type of changing pattern. In these cases, the buccal arch length tends to increase during the time of eruption of the permanent canine and first premolar, and to decrease during that of the second premolar. The case shown in Fig. 2–A is of the upper left buccal segment of No. 63–067 and the change on the buccal arch length was in the same fashion as mentioned above. The arrows indicate the emergence of each permanent tooth. The buccal arch length was 22.10 mm just before the change of dentition in buccal segment and 22.15 mm on the last observation. The table on the right of the graph shows the crown diameters of the deciduous and permanent buccal teeth and the amount of the leeway space.

The changing patterns in Figs. 2–A and 2–B were about the same. In Fig. 2–C, even though a remarkable decrease was noted in buccal arch length during the time of shedding of the deciduous second molar and the emergence of the permanent second premolar, the length was restored during the time of eruption of the permanent canine and first premolar. Owing to this increase, the canine would be able to erupt normally on the dental arch, where the first molar and the premolars had already been in contact with each other.

In Fig. 2–D, by contrast, a decrease in buccal arch length was observed after the emergence of the permanent canine. In this case, there were spaces around the deciduous canine on the cast before the change of dentition. This space was 1.75 mm in length and was larger than the difference

<table>
<thead>
<tr>
<th></th>
<th>No. of observation</th>
<th>No. of increase</th>
<th>%</th>
<th>Average amount (mm)</th>
<th>Min.–Max. (mm)</th>
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</thead>
<tbody>
<tr>
<td>Maxilla</td>
<td>51</td>
<td>46</td>
<td>86</td>
<td>1.10</td>
<td>0.15–2.25</td>
</tr>
<tr>
<td>Mandible</td>
<td>38</td>
<td>22</td>
<td>58</td>
<td>0.55</td>
<td>0.05–1.10</td>
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</tbody>
</table>
Fig. 2. Changing pattern of the buccal arch length (maxilla) (increase-decrease type).

in crown diameters between the deciduous and permanent canine. The erupted permanent canine contacted normally with both the permanent lateral incisor and the deciduous first molar, and this interdental space disappeared spontaneously. From these facts, it appears that the decrease in buccal arch length at this stage may result from the loss of a surplus
CHANGES IN Buccal ARCH SEGMENT

interdental space remaining after alignment of the permanent canine.

In the case shown in Fig. 2–E, the buccal arch length decreased at the emergence of the permanent first premolar, and then increased till the emergence of the permanent canine. Thereafter, no changes were noted with eruption of the permanent second molar. This is due both to the

Fig. 3–A

<table>
<thead>
<tr>
<th>No. 63–174 R</th>
<th>C/3</th>
<th>D/4</th>
<th>E/5</th>
<th>Sum.</th>
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<tbody>
<tr>
<td>Deciduous</td>
<td>6.95</td>
<td>6.90</td>
<td>8.70</td>
<td>22.55</td>
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<tr>
<td>Permanent</td>
<td>7.85</td>
<td>6.60</td>
<td>5.85</td>
<td>20.30</td>
</tr>
<tr>
<td>Leeway space</td>
<td></td>
<td></td>
<td></td>
<td>2.25</td>
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</table>

Fig. 3–B

<table>
<thead>
<tr>
<th>No. 64–135 R</th>
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<tbody>
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<td>C/3</td>
</tr>
<tr>
<td>Deciduous</td>
</tr>
<tr>
<td>Permanent</td>
</tr>
<tr>
<td>Leeway space</td>
</tr>
</tbody>
</table>

Fig. 3–C

<table>
<thead>
<tr>
<th>No. 63–156 R</th>
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</thead>
<tbody>
<tr>
<td>C/3</td>
</tr>
<tr>
<td>Deciduous</td>
</tr>
<tr>
<td>Permanent</td>
</tr>
<tr>
<td>Leeway space</td>
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Fig. 3–D

<table>
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<td>C/3</td>
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</tr>
<tr>
<td>Permanent</td>
</tr>
<tr>
<td>Leeway space</td>
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Fig. 3–E

<table>
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<th>No. 63–158 L</th>
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</thead>
<tbody>
<tr>
<td>C/3</td>
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<tr>
<td>Permanent</td>
</tr>
<tr>
<td>Leeway space</td>
</tr>
</tbody>
</table>

Fig. 3. Changing pattern of the buccal arch length (maxilla) (increase-decrease type)
proximity of the time of eruption and to the same amount of the change in length during the time of eruption, the increase and the decrease, between the permanent canine and second premolar.

Changing patterns of the buccal arch length observed during the time of simultaneous eruption of two or three buccal teeth are shown in Fig. 3. In the cases shown in Figs. 3–A and 3–B, both the permanent canine and first premolar emerged at the same period. In the case of Fig. 3–A, the buccal arch length increased till the emergence of both teeth, and then decreased towards and after the eruption of the permanent second premolar. This was almost the same changing pattern as shown in Figs. 2–A and 2–B. In the case of Fig. 3–B, by contrast, the decrease instead of the increase in buccal arch length was observed at the time of cusp emergence of the permanent canine and first premolar. With the progress of their eruption, however, the change in length turned to the increase and thereafter started to decrease again during the time of eruption of the permanent second premolar.

In Fig. 3–C, the buccal arch length kept on increasing even after the emergence of all buccal teeth and, after some time the change in length turned to the decrease.

In the case shown in Fig. 3–D, after the length decreased at the simultaneous emergence of the permanent first and second premolars, the buccal arch length increased greatly in accordance with the time of exchange between the deciduous and permanent canine. This increment in the latter stage seems to be for the accommodation of a larger permanent canine to the dental arch, on which the first molar and two permanent premolars were in contact with each other before.

The case with simultaneous emergence of all three buccal teeth followed the changing pattern presented in Fig. 3–E. The buccal arch length increased with those eruption and decreased thereafter. Even though the amount of the leeway space, or the difference in the sum of crown diameters in buccal segment between the deciduous and the permanent was approximately zero, the buccal arch length increased during the period of eruption of the permanent buccal teeth.

b) Increase Type of Changing Pattern

In four cases belonging to the increase type, the buccal arch length kept increasing through the period of change of dentition in buccal segment. An example is shown in Fig. 4.

c) Decrease Type of Changing Pattern

The decrease type was noted in only one case shown in Fig. 5. In this case, both the permanent canine and first premolar erupted about the same
period and the permanent second premolar started to erupt soon thereafter. The proximity of the time of their eruption and the decrease exceeding the increase in length seems to induce this changing pattern.

(2) Time of Change in Buccal Arch Length

Table 5 presents the relation between the change of the buccal arch length and the stage of eruption of each buccal tooth. During the time of eruption of the permanent canine, 22 out of 27 cases showed the increasing change in pre-eruption stage and 15 out of 27 cases did so in post-eruption stage. The buccal arch length generally increased in pre- and/or post-
eruption stage of the permanent canine. In three cases showing length decrease in pre-eruption stage, only cusp of this tooth was noted at its emergence and the length increased with eruption of this tooth in post-eruption stage. In most cases, however, while the cusp emergence of the permanent canine was noted, the buccal arch length increased in pre-eruption stage. In the case of the decrease in post-eruption stage, a short time after the emergence of the permanent canine, the other permanent buccal teeth erupted, especially the permanent second premolar. One of these decreasing cases is shown in Fig. 2-B.

In pre- or post-eruption stage of the permanent first premolar, changes in buccal arch length were like those of the permanent canine. Since the eruption of any tooth before emergence of the permanent first premolar affected the dimensional change of the buccal arch length, the observation was made on the change in some cases in which the first premolar erupted before the eruption of other buccal teeth. In these cases, an increase was noted in ten cases, decrease in six cases, and no change in three cases. The permanent first premolar has larger diameter than the deciduous first molar in some cases and, in other cases, less diameter than the deciduous predecessor. In order to detect the effect of this tooth size difference on the dimensional change of the buccal arch length, examination was made on the relationship between the difference of crown diameters and the tendency of the change in length during the time of eruption of the permanent first premolar (Table 6). In the cases showing increase in length till the emergence of the first premolar, this tooth had a larger diameter than the deciduous first molar. On the other hand, in the cases showing decrease, the first premolar had less diameter than its predecessor. In one case, the buccal arch length decreased while the first premolar had 0.8 mm larger diameter than its predecessor. In this case, there was 1.00 mm space between the permanent lateral incisor and the deciduous canine at the emergence of the first premolar. From this fact, the loss of this space seems to induce the decrease in length.

<table>
<thead>
<tr>
<th>Difference (D-4) mm</th>
<th>∅ D&gt;4</th>
<th>∅ D&lt;4</th>
</tr>
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<tbody>
<tr>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td></td>
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</tr>
<tr>
<td>0.3</td>
<td></td>
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</tr>
<tr>
<td>0.2</td>
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<td>0.0</td>
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<tr>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6. Relation between changes in buccal arch length and difference of crown diameters (D-4)
The increase in length following the emergence of the first premolar was noted in 23 out of 34 cases. In nine cases showing decrease, the permanent second premolar appeared a short time after the emergence of the first premolar. The case shown in Fig. 2-D is an example of such cases.

During the time of eruption of the permanent second premolar, the decrease in buccal arch length was generally noted. In six cases showing increase in the pre-eruption stage, the permanent canine and/or first premolar erupted a short time before the emergence of the second premolar. In post-eruption stage, the increase in buccal arch length was noted in six cases and, the increase in length depended on the emergence of other buccal teeth (Fig. 2-E).

2) Mandible

(1) Changing Pattern of the Buccal Arch Length

As shown in Table 3, about 74% of cases had the increase-decrease type of changing pattern, and the decrease type was noted in 10 cases and the increase type in none.

a) Increase-Decrease Type of Changing Pattern

In the case shown in Fig. 6-A, the buccal arch length decreased at the emergence of the permanent canine. With the eruption of this tooth, the buccal arch length increased. It seems that this increase made it possible for this tooth to align. The buccal arch length decreased thereafter.

In the case of Fig. 6-B, even though the crown diameter of the permanent first premolar was less than that of its predecessor, the buccal arch length increased slightly, then the length decreased at the emergence of the permanent canine, and in conjunction with the eruption of this tooth the increase in length was noted again. Thereafter, the decrease in length was noted during the time of eruption of the permanent second premolar.

In the case shown in Fig. 6-C, the decrease in length continued during the eruption of the permanent canine. However, in this case, the deciduous first molar had been shedding during the period of eruption of the permanent canine. The permanent canine would be able to make use of this space to erupt. The buccal arch length increased during the time of eruption of the first premolar and this increase seems to make up the lack of space for that tooth to align. In the case of Fig. 6-D, the buccal arch length kept increasing till the emergence of the second premolar. This increase in pre-eruption stage of the second premolar resulted from the eruption of the permanent canine and first premolar.

b) Decrease Type of Changing Pattern

In the case shown in Fig. 7, the second premolar erupted just after the cusp emergence of the permanent canine and first premolar. The buccal
Fig. 6. Changing pattern of the buccal arch length (mandible) (increase-decrease type)

Fig. 7. Changing pattern of the buccal arch length (mandible) (decrease type)
Table 7. Changes in buccal arch length (mandible)

<table>
<thead>
<tr>
<th>Tooth and stage of eruption</th>
<th>Canine</th>
<th>1st Premolar</th>
<th>2nd Premolar</th>
</tr>
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<tbody>
<tr>
<td>Increase</td>
<td>11</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>Decrease</td>
<td>13</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>No change</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

arch length showed only a decrease.

(2) Time of Change in Buccal Arch Length

Table 7 presents the change in buccal arch length during the time of eruption of each buccal tooth. In 13 out of 28 cases, the buccal arch length decreased in pre-eruption stage of the permanent canine. In these cases, the buccal arch length decreased at the cusp emergence of the permanent canine and then increased in conjunction with further eruption of this tooth (Figs. 6–A and 6–B). In post-eruption stage of the permanent canine, the increase in length was noted in approximately 54% of cases and the decrease was observed in about 29%. In those cases followed by decrease, the permanent premolar erupted a short time after the emergence of the permanent canine. In the case shown in Fig. 6–C, a decrease in length was observed since the deciduous first molar was shedding during the period of eruption of the permanent canine. In most cases, except those described above, the buccal arch length increased in pre- and/or post-eruption stage.

During the time of eruption of the first premolar, the buccal arch length decreased in most cases (Fig. 6–A). Since the lower first premolar usually has less diameter than its predecessor, the buccal arch length generally decreased through the replacement. In the case of Fig. 6–B, however, even though the first premolar had less diameter than its predecessor, the increase in length was noted at the emergence of the first premolar. This fact may suggest that the tooth eruption is one of factors increasing the buccal arch length.

In the case shown in Fig. 6–C, the permanent canine erupted in the space for the first premolar, and the space for the first premolar was not sufficient when it appeared. Therefore, in order that this tooth was able to erupt and to align, the buccal arch length increased during the time of eruption of this premolar.
During the time of eruption of the second premolar, the buccal arch length decreased in most cases. In only one case shown in Fig. 6-D, an increase in buccal arch length was observed at the pre-eruption stage. This increase depended on the eruption of the permanent canine and first premolar.

2. I.D.–2d. and I.D.–6m.

In order to know what causal factors induce the dimensional changes on the buccal arch length, examinations were made on what relative changes took place between the buccal arch length and I.D.–2d., and I.D.–6m. during the period of change of demition in buccal segment. I.D.–2d. is the linear distance from the lingual interdental papilla of the central incisors to the distal surface of the permanent lateral incisor, and I.D.–6m. means the linear distance from that to the mesial surface of the permanent first molar.

1) Maxilla

Fig. 8 illustrates the most frequently observed changes on the three dimensional length (buccal arch length, I.D.–2d., and I.D.–6m.). In the case shown in Fig. 8–A, the buccal arch length and I.D.–6m. showed about the same changing pattern but the change of I.D.–2d. appeared to be reverse of those changes. When the increase in buccal arch length took place, the decrease of I.D.–2d. was generally noted. This tendency was especially noted during the eruption of the permanent canine and was observed in 84% of the cases. This may suggest that the lateral incisor migrates mesially during the time of eruption of the permanent canine and the increase in buccal arch length depends on this migration. In the case shown in Fig. 8–A, the buccal arch length decreased and I.D.–2d. increased slightly during the eruption of the second premolar. From this fact, it can be considered that not only the mesial migration of the permanent first molar but the distal shift of the lateral incisor take place through the replacement of the deciduous second molar by the permanent one, and it is suggested that the crowding in anterior segment would be released during this period.

In the case shown in Fig. 8–B, the changes in buccal arch length and I.D.–6m. showed similar changing patterns as those in Fig. 8–A. However, the increase of I.D.–2d. was not observed during the time of eruption of the second premolar. Since the permanent canine went on to erupt in time with the eruption of the second premolar, the lateral incisor migrated mesially and the increase of I.D.–2d. was not noted. However, it took a long time from the emergence of the permanent canine to that of the second premolar, and I.D.–2d. increased at the emergence of the second premolar (Fig. 8–C). In the case shown in Fig. 8–C, I.D.–2d. increased at
the shedding of the deciduous canine. As the shedding of the deciduous canine appeared on the cast, I.D.–2d. generally increased.

In the case shown in Fig. 9-B, the order of eruption was 5 4 3. The buccal arch length and I.D.–6m. decreased till the emergence of the permanent second premolar and increased thereafter. On the other hand, I.D.–2d. increased through the replacement of the deciduous second molar by
Fig. 9. Relation of changes in three dimensions (maxilla)

its successor. In conjunction with the eruption of the buccal teeth, the buccal arch length and I.D.–6m. increased, and I.D.–2d. decreased. In the case shown in Fig. 9–C, three permanent buccal teeth appeared on the same cast. The buccal arch length increased during the time of eruption of these three teeth and decreased thereafter, and then, I.D.–2d. and I.D.–6m. decreased at the emergence of these three teeth. These changes may suggest that the increase in buccal arch length occurred in canine region while the
permanent first molar migrated mesially.

2) Mandible

The most frequent eruption order in mandible was 3 4 5 which was noted in about 61%. In the cases of this order, most frequent changing patterns of the three lengths are shown in Figs.10–A and 10–B. In the case of Fig. 10–A, the buccal arch length increased during the time of eruption

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### Fig. 10–A

<table>
<thead>
<tr>
<th></th>
<th>C/3</th>
<th>D/4</th>
<th>E/5</th>
<th>Sum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deciduous</td>
<td>6.15</td>
<td>8.70</td>
<td>10.60</td>
<td>25.45</td>
</tr>
<tr>
<td>Permanent</td>
<td>7.85</td>
<td>7.95</td>
<td>7.95</td>
<td>23.75</td>
</tr>
</tbody>
</table>

Leeway space | 1.70 |

---

### Fig. 10–B

<table>
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<tr>
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<th>D/4</th>
<th>E/5</th>
<th>Sum.</th>
</tr>
</thead>
<tbody>
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<td>8.35</td>
<td>10.75</td>
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<tr>
<td>Permanent</td>
<td>7.10</td>
<td>7.55</td>
<td>7.70</td>
<td>22.35</td>
</tr>
</tbody>
</table>

Leeway space | 2.80 |

---

### Fig. 10–C

<table>
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<tr>
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<th>D/4</th>
<th>E/5</th>
<th>Sum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deciduous</td>
<td>5.90</td>
<td>8.25</td>
<td>10.25</td>
<td>24.40</td>
</tr>
<tr>
<td>Permanent</td>
<td>7.15</td>
<td>8.00</td>
<td>8.05</td>
<td>23.20</td>
</tr>
</tbody>
</table>

Leeway space | 1.20 |

---

Fig. 10. Relation of changes in three dimensions (mandible)
of the permanent canine and decreased thereafter. On the other hand, I.D.-2d. went on decreasing till the emergence of the second premolar, and it increased transiently later.

In the case shown in Fig. 10-B, an increase on I.D.-6m. was noted as the buccal arch length and I.D.-2d. decreased at the emergence of the permanent canine. This increase of I.D.-6m. may suggested the growth on the anterior segment or on the part of the permanent first molar. After the emergence of the permanent canine, the three lengths changed in the same changing patterns as shown in Fig. 10-A.

Fig. 10-C presents the case in which the emergence of three buccal teeth was noted on the same cast. Three length appeared to decrease only.

**Discussion**

The permanent buccal teeth erupt after the emergence of the permanent incisors and first molars, and align on the part of the dental arch between the distal surface of the permanent lateral incisor and the mesial surface of the permanent first molar. However, it is unknown what changes take place on the buccal segment through the replacement of the deciduous buccal teeth by the permanent successors. The author studied the changes in buccal arch segment during the period of change of dentition by observation on the longitudinal dental casts.

1. Changes in Buccal Arch Length during the Change of Dentition
   1) Increase in Buccal Arch Length

   (1) Time of the Increase in Buccal Arch Length

   As shown in Tables 5 and 7, the main increase in buccal arch length takes place during the time of eruption of the permanent canine. Since the permanent canine has a larger diameter than the deciduous one, the space for the permanent canine is not enough to align through the replacement of the deciduous canine by the permanent successor. Therefore, this increase during the time of eruption of the permanent canine can make up for the lack of space of the permanent canine to align. As shown in Table 6, the increase in buccal arch length appears more frequently when the permanent first premolar has a larger diameter than its predecessor than when the permanent one has less diameter than its predecessor. And the increase during the time of eruption of the first premolar is observed more often in maxilla than in mandible, and the increase in buccal arch length is little noted through the replacement of the large deciduous second molar by the small permanent second premolar.

   From these facts, it can be considered that the increase in buccal arch
length occurs during the time of eruption of the permanent buccal tooth which has a larger diameter than the predecessor. However, in the case shown in Fig. 6-B, the increase in buccal arch length appeared during the eruption of this tooth though the permanent first premolar had less diameter than its predecessor and the space for the permanent first premolar was enough for this tooth to align. This fact may suggest that the eruptive force of the permanent buccal tooth is one of the factors for increase in buccal arch length.

(2) Regions of the Increase in Buccal Arch Length

It is considered that the following two factors make it possible for the buccal arch length to increase.

a) Mesial Migration of the Permanent Lateral Incisor

Since the increase in buccal arch length appeared during the time of eruption of the permanent canine, it can be considered that the mesial migration of the permanent lateral incisor is one of these factors. As reported by Broadbent1, the incisor spaces are closed and the permanent incisors align normally during the time of eruption of the permanent canine. The permanent canine during its eruption makes the lateral incisor to move mesially and closes the incisor spaces. As shown in Figs. 8 to 10, the decrease of I.D.–2d. was noted when the buccal arch length increased during the eruption of the permanent canine. This finding proves his investigations. From these facts, it can be considered that incisor spaces allow the permanent canine to align and the mesial surface of this tooth positions more mesially than that of the deciduous canine.

However, even in the case without incisor spaces, the increase in buccal arch is observed. Table 8 presents the difference of the changes in buccal arch length during the eruption of the permanent canine in the cases with and without incisor spaces. In both jaws, the increase in buccal arch length was observed in the cases without incisor spaces. As the increase in buccal arch length was observed during the eruption of the permanent canine, the increase of I.D.–6m. generally appeared, and when I.D.–2d. decreased during the period of eruption of the permanent canine, the buccal arch length and I.D.–6m. increased (Figs. 8 to 10). These facts may suggest the growth in anterior segment described by Lebret5).

b) Lateral Movement and Inclination of the Permanent First Molar

Since the buccal arch length is the linear distance from the distal surface of the permanent lateral incisor to the mesial surface of the permanent first molar, the increase in buccal arch length can occur by the lateral movement and inclination of the permanent first molar. As described by Moorress6 and Knott7, the arch width between the permanent first molar
Table 8. Relation between the change on the buccal arch length during the eruption of the permanent canine and incisor space

<table>
<thead>
<tr>
<th>Incisor space</th>
<th>Maxilla</th>
<th>Mandible</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spaced . Closed . Total</td>
<td>Spaced . Closed . Total</td>
</tr>
<tr>
<td>Buccal arch length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>26  23  49</td>
<td>9   16  25</td>
</tr>
<tr>
<td>Decrease</td>
<td>1   1   2</td>
<td>4   9   13</td>
</tr>
<tr>
<td></td>
<td>27  24  51</td>
<td>13  25  38</td>
</tr>
</tbody>
</table>

Spaced: Incisor spaces were noted before the emergence of the permanent canine.
Closed: No incisor space appeared before the emergence of the permanent canine.

increases in both jaws till the age of 14 or 15. This increase can affect the increase in buccal arch length. In addition to these factors, the growth of the jaw and alveolar process can be considered. However, as stated by Nakamura and Savara, the jaws grow a little during the period of change of dentition in buccal segment. Since the growth of the alveolar process is about the same as that of the jaw, it can be considered that the growth of the jaw and alveolar process has little affected on the increase in buccal arch length.

2) Decrease in Buccal Arch Length

(1) Time of the Decrease in Buccal Arch Length

The decrease in buccal arch length generally appeared through the replacement of the deciduous second molar by its successor. The decrease resulting from the shedding of the deciduous canine and first molar was noted when it took long from the shedding of the deciduous tooth to the emergence of its permanent successor. If the permanent second premolar erupts during the time of eruption of the permanent canine, the decrease during the eruption of the permanent second premolar is often compensated by the increase through the eruption of the permanent canine. Examples of this type of change are shown in Figs. 2–E, 3–C, 4, and 6–D.

(2) Regions of the Decrease in Buccal Arch Length

Most of the decrease in buccal arch length appeared through the replacement of the deciduous second molar by the permanent successor and, during the same period, the decrease of I.D.–6m. was generally noted. From these facts, the mesial migration of the permanent first molar described by Korkhaus, Bonnar, Lebret, Krakowiak, and Biggerstaff is the main factor for decrease in buccal arch length.
In addition to this mesial migration of the permanent first molar, the distal movement and distal inclination of the permanent lateral incisor can cause the buccal arch length to decrease. As shown in Fig. 8–C, the decrease in buccal arch length appeared at the shedding of the deciduous canine or the deciduous first molar. At this time, the increase of I.D.–2d. was noted. In these cases, in conjunction with the eruption of the permanent canine or the first premolar, the increase in buccal arch length and decrease of I.D.–2d. appeared.

2. Space for the Alignment of Permanent Buccal Teeth

The permanent canine is never smaller than its deciduous predecessor, while the permanent second premolar is always smaller than the corresponding deciduous tooth. The upper deciduous first molar is as often larger as smaller than its successor, while the lower permanent tooth is less than its predecessor. Therefore, through the alignment of the permanent buccal teeth, there is enough space for the alignment of the permanent second premolar and the lower permanent first premolar. However, the space for the permanent canine is always lacking for the alignment of this tooth. From these facts, the biggest question on the alignment of the permanent buccal teeth is what makes up for the lack of space for the permanent canine to align.

1) Space for the Alignment of Each Permanent Buccal Tooth

   (1) Canine

   In cases of the following conditions, the space for the permanent canine at emergence is not enough for this tooth to align.

   a. Cases in which the permanent canine erupts as the first of the permanent buccal teeth.

   b. Cases in which the permanent canine erupts after the alignment of the permanent first premolar and before the shedding of the deciduous second molar.

   c. Cases in which the permanent canine erupts after the permanent first premolar, the second premolar and the permanent first molar are in contact with each other.

   d. Cases in which the permanent canine and first premolar erupt during the same period and before the shedding of the deciduous second molar.

   In cases described above, the following discussion can be made how the permanent canine is able to align.

   a) Increase in Buccal Arch Length

   As shown in Tables 5 and 7, the increase in buccal arch length was noted at the emergence of the permanent canine. This tendency was re-
markable in maxilla and at the emergence of the permanent canine in the
first of the three permanent buccal teeth, and the average increment on the
buccal arch length shown in Table 4 was 1.10 mm in maxilla and 0.55 mm
in mandible. These increments are not small for the difference of crown
diameter between the deciduous canine and its permanent successor, and
between the sum of crown diameters of the deciduous canine and first
molar, and that of their permanent successors.

Cases shown in Figs. 2–A, 2–B, 2–D, 2–E, 6–A, 6–B, 6–C, and 10–A are
applicable to cases of a and b. In these cases, the buccal arch length in-
creased during the eruption of the permanent canine, and this increase
made it possible for the permanent canine to align. The increase during
the eruption of the permanent canine appeared in the cases shown in Figs.
2–C and 9–B which are applicable to cases of c.

The space required for the alignment of the permanent canine and
first premolar before the shedding of the deciduous second molar is gener-
ally larger than that occupied by the deciduous canine and first molar.
Therefore, if the permanent canine and first premolar erupt during the
same period and before the shedding of the deciduous second molar, the
space is not enough for these teeth to align. Cases shown in Figs. 3–A, 3–B,
6–D, and 7 are applicable to cases of d. The buccal arch length increased
in conjunction with the eruption of these teeth (Figs. 3–A, 3–B and 6–D).
However, in the case shown in Fig. 7, the increase in buccal arch length
was not noted. This resulted from the fact that, in this case, the sum of
crown diameters of the deciduous canine and first molar exceeded that of
their succeeding permanent teeth, and the permanent second premolar
erupted a short time after the emergence of these teeth.

b) Offering Each Other

Since in most cases the space required for the regular alignment of the
permanent buccal teeth is less than that occupied by the deciduous pre-
decessor, the permanent buccal teeth may be able to align by offering each
other. If the permanent buccal teeth were to align by this mechanism, the
buccal arch length should decrease during the period of change of denti-
tion in buccal segment. In cases shown in Figs. 5, 7, and 10–C in which the
buccal arch length only decreased, it would be considered that the perma-
nent canine may align by this mechanism. If the permanent canine aligns
by this mechanism, the permanent second premolar has to erupt during
the same period of eruption of the permanent canine. However, in the
case in which the emergence of three buccal teeth was noted on the same
cast, the increase in buccal arch length was observed (Fig. 9–C). In spite
of the fact that the permanent canine erupted a short time after the emer-
gence of the second premolar, the increase in buccal arch length appeared (Fig. 9–A). In these cases the increase in buccal arch length occurred, while the excessive space through the replacement of the deciduous second molar by smaller permanent successor can easily make up for the lack of space of the permanent canine to align. On the other hand, in the case shown in Fig. 10–C I.D.–2d. decreased, while the buccal arch length decreased during the period of change of dentition in buccal segment. This decrease of I.D.–2d. suggests that the permanent lateral incisor migrated mesially during the period of eruption of the permanent canine, while the space was enough for the permanent buccal teeth to align. From these facts, it can be considered that the increase in buccal arch length occurs at the canine region during the emergence of the permanent canine, but this increase is compensated by the decrease during the time of eruption of the permanent second premolar.

While the permanent canine and second premolar erupt during the same period, all the additional room for the permanent canine is not made up by the excess space through the replacement of the deciduous second molar by the permanent successor, and some of the additional room for the permanent canine is made up by the increase in buccal arch length.

In some cases in mandible, the sum of crown diameters of the deciduous canine and first molar is larger than that of their successors. Then the permanent canine can make use of this excess space to erupt (Fig. 7). However, in the case in which the permanent canine and first premolar erupted before the emergence of the permanent second premolar, the increase in buccal arch length can make it possible for the permanent canine to align (Fig. 6).

c) Space at Pre- and Post-canine

Space at pre- and/or post-canine in the dentition generally disappears after the alignment of the incisors or the emergence of the permanent first molar. In some cases, however, these spaces remain until the period of change of dentition in buccal segment. In these cases, this space can make up a part of lack for space of the permanent canine to align (Fig. 2–D).

d) Increase of the Arch Width

Since the permanent canine erupts more labially than the deciduous canine, the arch width increases. By this increase in arch width, the permanent canine can easily align. Though this increase is not noted in buccal arch length, it can be considered that this increase is possible for the permanent canine to align, as the increase in buccal arch length.

(2) First Premolar

Since the permanent first premolar has less diameter than the decidu-
ous one or the same diameter as its predecessor, almost all the permanent first premolars can erupt normally. However, in cases of the following conditions, the space for the permanent first premolar at the emergence is not enough for this tooth to align.

a. Cases in which the deciduous second molar and the permanent first molar migrate mesially during the period from the shedding of the deciduous first molar to the emergence of the permanent first premolar.

b. Cases in which the permanent canine erupts a short time after the shedding of a deciduous first molar and it makes use of the space for the permanent first premolar to erupt.

c. Cases in which the permanent first premolar has a larger diameter than its predecessor.

The case shown in Fig. 6–C is applicable to a and b. In this case, the buccal arch length increased during the period of eruption of the permanent first premolar and this increase made it possible for this tooth to align. While in the case shown in Figs. 2–B and 3–C the deciduous first molar had less diameter than the permanent successor, the buccal arch length increased. The lack of space for the permanent first premolar, if it occurs at all, is rare. If it does occur, the buccal arch length increases with the eruption of the permanent first premolar and this increase makes it possible for this tooth to align.

(3) Second Premolar

Since the permanent second premolar is always smaller than the deciduous predecessor, there is space enough for the permanent second premolar to erupt. Since it takes a few months from the shedding of the deciduous teeth to the emergence of their permanent successor, it can be considered that the permanent first molar can migrate slightly mesially during this period.

2) Leeway Space

In 1947, Nance found that the sum of the mesiodistal widths of the deciduous canine and molars usually exceeded that of the succeeding permanent teeth, and called this difference "leeway". It has been said that the leeway space supports the alignment of the permanent buccal teeth. However, there are some cases in which the permanent buccal teeth align normally, while the leeway space is minus (Fig. 11). Fig. 11 illustrates the distribution of the leeway space. The leeway space varied from -0.80 mm to 2.60 mm in maxilla and from 1.20 mm to 2.60 mm in mandible. From these facts, it is considered that the leeway space is not the only contributing factor for adjusting the alignment of the permanent buccal teeth.
(1) Relation between Leeway Space and Alignment of the Permanent Buccal Teeth

If the permanent buccal teeth make use of only the leeway space to align, the buccal arch length should keep decreasing during the period of change of dentition.

However, this tendency in buccal arch length was observed only in one case (about 2%) in maxilla and 10 cases (about 26%) in mandible. Since in these cases I.D.-2d. decreased during the period of eruption of the permanent canine, the space for the permanent buccal teeth increased in the canine region. Therefore, this increase in canine region made it possible for the permanent buccal teeth to align, even though the buccal arch length tended to decrease.

In the cases in which some of the increase in buccal arch length was noted, it can be considered that the additional room for the alignment of the permanent buccal teeth was the leeway space and the increase in buccal arch length. In the case in which the permanent canine and first premolar erupted before the shedding of the deciduous second molar, the additional room for the alignment of these two teeth was only the increase in buccal arch length.

(2) Relation between the Leeway Space and Migration of the Permanent First Molar

Through the replacement of the deciduous buccal teeth by the permanent successor, the permanent first molar migrates mesially. It has been said that the amount of the mesial migration of the permanent first molar
is the amount of the leeway space. In cases in which the increase in buccal arch length was noted, the permanent lateral incisor moved mesially during the eruption of the permanent canine positioned more mesially than its predecessor. Therefore, the permanent first molar is able to migrate mesially more than the leeway space.

In cases in which the permanent canine and first premolar aligned before the shedding of the deciduous second molar, the permanent first molar migrated mesially by the amount of the difference between the crown diameter of the deciduous second molar and its permanent successor. However, if the crowding of the anterior teeth was released or dissolved by the shedding of the deciduous second molar, the permanent canine moved distally. Therefore, it can be considered that the permanent first molar migrates the amount of the distal movement of the permanent canine shorter than the distance described above.

Since the leeway space in maxilla is less than that in mandible and the difference of the crown diameter between the deciduous second molar and the permanent second premolar in maxilla is less than that in mandible, the permanent first molar in mandible can migrate more mesially than that in maxilla.

From these facts, the leeway space is not always necessary for the permanent buccal teeth to align, and it is a part of available space for the alignment of the permanent buccal teeth. The leeway space is a part of the distance of the mesial migration of the permanent first molar.

The results of this report are summarized in Figs. 12 and 13. Fig. 12 shows the previous concept of the alignment of the permanent buccal teeth. The space for the permanent buccal teeth goes on decreasing during the period of change of dentition in buccal segment, and the permanent first molar migrates mesially by the amount of the leeway space.

Fig. 13 presents the author's new concept based on this study. The space for the permanent buccal teeth increases during the period of eruption of the permanent canine, and the permanent first molar is able to migrate mesially by the amount of the increase in buccal arch length in addition to the amount of the leeway space.

**CONCLUSION**

In order to know how the permanent buccal teeth align normally, changes in the buccal segment during the period of change of dentition was examined.

As a result of this study, the following conclusions can be made:

1) The space for the alignment of the permanent buccal teeth changes
Fig. 12: Previous concept of alignment of the permanent buccal teeth
A: Space for the buccal teeth
A₁: Deciduous Dentition
A₂: Transitional Dentition (A₂ ≤ A₁)
A₃: Permanent Dentition
a: Leeway space
b: Amount of migration of the permanent first molar (a=b)

Fig. 13: Author's new concept of alignment of the permanent buccal teeth
A: Space for the buccal teeth
A₁: Deciduous Dentition
A₂: Transitional Dentition (A₂ > A₁)
A₃: Permanent Dentition
a: Leeway space
b: Increase on the buccal segment
c: Amount of migration of the permanent first molar (c=a+b)

during the period of change of dentition in buccal segment. The main increase of this space occurs during the period of eruption of the perma-
nent canine and some of the permanent first premolar. This increase makes it possible for the permanent canine and the permanent first premolar to align normally. The main decrease of this space takes place through the replacement of the deciduous second molar by its permanent successor.

2) As the permanent canine positions more mesially than its predecessor, the permanent first molar is able to migrate mesially more than the amount of the leeway space between the crown diameters of the deciduous buccal teeth and those of their permanent successors.

3) The leeway space is not always necessary for the permanent buccal teeth to align, and it is a part of available space for the alignment of the permanent buccal teeth.

Acknowledgement

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References