Behavior of the Maxillary First Molar in Three Planes with Emphasis on its Role of Providing Room for the Second and Third Molars during Growth

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INTRODUCTION

Dental occlusion is not static. It changes with the growth of the jaws and during the transition from the deciduous to the permanent dentitions as well as with the wear of the teeth in later years. Since remarkable growth occurs in the jaws during puberty and because there are wide variations of this growth in amount, timing, rate and direction, puberty is a critical period in the development of the permanent dentition.

Earlier studies have shown that the maxilla and the mandible are carried in a downward and forward direction during growth and that mandibular growth generally exceeds maxillary. However, there is considerable range of opinion about the development of the dental arch and its basal bone in the third plane of space.[1-13] Early studies on the lateral development of the apical base were usually confined to the measurement of the alveolar process of the plaster model at its boundaries.[1,5,11,12] More recently, several studies were undertaken to determine growth and treatment changes of the apical base by projections between complementary frontal and lateral cephalometric roentgenograms and the plaster model.[14,15] The findings of these later investigations suggest that the crowns and roots of the teeth are under the influence of different body systems, that is, the crowns under the influence of the digestive system (tongue, lips and cheeks), while the apices are under the influence of the skeletal system.[12,13] Viewed in this manner, changes of the dental arch may not reflect only the changes of lateral development in the jaw skeleton. Furthermore, it would seem to indicate that the crowns of the teeth might show independent mesiodistal as well as buccolingual movements at the occlusal level to maintain existing occlusal relationships during growth.

Few studies have been directed to the three-dimensional investigation of the behavior of the teeth during growth. This has been due to lack of a method for determining their positions in three planes. The present study was undertaken to gain further insight into the behavior of the teeth during growth by studying the maxillary first molar serially in three planes of space.

MATERIAL

The investigation was based on the same material used in a previous study.[14] They were serial frontal (posteroanterior) and complementary lateral cephalometric roentgenograms and occlusal x-rays derived from plaster models. Four cases were eliminated from the previous group due to incompletion of occlusion of the first molars. Total number in the sample was twenty-six, fourteen males and twelve females, none of whom received either orthodontic or major dental treatment. Each series consisted of two sets of cephalometric roentgenograms of the head and x-rays of the plaster models

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of the dental arches. The first series was taken at the age of 8, ± 1 year and the second series at 16, ± 1 year. All exhibited excellent occlusions or mild Class I malocclusion and were taken from the files of the Orthodontic Department, University of Illinois.

Method

The purpose of this investigation required absolute values of measurements at the level of both the crown and the apex of the tooth. The x-ray image of the model of the dental arch was obtained by placing the model, teeth down, on a film and directing the x-ray beam at the center of the base of the model from a distance of five feet. This yields an image of the dental arch without measurable enlargement and with satisfactory detail of the outlines of the individual teeth. Bilateral as well as midsagittal structures significant to this study, revealed by both lateral and frontal cephalometric head films, were traced. Since frontal and lateral cephalometric films do not yield absolute values due to enlargement, it was necessary to coordinate the enlarged images of the head films, which showed the positions of the apices of the teeth, with the absolute image of the dental arch. The method used to do this was the same as that used in the previous study.[14] Briefly, the technique is based on Wylie's compensating method[16] as extended by Vogel.[17] The basic requirement for the use of this technique is the correct positioning of the head in the cephalometer and its maintenance while the frontal and lateral exposures are made. Then, either symmetrical or asymmetrical head structures can be measured in three planes as has been described. All measurements were obtained by this technique, mesiodistally as well as buccolingually, except the first molar intercrown distance (dental arch width) which was taken directly from the occlusal x-ray films.

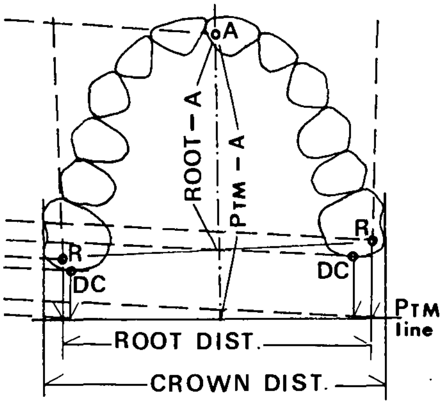

Fig. 1 Measurements in the horizontal plane derived from x-rays of models positioned by compensated projections from complementary frontal and lateral cephalometric x-ray films.

The following measurements were obtained (Fig. 1):

A. Mesiodistal measurements

1. Ptm-DC: Pterygomaxillary fissure (Ptm) to the most distal point of the crown of the maxillary first permanent molar (DC). Right and left measured. (Ptm-Crown)
2. Ptm-R: Pterygomaxillary fissure to the apex of the distobuccal root of the maxillary first permanent molar (R). Right and left measured. (Ptm-Root)
3. R-Pt. A: Apex of the distobuccal root of the maxillary first permanent molar to the most anterior point of the maxillary apical base (Point A), read on the midline. Tentatively accepted as representing the depth of anterior apical base in this study.
4. Ptm-Pt. A: Pterygomaxillary fissure to Point A, read on the midline. (Depth of total apical base)

B. Buccolingual measurements

1. Intercrown distance: Distance between the most lateral points

TABLE I

Total measurements (mm)

Measurements	*8 ± 1 year*	*16 ± 1 year*
Ptm-Crown (L)	6.3 ± 1.6	13.5 ± 2.1
Ptm-Crown (R)	6.2 ± 1.5	13.2 ± 2.3
Ptm-Root (L)	13.0 ± 1.9	18.1 ± 1.9
Ptm-Root (R)	12.9 ± 1.9	17.5 ± 1.6
Root-Pt. A	29.7 ± 1.8	29.4 ± 1.9
Ptm-Pt. A	42.8 ± 1.3	47.3 ± 2.2
Intercrown	52.9 ± 4.2	54.7 ± 4.1
Inter-root	47.8 ± 2.8	50.7 ± 3.7

TABLE II

Total increment over the eight to sixteen year age span. All but Root-Pt. A are significant at less than 1% level. Root-Pt. A insignficant at less than 5% level.

Measure-ments	*Mean & S.D.*	*Inc.*	*Dec.*	*N.C.*
Ptm-Crown (L)	7.0 ± 2.2	26	0	0
Ptm-Crown (R)	6.9 ± 2.3	26	0	0
Ptm-Root (L)	5.0 ± 1.8	26	0	0
Ptm-Root (R)	4.6 ± 1.5	26	0	0
Root-Pt. A	0.2 ± 1.1	10	12	4
Ptm-Pt. A	4.6 ± 1.3	26	0	0
Intercrown	1.7 ± 1.8	19	6	1
Inter-root	2.8 ± 2.3	23	2	1

of the crowns of the maxillary first permanent molars. (Dental arch width)

2. Interroot distance: Distance between the apices of the distobuccal roots of the maxillary first permanent molars.

Findings

Means and standard deviations of the total depths and widths and the increment of each component from ages eight to sixteen years were tabulated in absolute values. Table I shows the means and standard deviations of the total depths and widths at the age of eight and sixteen years. Table II shows the total increment of each component over the eight to sixteen year age span; the "t"-test was applied to the means to determine the significance of the differences between two stages.

Discussion

The purpose of this investigation was to outline the behavior of the maxillary first molar in normal occlusion in three planes of space during growth. The nature of the study made it necessary to deal with small degrees of change. No such irregularly shaped object as the human dentition can be evaluated by viewing it from only one side. The almost universal procedure of comparing serial stages by superimposing tracings of lateral films reduces the findings to those of a qualitative nature and may not be applicable for use to study the small changes occurring during growth and/or orthodontic therapy. Complementary frontal and lateral cephalometric x-ray films do not yield absolute dimensional values of widths of structures even if both are compensated. Changes in size and form of bilateral structures lying in the horizontal plane cannot be estimated, much less measured. The plaster model of the dentition offers an accurate source of measurement of changes occurring at the level of the crowns of the teeth. The occlusal x-ray of the model, when oriented to the frontal and lateral cephalograms, reveals any change at the level of apices of the teeth or any change in relation of the denture to the facial skeleton.

To investigate the changes that occurred simultaneously at the level of the crown and the root of the tooth in relation to the facial skeleton, it was necessary to coordinate the enlarged measurements derived from frontal and lateral cephalograms with the absolute value derived from the model on each individual case. The method was developed and discussed previously.[14]

In the present study the apex of the distobuccal root of the first molar was used to measure changes which occurred at the apical level of the teeth. It may raise questions regarding the propriety of the use of this root for certainty of measurements of growth

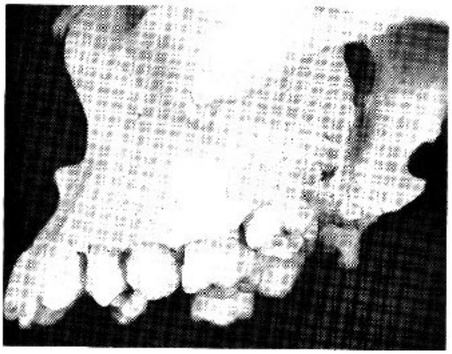

Fig. 2 Room behind the maxillary first molar of the estimated age of 11-13 years old dry skull. Notice the position of the developing third molar and distal inclination of the second. Space is available for the second but not the third molar at the crown level. (Occlusion: minor Class I malocclusion)

changes of maxillary width. It is not the distobuccal but the mesiobuccal root that is closer to the outer surface of the maxilla. Hence it is more likely to reflect change in the lateral development of the maxilla. However, because the study was undertaken to investigate the postural changes of the tooth during growth and since it was possible to accurately trace the distobuccal root on both the frontal and lateral cephalograms, this root was used to determine the changes which occurred at the apical level of the teeth.

The anteroposterior distance from Ptm to the most distal point on the crown of the maxillary first molar, measured parallel to FH plane, showed the same significant increases as that of the other study.[23] This increase serves to accommodate the second and third molars in the dental arch in later years as well as to maintain the existing occlusal relationship to the mandibular teeth. The mean increase was approximately 7 mm making the total average distance of Ptm-Crown about 13.5 mm at the age of sixteen. The average mesiodistal diameters of the crowns of the maxillary second and third molars are 9.0 and 8.5 mm, respectively, or a total of 17.5 mm.[19] The Ptm-Crown distance at sixteen years is not adequate to accommodate the third molar in the dental arch, although the crown of the tooth is usually completed at a higher level by this time.

The anteroposterior distance from Ptm to the apex of the distobuccal root of the maxillary first molar was measured parallel to the FH plane. It also showed significant increase, but less than that of Ptm-Crown. The crowns of the second and third molars are completed at the age of 7-8 years and 12-16 years, respectively.[19] The eruption of the second molar usually takes place at the age of 12-13 years, but that of the third molar at the age of 17-21 years. Adequate room must be provided at the apical level by the age of 7-8 years to accommodate the developing germ of the second molar and at the crown level by the age of 12-13 years to allow its eruption into occlusion. Likewise, adequate room must be provided for the third molar at the apical level by the age of 12-16 years to accommodate the developing tooth germ and at the crown level by the age of 17-21 years to allow its eruption (Fig. 2).

To summarize: At the age of eight years, adequate room is provided at the apical level behind the first molar for the development of the second molar but it is not yet provided at the crown level for its eruption. Sufficient room is not available behind the developing second molar for the third molar development (Fig. 3).

At sixteen years of age the distance from Ptm to the apex of the distobuccal root of the first molar averages 18 mm. The average mesiodistal diameter of the cervix of the second molar is 7.0 mm which leaves approximately 10-11 mm behind the second molar at the apical level. Therefore, adequate room is provided for the development

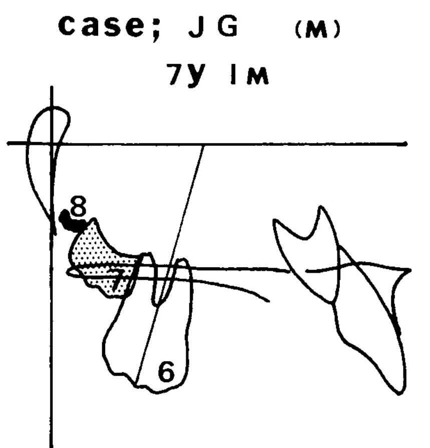

Fig. 3 Typical pattern of the maxillary molars at the age of 7-8 years. Room is provided at the apical level behind the first molar for the development of the second molar, but is not available at the crown level. Space is not available distal to the second molar for the development of the third.

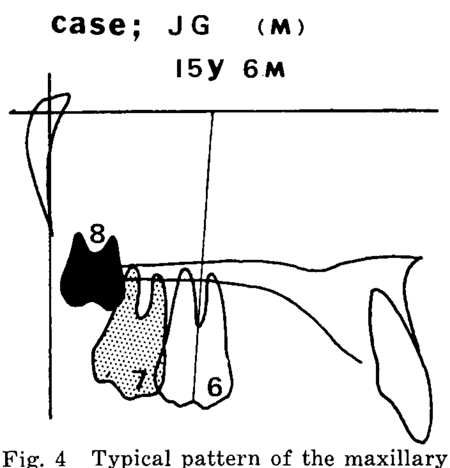

Fig. 4 Typical pattern of the maxillary molars at the age of 15-16 years. Space is provided at the apical level behind the second molar for the development of the third, but is not available at the crown level for its eruption.

of the third molar tooth germ at the apical level behind the second molar, but it is not yet sufficient at the crown level for its eruption (Fig. 4). The total increase of Ptm-Root was about 2-2.5 mm less than that of the Ptm-Crown during growth.

A "t"-test was applied to determine the statistical significance between the two mean values. It showed significant difference at the 1% level of probability (left, "t" = 3.35; right, "t" = 3.78). This indicates that the crown of the tooth comes farther forward than the root, i.e., the tooth rotates downward and mesially during growth. This increases the room posteriorly at the crown level.

It is well-known in the eruption of the human molars that the teeth undergo a downward and mesial rotation in the vertical plane. Weinmann and Sicher mentioned the rotary movements of the upper and lower molars when discussing the importance of the correlation of anteroposterior growth of the jaws and eruption of the teeth.[24] Brash stated that these rotary movements are normally completed before the teeth have come in contact with one another,[25] while Brodie said they will continue for sometime after.[26] Mason studied the behavior of the axes of the human molar teeth during growth and eruption.[27] He found that the rotation of the molars during eruption has been shown to be necessary for the development of normal occlusion and that the maxillary permanent first molar continued to decrease its distal inclination in occlusion. The present study also found the downward and mesial rotation of the maxillary first molar to continue after it has come into occlusion. There is controversy as to the cause of this rotation; Brodie indicated the possible influence of the buccinator muscle on the crowns of these teeth after eruption.[12] Thus, the original position of the maxillary first molar in basal bone, its downward and mesial rotation during and after eruption, and the growth of the maxilla during the period studied combine to provide room for the development and eruption of the sec-

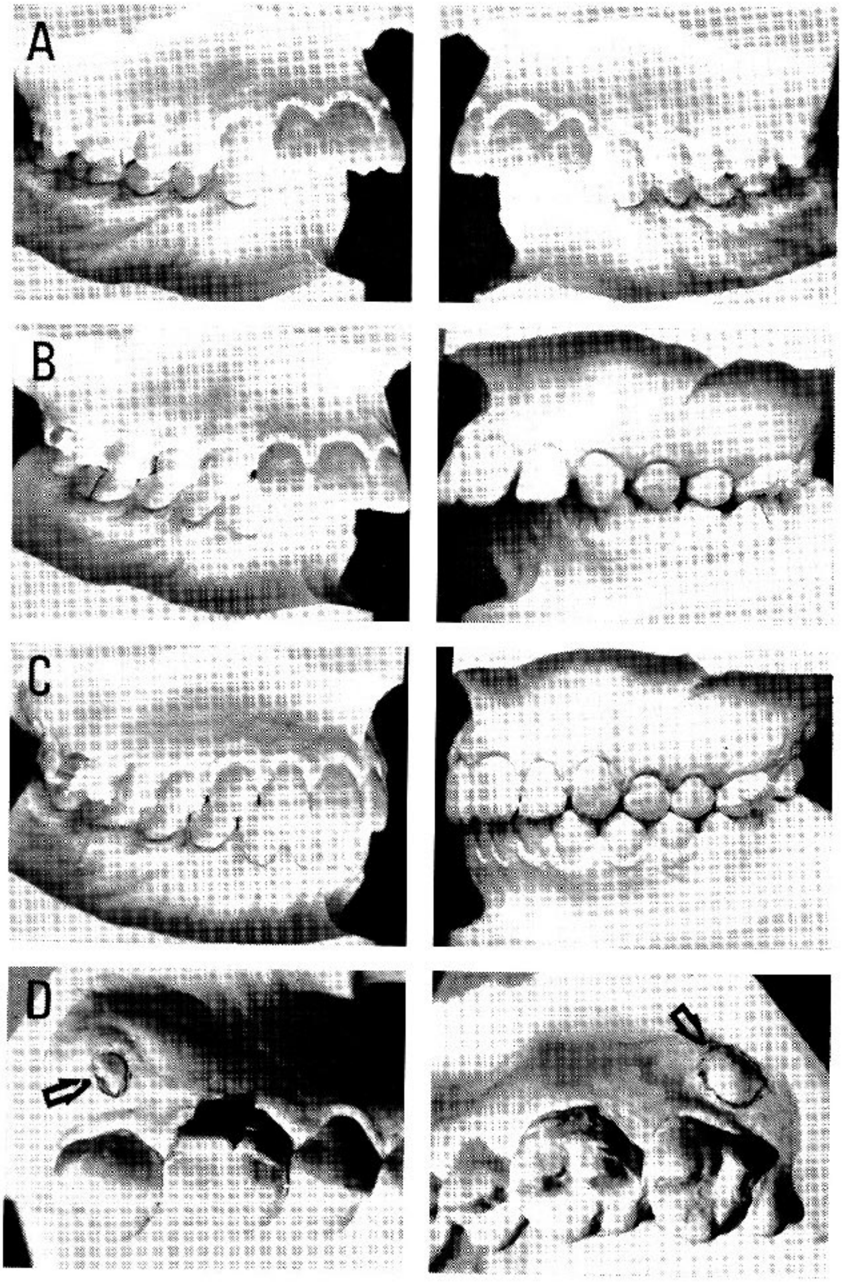

Fig. 5 Class II, Division 1 malocclusion, treated by cervical traction and edgewise appliance. A: Before treatment, B: Only cervical traction applied for A-P correction of molars, C: Retained, D: Displacement of the third molars at retention. (Courtesy of Dr. S. J. Kloehn)

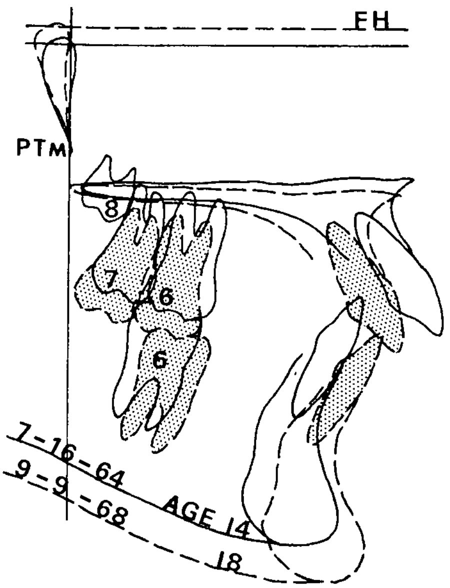

Fig. 6 Tracing of the case of Fig. 5, superimposed on Ptm, with parallel FH planes. No room was available behind the second molars at the crown level and the third molars were removed. (Courtesy of Dr. S. J. Kloehn)

ond and the third molars. Any failure of these would result in a critical inadequacy of room for the third molars.

Although it has been shown that jaw growth and tooth eruption are not strictly correlated in time,[20] it might seem that the current use of cervical traction in orthodontic therapy would act to reduce space behind the first molar and would cause inhibition or delay of eruption of the third molar or its displacement from its normal path of eruption. Any of these can and do result from excessive or too prolonged force if intervals of rest are not provided for recovery. Figure 5 shows a case representing the displacement of the third molars from their normal paths of eruption and Figure 6 depicts the tracings of the lateral cephalometric x-ray films superimposed before and after treatment. The case was treated by cervical traction and resulted in excellent correction of malocclusion and its subsequent stability. All third molars were removed at the time of retention. It may be a mistake to attribute the cause of displacement to the cervical traction for Kloehn gives his clinical observations as to the use of cervical traction as follows: "I have never found a displaced maxillary third molar after cervical anchorage treatment when there was adequate space for the eruption of the mandibular third molar. In other words, there is apparently a correlation between maxillary and mandibular growth except in severe dysplasias such as severe Class III malocclusion and cleft palatal abnormalities. I have never found it necessary to remove maxillary third molars in any Class II malocclusion if the mandibular third molars erupted into a good functioning relationship."[28]

The anteroposterior distance from the apex of the distobuccal root of the first molar to the most anterior point of the maxillary apical base (Point A), measured parallel to the FH plane, showed both increases and decreases, but both were of small degree over the eight year interval covered. Ten cases showed increases, twelve showed decreases, four remained the same and the mean values remained unchanged. A "t"-test was applied and showed insignificant differences of the mean values; there was no tendency for either increase or decrease during growth. This distance was tentatively accepted as representing the depth of the anterior part of the maxillary apical base. Richardson and Brodie measured the depth of the anterior apical base and concluded that the apical base of the maxilla, anterior to the first molars, becomes shorter.[11] The differing result of the present study lies in different methods employed in two studies. Theirs was based on outlines of apical base perimeters superposed on a transverse line connecting the mesial contact points of the first molars. This demonstrated the effect of the form of the perimeter on the size of the area being measured.

The Ptm-Pt. A distance showed increases of 4.5 ± 1.3 mm which was almost the same as that of the Ptm-Root increase, seeming to indicate that forward positioning of the entire maxilla occurs mainly as a result of the increase of the Ptm-Root increase. Coben made measurements of the Ptm-Pt. A distance of forty-seven individuals at eight and sixteen years and showed 5.5 ± 1.5 mm increases in males and 4.1 ± 1.4 mm increases in females.[21] This distance was tentatively accepted as representing the depth of the total maxillary apical base. Previous studies indicated that the forward growth of the mandible is much greater than that of the maxilla.[21,22] Although the synchronization of their growth in timing and velocity are essential to maintain existing occlusal relationship, a compensatory adjustment may be needed at the occlusal level to correct the anteroposterior discrepancy of growth between the two jaws. Individual teeth as well as the total arches must change posture, angulation, and/or their relation to the facial skeleton with age. Mesial inclination of the crown of the molar might be an essential adjustment of the maxillary teeth at the occlusal level (Fig. 7).

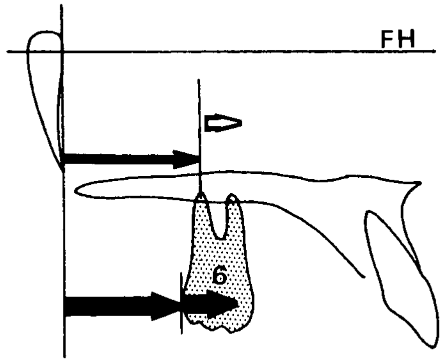

Fig. 7 Summary of the mesiodistal behavor of the maxillary first permanent molar during growth. Solid arrows indicate a definite tendency, blank arrow indicates an insignificant tendency.

The transverse distances between the apices of the right and left distobuccal roots and between the right and left most lateral points on the crowns of the first molars were measured. Interroot distance showed 2.8 ± 2.3 mm increase while intercrown distance showed 1.7 ± 1.8 mm increases. The interroot distance seems to indicate a greater tendency to increase during growth. As Brodie has pointed out, the apices of the roots of the teeth are under the influence of the skeletal system. Thus, the increase of the interroot distance seems to indicate a definite lateral development of the maxilla in the first molar regions during growth. The intercrown distance (arch width) also showed a tendency to increase during growth although it is less than that of the interroot distance. A "t"-test was applied to the two mean values to determine the significance of the difference and was found to be insignificant at 5% level (t = 1.78). Thus, there was no evidence to indicate a tendency toward either intercrown increases or decreases in the sample. When studied individually, sixteen cases showed more increase in width at the apical level than at the crown level, nine showed less increase, and one remained unchanged. Thus, there was no tendency to indicate a definite pattern of changing the lateral behavior of the first molar crown and the root during growth. Buccolingual changes seem to behave as individual variables with differences of direction and amounts between crowns and roots. This seems to indicate that the size of the apical base would not necessarily be the dominant factor in determining its adequacy in relation to any dental arch (Fig. 8).

In normal occlusion, lines of the oc-

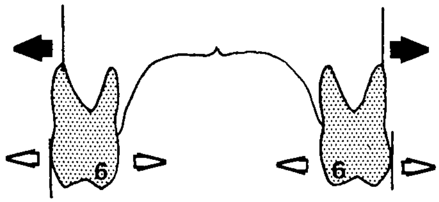

Fig. 8 Summary of the buccolingual behavor of the maxillary first permanent molar during growth. Behavior of the root and the crown are not the same in direction or amount.

clusal force brought to bear upon the maxillary teeth by the mandibular teeth are equalized and absorbed by the mutual aid of the teeth.[19] However, the maxilla is fixed to the cranium and is thus immobilized, whereas the mandible is independent and movable in mastication. Therefore, the maxillary and mandibular teeth must be arranged to obtain the proper occlusal contact and intercusp relations of all the teeth during the various functional mandibular movements. The proper mesiodistal and buccolingual inclinations of the upper and lower teeth would be essential to establish the proper occlusal relationship between them. A study of the arrangement of the roots of the teeth revealed a common pattern of inclination of roots, mesiodistally as well as buccolingually, in both the maxillary and the mandibular dental arches. Variability in the direction of inclination tended to increase from tooth to tooth through the second molar.[18] The present study revealed that the differing behavior of the crown and root of the first molar occurs mesiodistally as well as buccolingually during growth and within the limit of this common pattern of inclination.

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