Positional Changes of the Upper Canine and Posterior Teeth, Hard Palate, and Sinus Floor from Primary to Permanent Dentition

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ABSTRACT

This cross-sectional study investigated normal positional changes of the upper permanent canine and posterior teeth, hard palate, and sinus floor in normal Taiwanese children from the deciduous to early permanent dentition. In total, 261 panoramic radiographs were used. During the observation period, almost all structures changed their positions toward the distal and occlusal direction. The vertical positional changes of crowns of all teeth were greater than those of the root apices through all developmental stages. There were small positional changes in the mesial surfaces of the crowns of the upper buccal teeth until their roots had formed. There were continuous positional changes in the crowns and root apices of the permanent molars during tooth development and eruption. There were no significant changes in tooth inclination for any of the buccal teeth, whereas there were conspicuous changes in tooth inclination for the permanent molars. The floor of the maxillary sinus remarkably changed its position in an occlusal direction during the active eruption period of the first molar and buccal teeth. (*J Dent Child*. 2004;71:48-53)

KEYWORDS: UPPER PERMANENT CANINES, UPPER POSTERIOR TEETH, MAXILLARY SINUS, HARD PALATE, PANORAMIC RADIOGRAPH, POSITIONAL CHANGES

A greater understanding of the development of the posterior region of the maxilla is necessary to comprehend the normal growth of the maxillary complex. The bony chambers embedded in the bones around the nasal cavity and opening into the nasal cavity are called the "paranasal sinuses." The maxillary sinuses in the maxilla are the largest of these. The floor of the maxillary sinuses is formed by the alveolar process of the maxilla,[1] and its contiguity with the upper posterior teeth continues throughout life.[2]

Tooth eruption is intimately associated with normal dentofacial growth and occlusal development, and the control of eruption is clinically important. Ectopic eruption of teeth can occur in a wide variety of sites. These include the mandibular condyle, coronoid process, palate, nasal cavity, and maxillary sinus. Early detection of eruptive anomalies in the permanent teeth requires an understanding of their normal eruptive pattern.

The position of the maxillary sinus intimate to the apices of the developing teeth may cause some problems if peripheral inflammation or traumatic injury occurs. Although odontogenic sinusitis is a rare entity when compared to sinus diseases of rhinogenic origin, it is extremely important to identify a dental etiology when it does occur. Maxillary sinusitis due to dental causes is usually secondary to periodontal disease or periapical infection, while oromaxillary sinus perforation occurs occasionally with the extraction of a maxillary tooth, and it may cause an antro-oral fistula.[3] On the other hand, damage to the developing dentition may be a serious complication of maxillary sinus surgery or chronic infection.[4,5]

Relatively few studies have investigated the relationships of developmental changes between the maxillary permanent teeth and surrounding bony structures. Panoramic radiographs allow detailed analyses of tooth eruption and the interrelationship between the roots of the maxillary teeth and subjacent sinuses.[6,7]

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The purpose of this study was to analyze the normal positional changes of the upper permanent canines and posterior teeth, hard palate, and sinus floor on the basis of panoramic radiographic records.

METHODS

The materials for this investigation comprise panoramic radiographs of 261 Taiwanese children (136 girls and 125 boys) whose ages ranged from 4 to 14 years. Cases of trauma, agenesis, developmental disturbances, or supernumerary teeth in the study zone were excluded from the materials. None of these subjects had received orthodontic or orthopedic treatment before their radiological registration. All panoramic radiographs were of good quality.

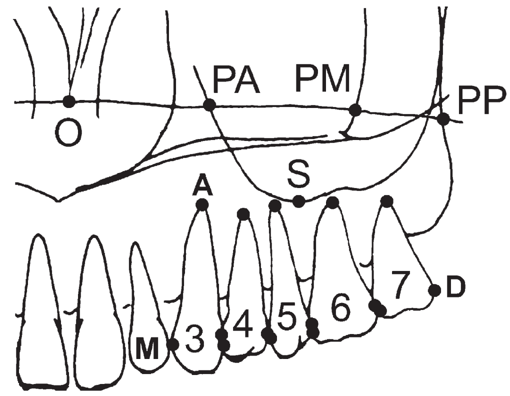
Hellman[8] sought an explanation of the development of human dental occlusion, linking the phenomenon of occlusion with the evolution of the dentition as a whole, and introduced a classification of dental development. In this study, the materials were divided into 6 groups according to Hellman's dental developmental stages:

1. completion of deciduous dentition (stage IIa);
2. eruption stage of the permanent first molar (stage IIc);
3. transitional stage of primary incisors to permanent incisors (stage IIIa);
4. transitional stage of primary buccal teeth to permanent buccal teeth (stage IIIb);
5. eruption stage of the permanent second molar (stage IIIc).

The distribution of the panoramic radiographs in each stage includes 33 in stage IIa, 39 in stage IIc, 70 in stage IIIa, 69 in stage IIIb, and 50 in stage IIIc.

All panoramic radiographs were traced on a light box using a sharp 4H pencil on a semi-mat acetate drafting sheet fixed to the film. Twenty reference points (on the hard palate, sinus floor, and upper buccal teeth and molars) were identified on each tracing (Figure 1). To measure intraexaminer reproducibility, the reference points from 20 randomly selected radiographs were remarked 2 weeks after the first tracing. A paired *t* test was applied to the first and second tracings, and the mean error for the markings was 0.10 mm (±0.12; range=0-0.20 mm). No error associated with the markings was found. The tracing of each radiograph was digitized by translating the reference points onto an X-Y coordinate system. The straight line that passes point O (the point that nasal septum intersects with hard palate) and point PA (the point that medial wall of maxillary sinus intersects with hard palate) was designated as the X axis. The straight line vertical to the X axis and passing through point O at a right angle was designated as the Y axis. The X coordinate value of each reference point was considered a horizontal position of the structure. The Y coordinate value of each reference point was considered a vertical position of the structure. The X and Y coordinate values of all reference points were calculated. Mean values and standard deviations were calculated for each coordinate value at the 5 stages of dental development.

Statistical analysis was performed using the Sigmastat (version 2.0) statistical software package. Analysis of variance (ANOVA) was used for comparison of the mean values for each coordinate value among the 5 dental developmental stages. The level of significance used in this study was predetermined at 0.05.



O: the point that nasal septum intersects with hard palate
PA: the point that medial wall of maxillary sinus intersects with hard palate (nasal floor side)
PM: the point that posterior wall of zygomatic process intersects with hard palate (nasal floor side)
PP: the point that posterior wall of maxillary tuberosity intersects with hard palate
S: the lowest point at floor of the maxillary sinus
3: upper left permanent canine
4: upper left first premolar
5: upper left second premolar
6: upper left permanent first molar
7: upper left permanent second molar
M: the most convex point on the mesial surface of the tooth
D: the most convex point on the distal surface of the tooth
A: the root apex of the tooth

Figure 1.

RESULTS

Tables 1 to 3 sum up the X and Y coordinate values used to determine the positions of the teeth, hard palate, and floor of the maxillary sinus. Figures 2 to 7 show the superimposition of the mean positions of each stage for these structures. Positions of each tooth are shown by triangles (Figures 2 to 6), while positions of the hard palate are shown with the lines that connect the reference points (Figure 7).

During the observation period, all X coordinate values except point PA significantly increased (changed their positions in a distal direction); whereas all Y coordinate values except the root apices of the buccal teeth significantly decreased (changed their positions in an occlusal direction).

DISCUSSION

Human tooth eruption occurs in 2 major stages: pre-emergent and postemergent. During the early part of tooth formation, called the follicular phase of eruption, the follicle enlarges concentrically in all directions. It may slightly move facially within the alveolar bone, but there is little or no eruptive movement.[9] When the tooth begins to erupt, the pre-emergent spurt phase of eruption is initiated; when crown formation is complete, root development begins.

From stages IIa to IIc, the mean positional changes of the upper permanent canines were similar to those of the premolars. The most convex point on the mesial surfaces of the teeth hardly changed, whereas the root apices and

Table 1. Mean Coordinate Values and Standard Deviations of the Reference Points in Each Stage

Reference	Point	Stage IIa	IIc	IIIa	IIIb	IIIc	Anova test
PAX	Mean	13.70	15.52	15.09	15.56	16.12	n.s.
	SD	3.70	3.46	3.95	4.01	3.54	
PMX	Mean	23.52	25.66	27.60	28.67	31.58	$P<0.001$
	SD	3.80	3.82	3.56	3.71	2.86	
PMY	Mean	–1.44	–1.62	–1.82	–2.80	–2.76	$P<0.001$
	SD	0.83	0.88	1.48	2.05	3.47	
PPX	Mean	26.72	29.78	33.29	34.14	37.75	$P<0.001$
	SD	4.70	4.80	5.01	5.00	3.86	
PPY	Mean	–2.51	–3.04	–3.07	–4.81	–4.74	$P<0.001$
	SD	1.16	1.09	1.98	2.72	4.28	
SX	Mean	19.24	21.54	22.89	24.09	25.61	$P<0.001$
	SD	3.75	3.28	3.51	3.98	3.10	
SY	Mean	–1.91	–2.11	–3.80	–7.07	–7.02	$P<0.001$
	SD	0.82	1.38	1.99	2.24	2.84	

PAX: X coordinate value of point PA.
PMX: X coordinate value of point PM.
PMY: Y coordinate value of point PM.
PPX: X coordinate value of point PP.
PPY: Y coordinate value of point PP.
SX: X coordinate value of point S.
SY: Y coordinate value of point S.

Table 2. Mean Coordinate Values and Standard Deviations of the Buccal Teeth in Each Stage

Reference	Point	Stage IIa	IIc	IIIa	IIIb	IIIc	Anova test
3MX	Mean	8.09	8.60	8.23	8.97	9.89	$P<0.001$
	SD	2.63	2.33	2.06	2.11	1.51	
3MY	Mean	–1.75	–1.63	–3.23	–11.57	–14.89	$P<0.001$
	SD	1.47	2.65	2.45	4.74	2.36	
3DX	Mean	13.30	14.08	13.55	14.53	15.77	$P<0.001$
	SD	3.29	2.76	2.46	2.58	1.78	
3DY	Mean	–2.07	–2.12	–4.49	–12.70	–15.55	$P<0.001$
	SD	1.44	2.38	2.37	4.48	2.49	
3AX	Mean	10.85	11.66	12.19	12.55	13.63	$P<0.001$
	SD	2.88	2.58	2.73	3.06	2.45	
3AY	Mean	1.57	2.75	2.75	–1.09	–3.30	$P<0.001$
	SD	1.47	2.01	2.70	3.13	2.27	
4MX	Mean	11.30	11.99	12.51	13.16	14.84	$P<0.001$
	SD	3.08	2.48	2.67	2.65	1.97	
4MY	Mean	–6.89	–6.71	–8.44	–15.88	–15.95	$P<0.001$
	SD	1.54	2.26	2.31	3.04	2.08	
4DX	Mean	15.78	17.31	17.33	18.23	20.42	$P<0.001$
	SD	3.07	2.91	3.03	3.02	2.19	
4DY	Mean	–6.86	–6.94	–9.06	–16.57	–16.45	$P<0.001$
	SD	1.19	2.31	2.01	3.11	2.43	
4AX	Mean	13.08	14.65	15.09	15.90	17.53	$P<0.001$
	SD	3.20	3.13	2.96	3.19	2.52	
4AY	Mean	–3.32	–2.59	–3.13	–6.61	–6.09	$P<0.001$
	SD	1.10	2.04	1.95	2.42	2.10	
5MX	Mean	15.69	16.85	17.09	17.79	19.72	$P<0.001$
	SD	3.89	3.28	3.24	3.16	2.21	
5MY	Mean	–5.78	–6.13	–7.21	–13.53	–15.93	$P<0.001$
	SD	1.20	1.74	1.79	3.41	2.57	
5DX	Mean	19.63	21.20	21.52	22.66	25.09	$P<0.001$
	SD	4.00	3.53	3.65	3.44	2.40	
5DY	Mean	–5.10	–4.75	–6.20	–13.23	–15.77	$P<0.001$
	SD	0.97	1.32	2.24	3.56	2.95	
5AX	Mean	16.70	17.80	18.61	19.02	20.82	$P<0.001$
	SD	4.08	3.60	3.42	3.41	2.57	
5AY	Mean	–2.50	–2.13	–2.25	–4.88	–6.35	$P<0.001$
	SD	0.88	1.13	1.81	2.63	2.55	

the most convex point on the distal surfaces of the teeth changed their positions toward the apical and distal directions, respectively. From Figures 2 to 4, it is clear that the crowns of the upper buccal teeth were not yet completed before stage IIc. This suggests that there is little positional change in the mesial surface of the crown of the upper buccal teeth and that the root apices of these teeth, especially the permanent canines, develop in the direction of the maxillary sinus before eruption begins. Therefore, it is important to prevent damage to the developing permanent tooth germs during intranasal antrostomy[4] if a patient's dental age is younger than early mixed dentition.

After stage IIIa, all buccal teeth dramatically changed their positions toward the occlusal direction. Changes in the crowns were greater than those of root apices. In this study, the upper first premolars showed no change in the vertical direction from stages IIIb to IIIc. This means that the upper first premolars emerged first among the 3 buccal teeth. All 3 upper buccal teeth gradually changed their horizontal positions toward a distal direction throughout all developmental stages. These distal positional changes may have been due to displacement caused by eruption of the permanent incisors in the case of the permanent canines and displacement by eruption of the permanent canines in the case of the premolars.

The amounts of change in the vertical direction with each stage for both the permanent first and second molar crowns were almost the same from stages IIa to IIIb. The vertical positional changes of the crowns of the permanent molars were greater than those of the root apices through all developmental stages. Unlike the buccal teeth, there were no apical positional changes in the root apices of the permanent molars during development. As to horizontal positional changes, however, as with the buccal teeth, both upper permanent molars gradually changed their positions distally, especially during stages IIIb to IIIc. Teeth stop forming after a predictable amount of root development has occurred, and they have distinct anatomic crown and root structures, but the alveolar bone continues to form and remodel in response to their eruption. The distal positional changes of the permanent molars may be based on the development of permanent molars and maxillary

Table 3. Mean Coordinate Values and Standard Deviations of the Molars in Each Stage

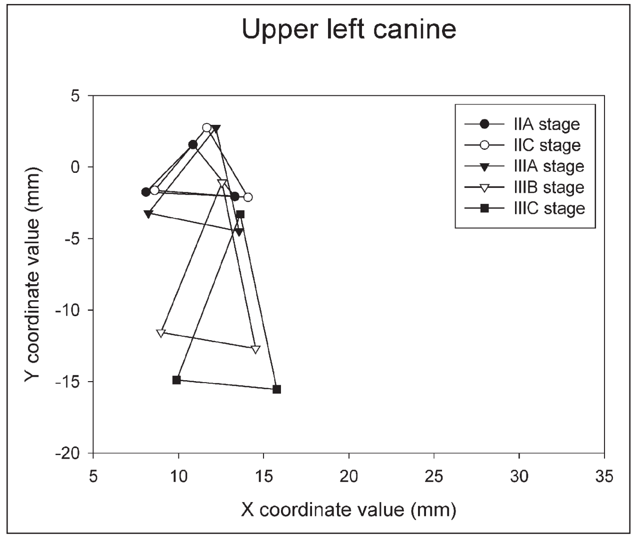
Reference	Point	IIa	IIc	IIIa	IIIb	IIIc	Anova test
		Stage					
6MX	Mean	20.88	22.26	22.58	23.43	25.93	P<0.001
	SD	4.21	3.24	3.47	3.57	2.55	
6MY	Mean	–6.69	–10.09	–13.34	–17.09	–15.96	P<0.001
	SD	1.37	2.22	2.09	2.24	2.89	
6DX	Mean	25.92	28.45	29.16	30.13	33.09	P<0.001
	SD	4.36	3.94	3.92	4.11	2.84	
6DY	Mean	–2.55	–6.89	–11.05	–15.12	–14.62	P<0.001
	SD	1.80	2.49	2.27	2.59	3.62	
6AX	Mean	20.99	22.94	23.49	24.23	26.68	P<0.001
	SD	4.78	4.27	3.93	4.12	3.02	
6AY	Mean	–0.42	–2.29	–3.00	–4.13	–4.46	P<0.001
	SD	1.03	1.44	1.72	2.27	2.98	
7MX	Mean	25.18	26.83	27.41	28.33	30.86	P<0.001
	SD	4.73	3.80	4.19	4.06	3.01	
7MY	Mean	–0.91	–3.67	–6.01	–10.20	–11.88	P<0.001
	SD	1.55	1.65	2.36	2.79	4.04	
7DX	Mean	27.39	30.73	32.22	33.15	36.65	P<0.001
	SD	4.82	4.65	4.53	4.80	3.31	
7DY	Mean	3.30	1.02	–1.62	–6.54	–9.31	P<0.001
	SD	1.46	1.39	2.55	3.31	4.55	
7AX	Mean	25.02	26.51	27.36	28.34	30.93	P<0.001
	SD	4.83	3.72	4.32	4.44	3.41	
7AY	Mean	2.39	0.83	–0.49	–2.68	–3.69	P<0.001
	SD	1.31	1.35	1.92	2.52	3.67	

MX: X coordinate value of the most convex point at mesial surface of the tooth.
MY: Y coordinate value of the most convex point at mesial surface of the tooth.
DX: X coordinate value of the most convex point at diatal surface of the tooth.
DY: Y coordinate value of the most convex point at diatal surface of the tooth.
AX: X coordinate value of root apex.
AY: Y coordinate value of root apex.

tuberosity. Our results indicated that there are continuous positional changes in the crowns and root apices of permanent molars during tooth development and eruption.

During the observation period, there were no significant changes in tooth inclination for the 3 buccal teeth, whereas there were conspicuous changes in tooth inclination for the permanent molars. Figures 5 and 6 show that the lines connecting points A and M maintained the same angulations, while the lines connecting points A and D changed angulation by 45° from stages IIa to IIIc. This also indicates that the axial direction of the upper permanent molars shifted from the distal to the occlusal during tooth development and eruption.

The growth of the maxilla has been described by many authors, several of whom have studied experimental animals.[10,11] With increasing age, the extension of the contact surfaces of the palatine bone increases with adjacent bones, the maxilla, and pterygoid process of the sphenoid bone.



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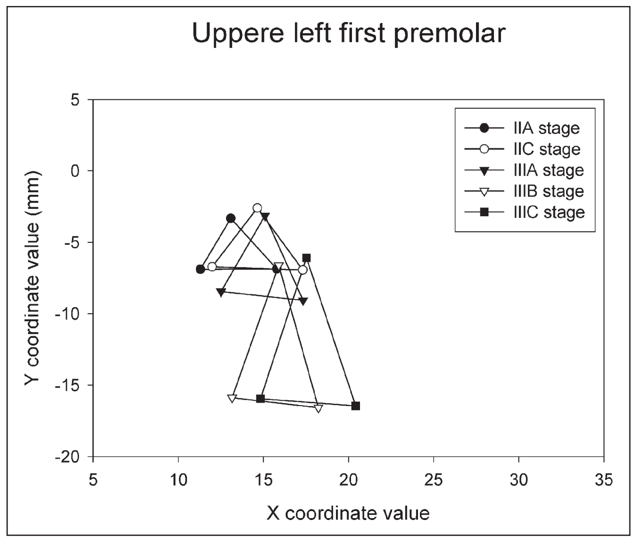

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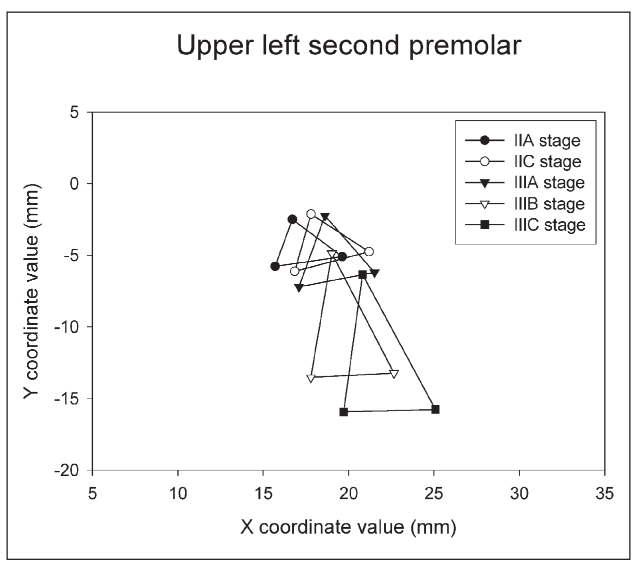

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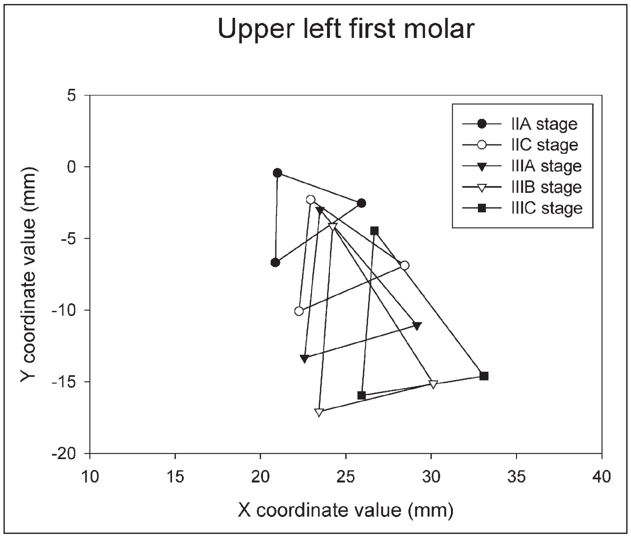

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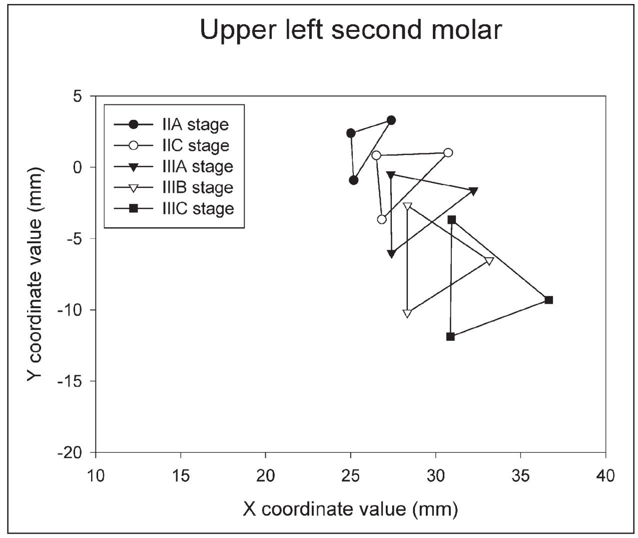

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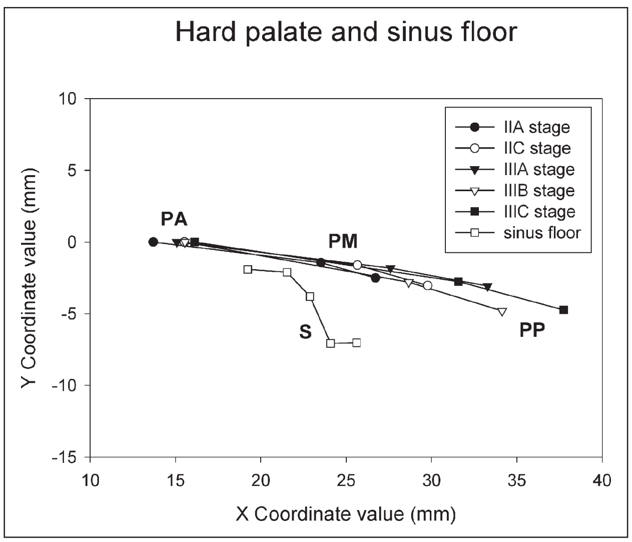

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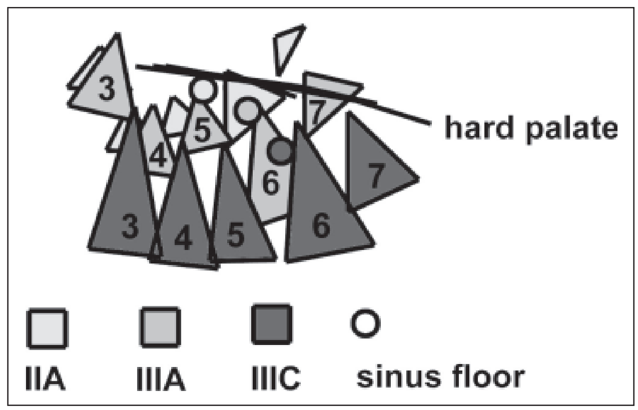

Figure 8.

Longitudinal cephalometric studies have demonstrated a lowering of the posterior part of the hard palate following that of the anterior maxillary part.[12] Sutural growth and remodeling (resorption of the nasal surface and apposition on the oral side) are factors involved in the descent of the hard palate. The posterior part, formed by the horizontal process of the palatine bone, articulates with the pterygoid process and maxilla. A lowering of the posterior part parallel to the anterior part of the palate implies a downward displacement of the palatine bone in relation to the pterygoid process.

Panoramic roentgen anatomy of the maxillary sinuses was investigated by Ohba and Katayama.[13] According to their findings, anterior and posterior walls of the maxillary sinus are superimposed upon the medial wall. The anterior wall occupies the medial two thirds of the maxillary sinus image, while the posterior wall occupies the lateral one third of the maxillary sinus image. In this study, there were no statistically significant differences in the mean X coordinate values of the reference point PA among the 5 developmental stages. This suggests that the point at which the medial wall of the maxillary sinus intersects with the hard palate on panoramic radiographs is comparatively stable during development of the teeth and alveolar bone. The reference points PM and PA gradually changed their positions in the distal and occlusal directions from the primary dentition to the early permanent dentition. These results coincide with those of a previous study.[12]

Figure 8 shows the superimposition of the mean positions of all reference points for stages IIa, IIIa, and IIIc. The position of the root apex of the permanent first molar was almost on the hard palate in stage IIa and was separated from the hard palate after stage IIa. The positions of the root apices of the permanent canine and second molar were above the hard palate from stages IIa to IIIa and were below the hard palate after stage IIIa. The positions of the root apices of the other teeth (premolars) were already below the hard palate by stage IIa. These results provide an effective means of understanding the relation between the structures of the posterior region of the maxilla from primary dentition to early permanent dentition.

In the horizontal direction, the sinus floor gradually changes its position distally through all stages. It is situated near the middle position of the second premolar and permanent first molar in stage IIa but moves toward the root apex of the permanent first molar with growth. In the vertical direction, the sinus floor remarkably changes its position occlusally between stages IIc and IIIa and between stages IIIa and IIIb. Stages IIc to IIIa are an active eruption period for the permanent first molar, and stages IIIa to IIIb are an active eruption period of the buccal teeth. The teeth most frequently related anatomically to the sinus are the upper permanent molars and second premolar.[7] It has been suggested that the development of the maxillary sinuses, which have a close relationship with the maxilla structure[14] and with the upper posterior teeth, might be affected by dental development.

Cysts of the maxillary sinus of odontogenic origin have been well documented in the literature.[15] Pulpal infection involving teeth near the maxillary sinus sometimes spreads into the sinus and causes serious complications.[16] Chronic sinus infections treated with maxillary sinus curettage in young children may have caused agenesis of the roots.[5] Therefore, the close relationship of the teeth and maxillary sinus necessitates both communication and cooperation between the dentist and the ENT specialist to ensure the best outcome for the patient. From this point of view, this study provides information of clinical significance; the teeth intimate with the maxillary sinus were the permanent canine and permanent second molar before stage IIIa, while it was the permanent first molar after stage IIIa.

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