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Three-dimensional space changes after premature loss of a maxillary primary first molar

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Background. A space maintainer is generally preferred when a primary first molar is lost before or during active eruption of the first permanent molars in order to prevent space loss. However, controversy prevails regarding the space loss after eruption of the permanent first molars.
Aim. The purpose of this study was to examine spatial changes subsequent to premature loss of a maxillary primary first molar after the eruption of the permanent first molars.
Design. Thirteen children, five girls and eight boys, expecting premature extraction of a maxillary primary first molar because of caries and/or failed pulp therapy, were selected. Spatial changes were investigated using a three-dimensional laser scanner by comparing the primary molar space, arch width, arch length, and arch perimeter before and after the extraction of a maxillary primary first molar. Also, the inclination and angulation changes in the maxillary primary canines, primary second molars, and permanent first molars adjacent to the extraction site were investigated before and after the extraction of the maxillary primary first molar in order to examine the source of space loss.
Results. There was no statistically significant space loss on the extraction side compared to the control side ($P = 0.33$). No consistent findings were seen on the inclination and angulation changes on the extraction side.
Conclusions. The premature loss of a maxillary primary first molar, in cases with class I molar relationship, has limited influence on the space in permanent dentition.

Introduction

The premature loss of a primary molar may influence the developing occlusion. Although it is influenced by various factors, premature loss is bound to alter the relationship of the adjacent teeth. Tipping and loss of space within the dental arch leading to crowding and impaction of the permanent successors are some of the effects of such disturbances[1]. An appropriate measure to prevent the space problem is to use a space maintainer. A space maintainer is generally preferred when a primary second molar is prematurely lost. Also, space loss can arise when the primary first molar is lost before or during the active eruption of the first permanent molar[2,3]. It is still controversial, however, as to the extent of the consequences following the premature loss of a maxillary primary first molar after the permanent first molars are fully erupted.

Many of the earlier studies have misinterpreted their results regarding space changes after the premature loss of a primary first molar because of insufficient sample size, cross-sectional nature of the study, and lack of clarification regarding the eruption state of the permanent first molars. Also, two-dimensional analysis of a dental cast can complement measurement errors to what is actually a three-dimensional (3-D) record. Thus, this study was designed to use a computer-interfaced 3-D laser scanner in evaluating the mean spatial changes subsequent to a unilateral premature loss of a maxillary

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primary first molar. Also, the amount of tooth movement in primary canines, primary second molars, and permanent first molars adjacent to the extraction site was examined with regard to direction (angulation and inclination) to investigate the source of space change.

Methods

Thirteen children, five girls and eight boys, expecting premature extraction of a maxillary primary first molar because of caries and/or failed pulp therapy, were selected from the Department of Pediatric Dentistry at Samsung Medical Center, Seoul, South Korea. All of the subjects complied with the following criteria specified for this study: (i) premature extraction of a maxillary primary first molar at least 12 months ahead of the expected eruption of the permanent successors; (ii) a unilateral extraction of the maxillary primary first molar with an intact contralateral primary first molar to be used as the control; (iii) the maxillary permanent incisors and permanent first molars have erupted; (iv) the maxillary primary canines and primary second molars were present throughout the duration of the study; and (v) class I molar relationships on both sides were apparent.

This study was reviewed and approved by the Institutional Review Board of Samsung Medical Center.

The initial study casts were made from alginate impressions just before the extraction of the maxillary primary first molar. The ages of the children at the time of the initial impression ranged from 5 years, 11 months to 10 years, with a mean age of 7 years, 11 months. None of the subjects received a space maintainer after the extraction and throughout the duration of the study. The final study casts were also made from alginate impressions at least 6 months after the extraction. The mean observation time from extraction to the final impression was 12 months, with a range of 8–23 months (Table 1).

Table 1. Sample description (n = 13).

Gender (n)	
Male	8
Female	5
Age at initial examination (Y/M)	
Mean	7/11
Minimum	5/11
Maximum	10/0
Age at final examination (Y/M)	
Mean	8/11
Minimum	6/8
Maximum	11/9
Interval between examinations (M)	
Mean	12
Minimum	8
Maximum	23

Measuring 3-D spatial changes

Both the initial and the final dental casts were scanned with 3-D laser scanner (Orapix Scanner KOD300, Orapix Co. Ltd, Seoul, Korea), which is capable of registering numerous coordinates in three dimensions with ±20 μm precision. RapidForm 2006 software (INUS Technology Inc., Seoul, South Korea) was used to reconstruct the scanned image into a 3-D model. Four measurements concerning space loss and dental arch development, including the primary molar space (D + E space), arch width, arch length, and arch perimeter were measured on these 3-D models with RapidForm 2006 program.

D + E space refers to the space occupied by the primary first and second molars (Fig. 1). It is defined as the distance between the mesial midpoint of the first permanent molar and the distal midpoint of the primary canine. This measurement has been previously recommended by several studies as a segment of arch length that is easily defined and monitored with limited number of factors that could influence space changes[4,5]. The opposite quadrant with unaffected primary first molar for the duration of the study served as control. The arch width was measured between the central fossa on the occlusal surface of two second primary molars. The arch length was measured from the contact point on the central incisors perpendicular to the arch width. The arch perimeter measured the arc from the mesial midpoint of the permanent first molar through the cusp tip of the canine and the incisal edges of the incisors to the opposite mesial midpoint of the permanent first molar. All the measurements were performed by one experienced investigator with the computer program.

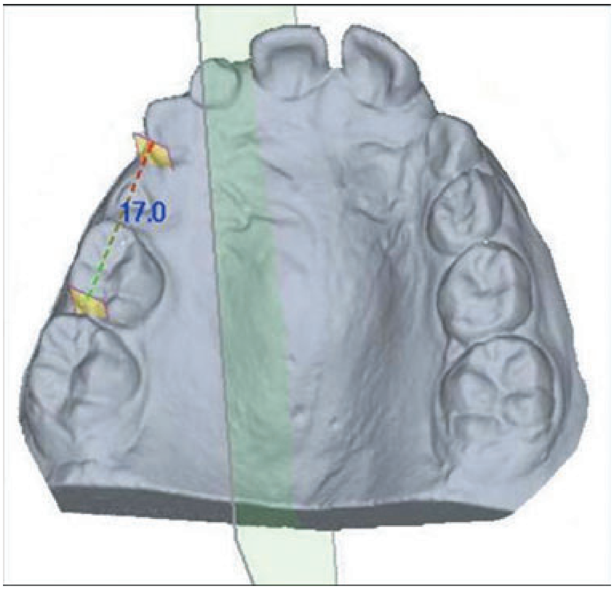

Fig. 1. D + E space measurement.

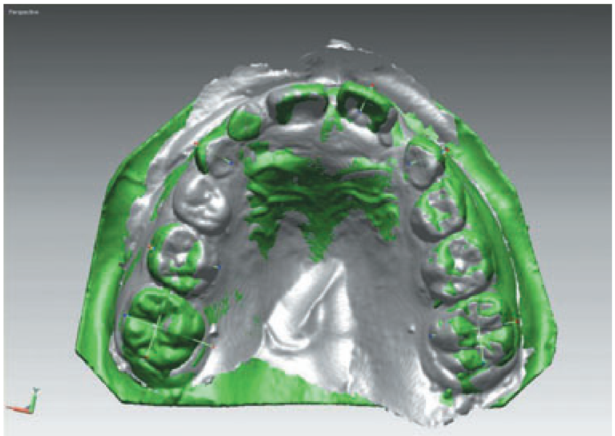

Fig. 2. Superimposition of the initial and the final three-dimensional scanned models.

Measuring angulation and inclination changes

To investigate the amount of tooth movement with regard to direction, inclination and angulation changes of the teeth adjacent to the extraction side, as well as the first permanent molars, were measured and compared to those of the control side. The initial and the final scanned models were superimposed on palatal rugae area with the use of 3-D surface-to-surface matching registration function of the RapidForm 2006 software (Fig. 2). The reference points recorded by this function of the software have been found to be stable enough to allow reliable sequential superimposition of scanned casts[6,7]. Then, the incisal edges of the permanent incisors and the buccal cusp tips of the permanent first molars were used to construct an occlusal plane which was used to create vectors for measuring angulation and inclination of teeth (Fig. 3). The midpoint of mesio-distal width and cervico-incisal length of the clinical crown was constructed on the buccal surface of the tooth to be measured, and this midpoint served as the reference point to create a vector parallel to the axis of the tooth, the reference line. From the reference line, the inclination and the angulation of the primary canines, primary

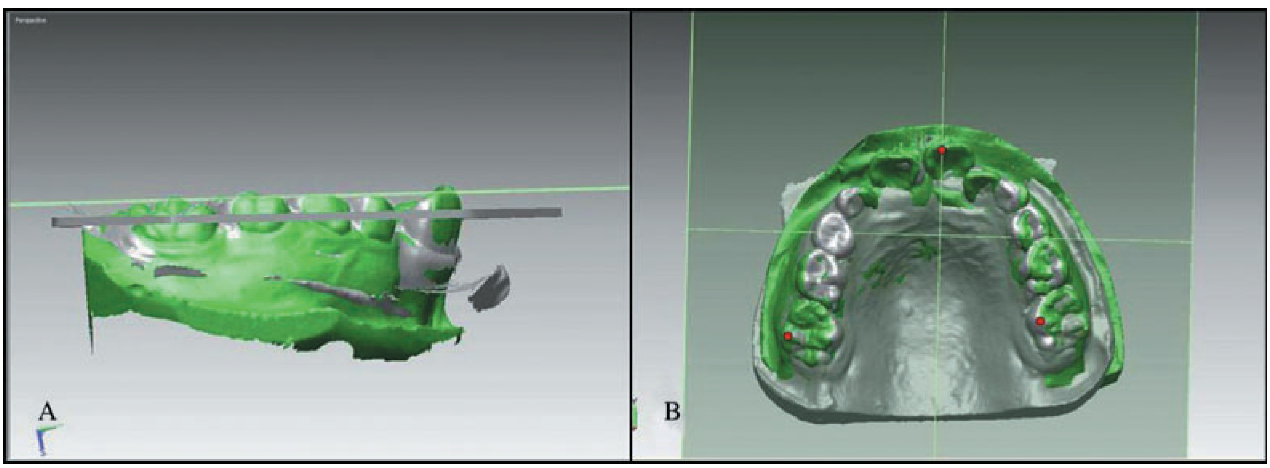

Fig. 3. Construction of the occlusal plane. (A) Lateral view of the occlusal plane. (B) Occlusal view of the occlusal plane.

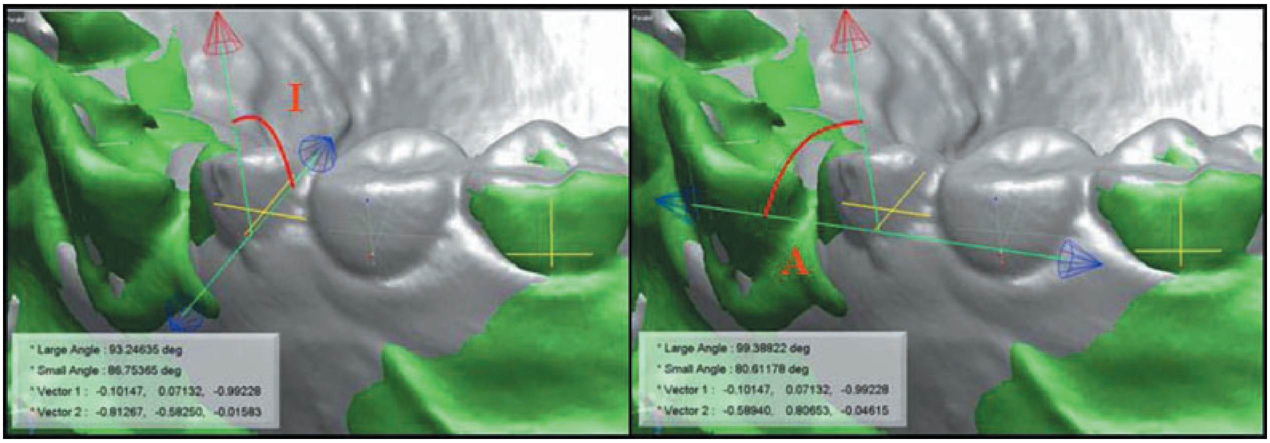

Fig. 4. Measuring of inclination and angulation. A, angulation; I, inclination.

second molars, and permanent first molars in both extraction side and control side were measured in magnitude (Fig. 4). The differences between these measurements in the initial and the final models were calculated in both magnitude and direction, so the direction of space loss could be identified in reference to the buccal plane of the tooth.

Statistical analysis

A paired *t*-test was used to compare the differences between the initial and the final measurements of D + E space. A Student's *t*-test was used to compare the D + E space changes in the extraction side with those of the controls.

The directional differences in angulation and inclination between the extraction and the control sides were compared with the two-way analysis of variance, whereas the amounts of angulation and inclination changes were compared with the Student's *t*-test and the Wilcoxon two-sample test. The paired *t*-test was used to compare the arch width, length, and perimeter between the initial and the final models.

Results

D + E space analysis

Two of the subjects lost the primary first molar on the control side during the observation period and were excluded from the study. Table 2 shows the D + E space changes between the initial and the final examinations of the rest of the subjects. The mean D + E space measured at the initial examination before extraction of the primary first molar was not significantly different between the extraction side (16.47 mm ± 1.03 mm) and the control side (16.09 mm ± 0.85 mm). The mean D + E space in the extraction side (15.90 mm ± 1.21 mm) was not significantly different from that of the control side (15.78 mm ± 0.92 mm) at the final examination. The mean D + E space change between the initial and the final examinations of the extraction side was 0.57 mm ± 0.83 mm. The

Table 2. D + E space changes (mm) between the initial and the final examinations on extraction and control sides.

	Extraction side (mm)		Control side (mm)	
Case no.	Initial	Final	Initial	Final
1	17.3	16.9	16.8	16.9
2	17.3	17.5	16.6	15.6
3	17.8	17.0	17.4	17.0
4	14.6	14.9	14.5	14.1
5	15.9	16.1	15.8	16.1
6	16.4	13.9	16.5	16.0
7	15.8	14.5	15.7	15.6
8	16.2	16.2	15.7	15.7
9	15.6	15.3	15.3	14.9
10	18.0	17.3	17.0	16.8
11	16.3	15.3	15.7	14.9
Mean ± SD (mm)	16.5 ± 1.0	15.9 ± 1.2	16.1 ± 0.8	15.8 ± 0.9
D + E space changes (mm)	0.57 ± 0.83		0.31 ± 0.38	

Table 3. Angulation and inclination changes (°) between the initial and the final examinations in extraction and control sides.

		Inclination (°)			Angulation (°)		
		Direction	***n***	**Mean (SD)**	**Direction**	***n***	**Mean (SD)**
Primary canine	Extraction	Labial	3	5.54 (3.09)	Mesial	8	6.65 (5.60)
	($n = 10$)	Palatal	7	3.67 (3.13)	Distal	2	2.76 (1.49)
	Control	Labial	3	1.81 (1.98)	Mesial	6	6.82 (3.92)
	($n = 11$)	Palatal	8	3.59 (3.17)	Distal	5	8.05 (10.98)
Primary second molar ($n = 11$)	Extraction	Buccal	–	–	Mesial	7	4.21 (3.41)
		Palatal	11	2.75 (2.40)	Distal	4	3.01 (0.81)
	Control	Buccal	–	–	Mesial	4	2.55 (1.85)
		Palatal	11	4.21 (7.06)	Distal	7	2.87 (1.21)
Permanent first molar ($n = 11$)	Extraction	Palatal	11	6.83 (5.98)	Distal	11	6.31 (4.29)
	Control	Palatal	11	3.65 (1.98)	Distal	11	6.33 (5.08)

mean D + E space change between the initial and the final examinations of the control side was 0.31 mm ± 0.38 mm. There was no statistically significant difference in the amount of space loss on the extraction side compared to the control side ($P = 0.33$).

Angulation and inclination changes

One of the primary canines in the extraction side was excluded from the study because of its mobility that compromised the accuracy of the results (Table 3). In the rest of the primary canines, there was no significant difference in the amount of inclination ($P = 0.39$) and angulation ($P = 0.75$) changes between the extraction and the control sides. For the primary second molars, there was also no significant difference in the amount of inclination ($P = 0.62$) and angulation ($P = 0.51$) changes between the extraction and the control side. Generally, however, the primary second molars in the extraction side showed a tendency towards mesial and palatal tilting which was of no clinical significance. The permanent first molars also showed no significant difference in the amount of inclination ($P = 0.12$) and angulation ($P = 0.99$) changes between the extraction and the control sides.

Arch width, length, and perimeter

As Table 4 shows, arch width, length, and perimeter significantly increased at the final examination compared to the initial examination.

Table 4. Changes in arch width, length, and perimeter (mm) between the initial and the final examinations.

	Arch width (mm)	Arch length (mm)	Arch perimeter (mm)
Initial	41.83	23.05	82.36
Final	42.37*	24.15*	84.20*

*Statistically significant ($P < 0.05$).

Discussion

A space maintainer is adequate for preventing space loss; however, it may also increase caries susceptibility because of poor oral hygiene, and cause discomfort with its long-term usage. Also, failure of a space maintainer may cause the parents to wonder about the cost effectiveness of such appliances[8]. Regarding the early loss of a primary first molar, previous studies have clearly showed that it is beneficial in cases where the loss occurs before or during the active eruption of the permanent first molars[2,3]. Several studies, however, have reported that its usage may be irrelevant in situations where the first permanent molars have erupted. Terlaje and Donly suggested that space maintainer is not necessary for unilateral loss of a primary first molar in whom the permanent first molars have erupted[9]. They argued that the erupted molars are passive, thereby not producing a mesial component of eruption force. Also, Lin *et al*. have stated that the effects of space maintainers need to be re-evaluated in cases of a unilateral premature loss of a maxillary primary first molar[10]. The significant increase in all of the arch dimensions during the observation period also reassures that there was no permanent loss of space clinically and that normal pattern of growth has occurred[11]. The results of this study show similar findings. The space maintainer may not be necessary in situations where the first permanent molars have erupted and interdigitation has occurred, preventing them from drifting mesially and causing space loss. The spatial changes on the extraction side, as measured by D + E space at the final examination, revealed no significant space loss compared to the D + E space before the extraction. Also, D + E space on the extraction sides, both at the initial and the final examinations, showed no significant difference in comparison to those of the control side.

Although individual factors such as eruption sequence and time, skeletal and muscular characteristics, periodontal factors, and growth can further clarify changes in variations, the ultimate effect of early loss of primary teeth can be related to the degree of drifting of the adjacent teeth[12]. Tooth drifting is dependent mainly on the factors of dental age at the time of extraction, intercuspation status, and space conditions. The previous study by Davey has shown that mesial drift of a maxillary permanent first molar is related to its cusp height[2]. For each millimetre less of cusp height, there was 2.367 mm more mesial drift. The availability of leeway space is also related to space loss. Davey also showed that the mesial migration of the maxillary first permanent molars occurred in potentially crowded arches with each millimetre less of leeway resulting 0.305 mm more mesial drift. The inclusion criteria stipulated for this study excluded those with moderate to severe space problems and only included cases with class I molar relationship on both sides with full intercuspation in order to eliminate such factors influencing the space loss. Also, when angulation and inclination changes were evaluated, both direction and amount of change were taken into consideration to identify the source of space loss. The statistical analysis for angulation changes showed that there was no significant tilting of the teeth adjacent to the extraction space in comparison to the teeth in the control side. Also, the inclination changes in the teeth adjacent to the extraction space were of no significant difference in magnitude. Because all measurements were performed by one investigator, we made an effort with repeated measurements each case to get consistent measurement. However, the high standard deviation, in this study, implies greater variation in the outcome, and the small sample size also limits the consistency of the results.

The palatal rugae area, which is known to be the most stable anatomic structure in the maxilla, was used for superimposition of the initial and the final scanned models. Although the software used in the study has been found to be stable for sequential superimposition of scanned casts, the reliability of the method utilized to measure inclination and angulation has yet been proven. Thus, the results of inclination and angulation changes need to be analysed with caution, and further study is necessary to prove the credibility of this method.

The findings from this study are valuable; however, they disclose only a part of the scenario related to the inclusion criteria stipulated for this study. Also, several limitations pertaining to longitudinal study of arch space such as continual changing of the landmarks, distortions during the making and scanning of the models, as well as technical errors involved in measuring may limit the accuracy of the results. Thus, further research with larger sample size is necessary for future references.

Conclusion

The premature loss of a maxillary primary first molar, in cases with class I molar relationship, has limited influence on the space in the permanent dentition.

What this paper adds

- This paper adds knowledge about 3-D space changes following the premature loss of a maxillary primary first molar after the permanent first molars have erupted.
- The results indicate that the premature loss of a maxillary primary first molar, in cases with class I molar relationship, has limited influence on the space in the permanent dentition.

Why this paper is important to paediatric dentists

- This paper supports evidence that when a maxillary primary molar is prematurely lost after complete eruption of the permanent first molars, periodic monitoring for possible space loss may be adequate without the use of a space maintainer.

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