Original Article

Comparison of tooth development stage of the maxillary anterior teeth before and after secondary alveolar bone graft

Unilateral cleft lip and alveolus vs unilateral cleft lip and palate

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ABSTRACT

Objective: To compare the effect of secondary alveolar bone graft (SABG) on the tooth development stage of the maxillary central incisor (MXCI) and maxillary canine (MXC) in terms of the severity of unilateral cleft.

Materials and Methods: The subjects consisted of 50 boys with unilateral cleft lip and alveolus (UCLA) or unilateral cleft lip, alveolus, and palate (UCLP). The age- and sex-matched subjects were divided into group 1 (UCLA, n=25; 9.3 ± 0.8 years old) and group 2 (UCLP, n=25; 9.4 ± 0.6 years old). In panoramic radiographs taken 1 month before (T0) and 1 year after SABG (T1), tooth development stage was evaluated according to the Nolla developmental (ND) stage. A panoramic radiograph taken 3 years after SABG was used as a reference for the final root length of individual tooth.

Results: In groups 1 and 2, the ND stage of the MXCI did not exhibit differences between the cleft and non-cleft sides at T0 and T1, respectively. However, although the ND stage of the MXC of group 2 was delayed on the cleft side compared with the non-cleft side at T0 ($P < .05$), the MXC on the cleft side developed faster than that on the non-cleft side after SABG ($P < .01$). In terms of tooth development speed, group 2 showed a higher rate of faster developed MXCs on the cleft side compared with the non-cleft side after SABG than group 1 (36.0% vs 8.0%, $P < .05$).

Conclusion: SABG performed at approximately 9 years of age might increase tooth development speed of MXC in patients with UCLP compared with patients with UCLA. (*Angle Orthod.* 2014;84:989–994.)

KEY WORDS: Tooth development stage; Secondary alveolar bone graft; Unilateral cleft lip and alveolus; Unilateral cleft lip and palate

INTRODUCTION

Cleft lip and/or palate (CL/P) is one of the most common craniofacial deformities in humans.[1,2] Some dental abnormalities, including hypodontia, supernumerary tooth, delay in tooth formation, and asymmetric tooth formation have been reported in patients with CL/P.[3,4] Previous studies suggested that the formation of permanent tooth was delayed from 0.3 to 0.9 years in patients with CL/P compared with healthy populations,[3,5] and that an asymmetrical pattern of tooth formation was observed in patients with unilateral CL/P.[4] Several etiologic factors, including maternal or genetic influences, growth retardation due to nutritional deficits, lack of space in the hypoplastic quadrant of the maxilla on the cleft side, and surgical procedures might influence the occurrence of these dental abnormalities in patients with cleft.[3,5–7]

Alveolar bone graft (ABG) has become a critical procedure in the overall management of patients with CL/P.[8] The purposes of ABG are to fill the bony gap, to stabilize the overall dental arch, to provide bony support for the teeth adjacent to the cleft area, to close the residual oronasal fistula, and to support the

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Table 1. Comparison of Age and Observation Duration in Patients with UCLA and UCLP[a]

		Cleft Type		
	Stage	UCLA (N = 25 boys)	UCLP (N = 25 boys)	*P*-Value[b]
Age (years)	T0	9.27 ± 0.84	9.43 ± 0.64	.4809
	T1	10.56 ± 0.84	10.68 ± 0.62	.5671
Observation duration (T0-T1) (years)		1.28 ± 0.22	1.24 ± 0.25	.4640

[a] UCLA indicates unilateral cleft lip and alveolus; UCLP, unilateral cleft lip, alveolus, and palate; T0, 1 month before secondary alveolar bone graft (SABG); T1, 1 year after SABG.
[b] Independent *t*-test was performed.

Table 2. Nolla Developmental Stages[15]

1. Presence of crypt
2. Initial calcification
3. One-third of the crown completed
4. Two-thirds of the crown completed
5. Crown almost completed
6. Crown fully completed
7. One-third of the root completed
8. Two-thirds of the root completed
9. Root almost completed
10. Closed apex

Table 3. Results of Intraexaminer Reliability[a]

			Cohen's Kappa Coefficient[b]	
Stage	Side	Tooth	Group 1 (UCLA)	Group 2 (UCLP)
T0	Cleft	MXCI	1.0000	1.0000
		MXC	0.8387	0.9153
	Non-cleft	MXCI	1.0000	1.0000
		MXC	0.9110	0.9153
T1	Cleft	MXCI	1.0000	1.0000
		MXC	0.8664	0.9110
	Non-cleft	MXCI	1.0000	1.0000
		MXC	0.8270	0.9110

[a] UCLA indicates unilateral cleft lip and alveolus; UCLP, unilateral cleft lip, alveolus, and palate; T0, 1 month before secondary alveolar bone graft (SABG); T1, 1 year after SABG; MXCI, maxillary central incisor; MXC; maxillary canine.
[b] Cohen's Kappa coefficient was used to verify intraexaminer reliability. All of the subjects were reassessed by the same operator (Heon-Mook Park) after 1 month.

lip and nose.[9,10] Although a number of protocols for ABG have been suggested according to donor site and surgical timing,[11,12] secondary ABG with particulate cancellous bone and marrow from the iliac bone is the most acceptable procedure to provide periodontal support for the permanent teeth adjacent to the cleft and spontaneous migration of the permanent maxillary canine (MXC) into the graft area.[9,11]

Although the tooth development stage may be the same in subjects with similar ages, it may differ according to gender, ethnic group, and cleft severity.[3,13] Because previous studies did not use subjects from the same ethnic background and with the same age range, gender, cleft severity, bone graft technique, or orthodontic treatment protocol, it has been difficult to obtain consistent and objective outcomes. In addition, although several previous studies have reported delays in tooth development in children with CL/P and differences in the eruption pattern of the permanent MXC after secondary ABG (SABG),[3,4,8,14] they did not analyze the relationship between SABG and tooth development stage. Therefore, further study is needed using subjects with the same ethnic background and gender and similar ages. In addition, because bilateral CL/P makes it difficult to compare tooth development stage, unilateral CL/P is preferred for investigating differences in tooth development stage before and after SABG.

The purpose of this retrospective study was to compare the effect of SABG on the tooth development

Table 4. Comparison of Tooth Development Stage of the MXCI between groups 1 and 2[a]

		UCLA						UCLP			
		Cleft Side (N = 25)		Non-cleft Side (N = 25)		*P*-Value	*P*-Value	Cleft Side (N = 25)		Non-cleft Side (N = 25)	
	MXCI	T0	T1	T0	T1	at T0[b]	at T1[b]	T0	T1	T0	T1
Mean		9.04	9.92	9.08	9.92	.5637	1.0000	9.00	9.92	9.00	9.96
SD		0.35	0.28	0.28	0.28			0.00	0.28	0.00	0.20
Median		9.00	10.00	9.00	10.00			9.00	10.00	9.00	10.00
95% CI	Lower bound	8.90	9.81	8.97	9.81			9.00	9.81	9.00	9.88
	Upper bound	9.18	10.00	9.19	10.00			9.00	10.00	9.00	10.00

[a] UCLA indicates unilateral cleft lip and alveolus; UCLP, unilateral cleft lip, alveolus, and palate; MXCI, maxillary central incisor; T0, 1 month before secondary alveolar bone graft (SABG); T1, 1 year after SABG.
[b] Wilcoxon signed rank test was performed to compare the differences between the cleft and non-cleft sides in each group and the amount of change in the Nolla developmental stage after SABG.
[c] Mann-Whitney U-test was performed to compare the differences between two groups.

stage of the maxillary central incisor (MXCI) and MXC between patients with unilateral cleft lip and alveolus (UCLA) and unilateral cleft lip, alveolus, and palate (UCLP). The null hypotheses of this study were (1) that there was no significant difference in tooth development stage of the MXCI and MXC between the cleft and non-cleft sides before and after SABG in patients with UCLA and UCLP, respectively; and (2) that there was no significant difference in tooth development speed of the MXCI and MXC on the cleft side after SABG between patients with UCLA and UCLP, respectively.

MATERIALS AND METHODS

The age- and sex-matched subjects consisted of 50 boys with UCLA and UCLP treated at the Department of Orthodontics, Seoul National University Dental Hospital, Seoul, Korea. According to the cleft severity, they were divided into group 1 (UCLA, n = 25 boys; right side n = 9; left side n = 16; 9.3 ± 0.8 years old) and group 2 (UCLP, n = 25 boys; right side n = 8; left side n = 17; 9.4 ± 0.6 years old) (Table 1). This retrospective study was reviewed and approved by the Institutional Review Board of Seoul National University Dental Hospital (CRI 13015).

Inclusion criteria for subjects were Korean boys who had non-syndromic UCLA or UCLP and received SABG; in addition, to avoid the effect of gender and age on tooth development stage, only boys with similar ages were included as subjects (8.4–10.4 years old). Exclusion criteria were as follows: (1) patients who had bilateral CL/P or other craniofacial anomalies; (2) patients who had received primary or tertiary ABG; and (3) patients with abnormal root shape that could interfere with the accurate measurement of root development stage in the panoramic radiograph.

In addition, all of the subjects were treated with the same surgical and orthodontic treatment protocol: (1) timing of the primary surgeries (lip repair from 3 to 5 months old and palatal surgery from 18 to 24 months old); (2) expansion of the maxillary arch before SABG; (3) SABG with particulate cancellous bone and marrow from the iliac crest during mixed dentition; and (4) fixed orthodontic treatment during permanent dentition.

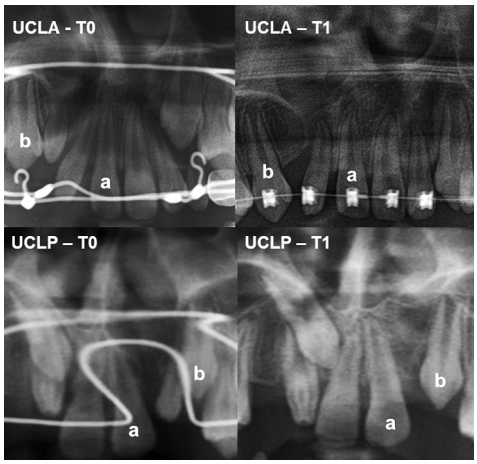

Figure 1. Examples of tooth development in patients with unilateral cleft lip and alveolus (UCLA) and unilateral cleft lip and palate (UCLP). T0 indicates 1 month before secondary alveolar bone graft (ABG); T1, 1 year after secondary ABG; a, maxillary central incisor; b, maxillary canine.

In panoramic radiographs taken 1 month before SABG (T0) and 1 year after SABG (T1) (Figure 1), tooth development stage was evaluated according to Nolla developmental (ND) stage (Table 2)[15] by a single operator (HMP). A panoramic radiograph taken 3 years after SABG was used as a reference for the final root length of individual teeth after completion of root apex closure.

All of the subjects were reassessed by the same operator after 1 month. Cohen's kappa coefficient was used to verify intraexaminer reliability. Because there was no significant difference between the first and second measurements, the first set of measurements was used (Table 3).

Table 4. Extended

UCLP		ΔUCLA			ΔUCLP			ΔUCLA vs ΔUCLP	
P-Value at T0 [b]	*P*-Value at T1 [b]	Cleft Side (N = 25)	Non-cleft Side (N = 25)	*P*-Value [b]	Cleft Side (N = 25)	Non-cleft Side (N = 25)	*P*-Value[b]	*P*-Value at Cleft Side[c]	*P*-Value at Non-cleft Side[c]
1.0000	.3173	0.88	0.84	.5637	0.92	0.96	.3173	.6407	.1615
		0.33	0.37		0.28	0.20			
		1.00	1.00		1.00	1.00			
		0.74	0.69		0.81	0.88			
		1.02	0.99		1.03	1.04			

Table 5. Comparison of Tooth Development Stage of the MXC Between Groups 1 and 2[a]

		UCLA						UCLP			
		Cleft Side (N = 25)		Non-cleft Side (N = 25)		*P*-Value at T0[b]	*P*-Value at T1[b]	Cleft Side (N = 25)		Non-cleft Side (N = 25)	
MXC		T0	T1	T0	T1			T0	T1	T0	T1
Mean		7.60	8.64	7.64	8.60	.5637	.3173	7.36	8.68	7.72	8.68
SD		0.50	0.49	0.49	0.58			0.49	0.48	0.46	0.48
Median		8.00	9.00	8.00	9.00			7.00	9.00	8.00	9.00
95% CI	lower bound	7.39	8.44	7.44	8.36			7.16	8.48	7.53	8.48
	lower bound	7.81	8.84	7.84	8.84			7.56	8.88	7.91	8.88

[a] MXC indicates maxillary canine; UCLA, unilateral cleft lip and alveolus; UCLP, unilateral cleft lip, alveolus, and palate; T0, 1 month before secondary alveolar bone graft (SABG); T1, 1 year after SABG.

[b] Wilcoxon signed rank test was performed to compare the differences between the cleft and non-cleft sides in each group and the amount of change in the Nolla developmental stage after SABG.

[c] Mann-Whitney U-test was performed to compare the differences between two groups.

* $P < .05$; ** $P < .01$.

Power analysis for sample-size determination was performed using the Sample Size Determination Program version 2.0.1 (Seoul National University Dental Hospital, Registration number 2007-01-122-004453). Mean and standard deviation values of dental age difference from Tan et al.[4] were used for power analysis.

The independent *t*-test was used to measure the difference in age and observation duration (T0-T1) between the two groups. The Wilcoxon signed rank test was performed to compare the differences between the cleft and non-cleft sides in each group and the amount of change in the ND stage after SABG. In addition, the Mann-Whitney U-test was used to compare the differences in the ND stage between the two groups. Fisher's exact test was used to compare the rate distribution of tooth development speed of the MXC on the cleft side after SABG between groups 1 and 2.

RESULTS

There were no significant differences in age and no differences in observation duration (T0-T1) between groups 1 and 2 at T0 and T1, respectively (Table 1). In groups 1 and 2, the ND stage of the MXCI did not exhibit significant differences between the cleft and non-cleft sides at T0 and T1, respectively (9.04 vs 9.08 in group 1 at T0; 9.00 vs 9.00 in group 2 at T0; 9.92 vs 9.92 in group 1 at T1; 9.92 vs 9.96 in group 2 at T1, all $P > .05$; Table 4).

However, group 2 showed that the ND stage of the MXC was delayed on the cleft side compared with the non-cleft side at T0 (7.36 vs 7.72, $P < .01$, stage 7 means that one-third of root development is complete, Table 5). In group 2, after SABG the MXC on the cleft side developed faster than that on the non-cleft side (amount of change in tooth development: 1.32 vs 0.96, $P < .01$, Table 5). However, there was no difference in the amount of change in tooth development between the cleft and non-cleft sides in group 1 (1.04 vs 0.96, $P > .05$, Table 5). In addition, there were significant difference in the amount of change in tooth development of the MXC on the cleft side between subjects with UCLA and UCLP ($P < .05$, Table 5).

In terms of the rate distribution of tooth development speed of the MXC, group 2 exhibited a higher rate of faster developed MXCs on the cleft side compared with the non-cleft side after SABG than group 1 (8.0% in group 1 vs 36.0% in group 2, $P < .05$, Table 6).

DISCUSSION

The present study was performed to compare the effect of SABG on the tooth development stage of the MXCI and MXC in terms of the severity of unilateral

Table 6. Comparison of Tooth Development Speed of the MXC Between Groups 1 and 2[a]

		Cleft Type		
MXC		Group 1 (UCLA)	Group 2 (UCLP)	*P*-Value
Tooth development speed of the cleft side compared with the non-cleft side during T0-T1	Faster	2 (8.0%)	9 (36.0%)	.0169*
	Same or slower	23 (92.0%)	16 (64.0%)	
Sum		25	25	

[a] MXC indicates maxillary canine; UCLA, unilateral cleft lip and alveolus; UCLP, unilateral cleft lip, alveolus, and palate; T0, 1 month before secondary alveolar bone graft (SABG); T1, 1 year after SABG.

* $P < .05$; Fisher's exact test was performed.

Table 5. Extended

UCLP		ΔUCLA			ΔUCLP			ΔUCLA vs UCLP	
P-Value at T0[b]	*P*-Value at T1[b]	Cleft Side (N = 25)	Non-cleft Side (N = 25)	*P*-Value[b]	Cleft Side (N = 25)	Non-cleft Side (N = 25)	*P*-Value[b]	*P*-Value at Cleft Side[c]	*P*-Value at Non-cleft Side[c]
.0027**	1.0000	1.04	0.96	.3173	1.32	.96	.0027**	.0243*	1.0000
		0.35	0.45		0.48	0.45			
		1.00	1.00		1.00	1.00			
		0.90	0.77		1.12	0.77			
		1.18	1.15		1.52	1.15			

cleft using subjects from the same ethnic group and with the same gender, age, surgical technique, and orthodontic treatment protocol.

The finding that the ND stage of the MXCI was not different between groups 1 and 2 (Table 4) disagrees with the findings of Tan et al.,[4] who reported that the development of the maxillary anterior teeth was commonly delayed (maxillary lateral incisor, 73.3%; MXCI, 37.3%; MXC, 11.7%). Because they sampled younger patients with a wider age range (5–9 years old) compared with the present study, the MXCI was in the root development stage and the MXC was still in the crown formation stage.[4] However, because the present study performed SABG when the root development of the MXCI was nearly completed (just before final closure of the root apex) and when the MXC was between one-fourth and two-thirds of its final root length, these timing differences in ABG could explain the differences between the results from Tan et al.[4] and those of the present study.

Tooth development of the MXC on the cleft side in group 2 was significantly delayed at T0 compared with group 1 ($P < .01$, Tables 5), which is in accordance with the results of Pioto et al.,[16] who reported that the higher cleft severity in itself might be a contributing factor in tooth development delay in the permanent teeth. Sofaer[17] also suggested that developmental delay of the MXC can be attributed to the position of the MXC adjacent to the cleft defect.

In addition, the presence or absence of the lingual process in the cleft bony defect area in patients with UCLA and UCLP might also be an etiologic factor. Kim et al.[11] reported that the lingual cortical plate in the cleft bony defect was present in patients with UCLA but not in those with UCLP. If the lingual cortical plate adjacent to the cleft area can provide a space for root development of the MXC, tooth development before SABG (T0) might be delayed in patients with UCLP who do not have lingual cortical plate compared with that of patients with UCLA who have the lingual cortical plate.

The findings that the MXC on the cleft side of group 2 developed faster after SABG than the non-cleft side tooth (1.32 vs 0.96, $P < .01$, Table 5) and that group 2 showed a higher rate of faster developed MXC on the cleft side compared with the non-cleft side after SABG than group 1 (8.0% in group 1 vs 36.0% in group 2, $P < .05$, Table 6) indicate that restoration of the sufficient labiolingual thickness of the alveolar bone by SABG can create space for the root development of the MXC. Therefore, the underdeveloped MXC on the cleft side of patients with UCLP who have sufficient labiolingual thickness of the alveolar bone tooth after SABG might grow fast enough to catch up to the developmental stage of the non-cleft side MXC.

Ribeiro el al.[18] reported that root development of the maxillary lateral incisor on the cleft side was also significantly delayed compared with the non-cleft side tooth. However, in the present study, the tooth developmental stage of the maxillary lateral incisor was not analyzed because of the high rates of congenital missing, abnormally shaped, ectopically erupted, or impacted maxillary lateral incisors on the cleft side of patients with UCLP. Therefore, it will be necessary to include more patients with fully erupted and normal-shaped maxillary lateral incisor on the cleft side in order to analyze the effect of SABG on tooth development of the maxillary lateral incisor.

In the present study, two-dimensional panoramic radiographs before and after SABG were used to investigate the tooth development stage. Therefore, three-dimensional volume and position of the permanent tooth adjacent the cleft side before and after SABG and the amount of change in the tooth and cleft area could not be completely analyzed. Further examination of the relationship between the three-dimensional volume of the bony defect and the root development stage adjacent to the cleft side is needed in future studies. In addition, because the severity or size of bony defect might be one of the etiologic factors causing a difference in the initial position of the MXC between patients with UCLA and UCLP, it is needed to perform further studies for comparison of the initial position of the MXC between patients with UCLP and UCLA using three-dimensional computed tomogram data rather than two-dimensional panoramic radiographs.

CONCLUSION

- SABG performed at approximately 9 years of age might increase tooth development speed of the MXC in patients with UCLP compared with patients with UCLA.

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