Effect of Timing of Secondary Alveolar Bone Grafting on Maxillary Incisor Development in Patients with Cleft Lip and Palate

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Introduction

Alveolar bone grafting (ABG) is a standard procedure in cleft lip and/or palate (CLP) care, offering benefits such as improved bony support, facilitation of tooth eruption, and maxillary stability. While secondary ABG (sABG), typically performed between ages 9-12 before canine eruption, is now preferred over primary ABG due to better long-term outcomes, optimal timing remains debated.

Recent interest has shifted toward earlier sABG, prior to central incisor eruption, to improve periodontal health and crown development. Early sABG may also enhance graft volume and support lateral incisor eruption, though concerns persist about potential graft failure and maxillary growth restriction.

Dental anomalies are common in CLP, particularly in maxillary incisors near the cleft, making it important to assess whether sABG timing further affects their development. Most prior studies used 2D imaging and found age to be the only consistent predictor of success. Few have examined sABG timing in relation to incisor development using 3D imaging like CBCT.

This study aimed to evaluate whether the timing of sABG impacts the anatomical development of maxillary central and lateral incisors, using CBCT to assess tooth morphology and structure in patients with CLP.

Methods

The study was approved by the Internal Review Board of Cincinnati Children's Hospital Medical Center, #2023-0730. A retrospective chart review was performed of patients who underwent alveolar bone grafting at a single institution.

Inclusion criteria were: 1) patients with cleft lip and palate followed at CCHMC and 2) fully erupted maxillary central incisor(s) with complete root development at the time of CBCT imaging. Exclusion criteria were: 1) absence of an alveolar cleft, 2) diagnosis of craniofacial syndromes, 3) lack of CBCT imaging, and 4) CBCT images that were unreadable or unmeasurable based on study parameters. Records were screened manually. Demographic and clinical data, incldiung medical record number, date of birth, diagnosis, date of exam, and grafting details, were collected from the patients' dental records. Radiographic data were extracted from Planmeca Romexis CBCT system.

Central and lateral incisors on both cleft and non-cleft sides were measured. Parameters included: 1) crown size: mesial-distal and buccal-lingual width, 2) root length and abnormality in root shape (i.e., root dilaceration), and 3) crown-to-root ratio. Subjects were divided into three groups based on age at the time of sABG: early (6-7 years), middle (8-9 years), and late (>10 years). Measurements were compared across all three groups to determine if there was a statistically significant difference.

Continuous variables (i.e., age) were summarized as means and standard deviations, and categorical variables were summarized as counts and percentages. ANOVA and chi square tests were used for comparisons. A two-sided p-value <.05 was used to determine the significance of variables in all analyses. Analyses were performed using SAS version 9.4.

Results

CBCT images of a total of 101 patients (38 females, 63 males) were retrospectively analyzed. Two CBCT images were taken pre-ABG and 89 CBCT images were taken at least 6 months post-ABG. Of note, 10 subjects had not undergone sABG at the time the CBCT images were taken. 63 unilateral and 88 bilateral CLP patients were identified. The ages of the patients included in the study ranged from 6 to 18 years old, with a mean age of 9.26 ± 2.15 at the time of ABG.

The prevalence of misisng teeth on the cleft and non-cleft sides is summarized in Table 2. In patients with CLP, 77.2% of lateral incisors were absent on the cleft side, whereas 97.8% of central incisors were present. Interestingly, on the non-cleft side, 48.4% of lateral incisors were missing, while 98.4% of central incisors were present.

Measurements across the three age groups showed minimal variation. There were no significant differences in root length of central and lateral incisors based on the timing of sABG. Similarly, the crown-to-root ratio of tooth #7 remained consistent across all groups at 0.7 (p=0.908). Root shape abnormalities were observed in 3 out of 16 right lateral incisors (#7) in the 8 to 9-year-old group and in 2 out of 7 right lateral incisors (#7) in the >10-year-old group. Overall, 18.8% of right lateral incisors (#7) exhibited root shape abnormalities, compared to 13.5% of right central incisors (#8). Notably, tooth #9 demonstrated the highest rate of root shape abnormalities, with 39.5% in the middle age group and 42.4% in the late age group.

Tooth #7	Sub Cat	Non-Cleft margin (n=25)	Cleft margin (n=6)	P Value
Crown buccal-lingual width (mm)	Mean (SD)	6.3 (0.9)	5.6 (0.9)	0.080
Crown length (mm)	Mean (SD)	8.4 (1.4) 12.4 (1.8) 6.6	8.4 (1.0) 9.2 (2.5)	0.951
Root length (mm)	Mean (SD)	(0.9)	5.2 (0.8)	0.001
Crown mesial-distal width (mm)	Mean (SD)	22 (88.0)	2 (33.3)	
Root shape abnormality rate (N/%)	No	3 (12.0) 0.7 (0.2)	4 (66.7) 1.0 (0.4)	0.001
	Yes Mean (SD)			0.014
Crown/root ratio				0.005

Tooth #8	Sub Cat	Non-Cleft margin (n=53)	Cleft margin (n=45)	P Value
Crown buccal-lingual width (mm)	Mean (SD)	6.9 (0.6)	6.6 (0.7)	0.006
Crown length (mm)	Mean (SD)	10.3 (1.0)	9.8 (1.4)	0.029
Root length (mm)	Mean (SD)	11.5 (2.1)	10.8 (2.4)	0.106
Crown mesial-distal width (mm)	Mean (SD)	8.1 (0.6)	8.0 (0.8)	0.723
Root shape abnormality rate (N/%)	No Yes	49 (92.5)	29 (65.9)	0.002
	Mean (SD)	4 (7.5)	15 (34.1)	
Crown/root ratio		0.9 (0.3)	0.9 (0.3)	0.969

Tooth #9	Sub Cat	Non-Cleft margin (n=26)	Cleft margin (n=74)	P Value
Crown buccal-lingual width (mm)	Mean (SD)	7.0 (0.9)	6.6 (0.8)	0.040
Crown length (mm)	Mean (SD)	10.3 (1.2)	9.8 (1.1)	0.037
Root length (mm)	Mean (SD)	12.1 (2.9)	10.7 (2.2)	0.014
Crown mesial-distal width (mm)	Mean (SD)	8.1 (0.6)	7.8 (0.8)	0.091
Root shape abnormality rate (N/%)	No	24 (92.3)	38 (51.4)	<0.001
	Yes	2 (7.7)	36 (48.6)	
Crown/root ratio	Mean (SD)	0.9 (0.2)	1.0 (0.3)	0.174

Tooth #10	Sub Cat	Non-Cleft margin (n=10)	Cleft margin (n=22)	P Value
Crown buccal-lingual width (mm)	Mean (SD)	6.2 (0.6)	5.3 (0.9)	0.014
Crown length (mm)	Mean (SD)	8.5 (2.1)	7.6 (1.6)	0.196
Root length (mm)	Mean (SD)	12.3 (2.1)	10.2 (2.2)	0.021
Crown mesial-distal width (mm)	Mean (SD)	6.0 (1.2)	5.3 (0.9)	0.118
Root shape abnormality rate (N/%)	No Yes	9 (90.0) 1	11 (50.0)	0.050
	Mean (SD)	(10.0)	11 (50.0)	
Crown/root ratio		0.7 (0.2)	0.8 (0.3)	0.392

Table 3b: Comparison table for teeth characteristics between margin and non-margin groups

Results

Significant differences were observed between teeth located on the cleft margin and those that were not (Table 3b). Right lateral incisors on the cleft margin exhibited shorter root lengths (9.2 ± 2.5 mm vs. 12.4 ± 1.8 mm; p=0.001, smaller mesial-distal crown widths (5.2 ± 0.8 mm vs. 6.6 ± 0.9 mm; p=0.001), higher crown-to-root ratios (1.0 ± 0.4 mm vs. 0.7 ± 0.2 mm; p=0.005), and increased incidence of root shape abnormalities (66.6% vs. 12.0%; p=0.014).

Similarly, right central incisors on the cleft margin displayed reduced buccal-lingual crown widths (6.6 ± 0.7 mm vs. 6.9 ± 0.6 mm; p=0.005), shorter crown lengths (9.8 ± SD: 1.4 mm vs. 10.3 ± 1.0 mm; p=0.029), and higher prevalence of root shape abnormalities (34.1% vs. 7.5%; p=0.002). On the left side, central incisors on the cleft margin exhibited narrower buccal-lingual crown widths (6.6 ± 0.8 mm vs. 7.0 ± 0.9 mm; p=0.04), shorter crown lengths (9.8 ± 1.1 mm vs. 10.3 ± 1.2 mm; p=0.037), shorter root lengths (10.7 ± 2.2 mm vs. 12.2 ± 2.9 mm; p=0.014), and increased incidence of root shape abnormalities (48.6% vs 7.7%; p=<0.001). Additionally, left lateral incisors on the cleft margin had a higher frequency of root shape abnormalities compared to those not on the margin (50.0% vs 10.0%; p=0.05).

Variable	Sub Cat	ABG 6-7 years	ABG 8-9 years	ABG ≥10 years	P Value
Central incisors on the cleft margin					
Number of subjects		n=19	n=49	n=42	
Crown buccal-lingual width (mm)		6.8 (1.0)	6.5 (0.7)	6.8 (0.7)	
	Mean (SD)				0.108
Crown length (mm)	Mean (SD)	9.7 (1.0)	9.7 (1.4)	9.7 (1.2)	0.999
Root length (mm)	Mean (SD)	11.6 (2.7)	10.8 (2.1)	10.4 (2.3)	0.181
Crown mesial-distal width (mm)	Mean (SD)	8.1 (1.1)	7.9 (0.7)	7.8 (0.8)	0.546
Root shape abnormality rate (N/%)	No	12 (63.2)	29 (59.2)	22 (52.4)	0.686
	Yes	7 (36.8)	20 (40.8)	20 (47.6)	
Crown/root ratio	Mean (SD)	0.9 (0.2)	0.9 (0.3)	1.0 (0.3)	0.254
Central incisors not on the cleft margin					
Number of subjects		n=18	n=26	n=24	
Crown buccal-lingual width (mm)	Mean (SD)	6.9 (0.6)	7.0 (0.5)	6.8 (0.8)	0.553
Crown length (mm)	Mean (SD)	9.6 (1.0)	10.6 (1.0)	10.4 (0.7)	0.005
Root length (mm)	Mean (SD)	12.9 (2.2)	11.8 (2.1)	11.2 (2.6)	0.080
Crown mesial-distal width (mm)	Mean (SD)	8.2 (0.6)	8.1 (0.6)		0.355
Root shape abnormality rate (N/%)	No	16 (88.9)	26 (100.0)	7.9 (0.6)	0.173
				21 (87.5)	
	Yes	2 (11.1)	0 (0.0)	3 (12.5)	
	Mean (SD)	0.8 (0.1)	0.9 (0.3)	0.9 (0.2)	
Crown/root ratio					0.017

Table 4: Comparison table for teeth characteristics among three sABG age groups for central incisors

Tooth characteristics were further analyzed based on the location of central incisors relative to the cleft margin (Table 4). Central incisors that were not located on the cleft margin were observed to have different developmental features depending on the timing of the alveolar bone graft. In patients who underwent early ABG, central incisors away from the cleft margin were observed to have shorter crown lengths (9.6 ± 1.0 mm vs. 10.6 ± 1.0 in the middle group and 10.4 ± 0.7 mm in the late group; p=0.005) and decreased crown-to-root ratios (0.8 ± 0.1 mm vs. 0.9 ± 0.3 mm in the middle group and 0.9 ± 0.2 mm in the late group, respectively; p=0.017). However, the timing of sABG did not significantly affect the morphology of central incisors located on the cleft margin.

Discussion

Secondary alveolar bone grafting (sABG) plays a critical role in the treatment of cleft lip and palate, though the optimal timing for the procedure remains debated. Early sABG, typically performed around ages 6-7, is believed to support normal tooth eruption and maximize bone volume. However, this study found no significant difference in central incisor anomalies between patients who received early versus late sABG. Instead, the location of the incisor relative to the cleft margin proved to be a more influential factor, with cleft-adjacent teeth showing more developmental differences regardless of graft timing.

Using cone-beam computed tomography (CBCT), the study provided a detailed three-dimensional evaluation of incisor crown and root morphology, offering more accurate insights than traditional 2D imaging. While early sABG is often associated with better bone retention, it can limit the opportunity for pre-graft orthodontic treatment, which helps align alveolar segments and optimize surgical access. Even so, findings suggest that early grafting does not significantly alter incisor development outcomes when cleft proximity is considered.

Across all age groups studied, central incisors positioned on the cleft margin consistently exhibited narrower crowns, shorter root lengths, and more root shape abnormalities. These results reinforce that tooth development in cleft patients is more closely related to anatomical location than to the age at which grafting is performed. As such, treatment planning should prioritize individual anatomical considerations over fixed grafting timelines.

This study's limitations include its retrospective design and small sample size, which may affect the generalizability of our findings. The absence of a non-CLP control group also limits direct comparisons, though general population data on incisor development exist. Additionally, missing data on tooth eruption age prevented us from determining whether sABG occurred before or after eruption. Future prospective studies with larger cohorts and detailed eruption records could reduce bias and improve consistency.

Conclusions

1. The timing of the secondary alveolar bone grafting (sABG) did not significantly impact the presence of incisor crown or root shape abnormalities.
2. Teeth located on the cleft margin exhibited significant differences in incisor development, including narrower buccal-lingual crown widths, shorter crown lengths, and a higher rate of root shape abnormalities.
3. Cone beam computed tomography (CBCT) is a valuable tool for assessing tooth morphology and provides enhanced evaluation of sABG outcomes in patients with cleft lip and palate.

References

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