

## ABSTRACT

### BACKGROUND

Secondary alveolar bone grafting (SABG) using autogenous iliac crest bone remains the gold standard for reconstruction of alveolar clefts, enabling bony continuity, canine eruption, periodontal support, and oronasal fistula closure. Although SABG is traditionally recommended before eruption of the permanent canine, delayed grafting still occurs in clinical practice due to barriers such as late referral and access to multidisciplinary care. Evidence comparing outcomes between pre- and post-eruption grafting remains heterogeneous and often limited by small sample sizes and inconsistent protocols.

### OBJECTIVE

To evaluate the impact of SABG timing relative to permanent canine eruption on graft success, postoperative complications, canine eruption patterns, and need for additional surgical or orthodontic interventions in a large, standardized cohort.

### METHODS

A retrospective cohort study was conducted including patients aged 6–18 years who underwent SABG with autogenous iliac crest bone between 2005 and 2025 at a single tertiary craniofacial center. Patients were categorized as undergoing SABG before canine eruption (pre-eruption) or after eruption (post-eruption). Primary outcome was graft success defined as Bergland grade I–II. Secondary outcomes included spontaneous canine eruption, complications, revision grafting, periodontal bone support, and orthodontic treatment burden. Univariate and multivariate regression analyses were performed to identify predictors of outcomes.

### RESULTS

Eighty-eight patients were included, with 67 undergoing pre-eruption SABG and 21 post-eruption SABG. Overall graft success and complication rates were comparable between groups. Timing of SABG was not significantly associated with graft success ( $p = 0.36$ ) or postoperative complications. Among pre-eruption patients, 91.7% of canines eventually erupted, with 38% erupting spontaneously. Pre-eruption SABG was associated with a higher likelihood of additional surgical procedures, primarily planned non-complication-related interventions (OR 1.62,  $p = 0.012$ ). Graft success was associated with reduced odds of tooth extraction.

### CONCLUSIONS

In this contemporary cohort treated with standardized surgical and orthodontic protocols, SABG performed before or after canine eruption resulted in comparable graft success and low complication rates. Pre-eruption grafting supported favorable canine eruption but was associated with increased planned surgical interventions, likely reflecting institutional treatment sequencing. These findings support individualized timing of SABG based on patient-specific and logistical factors rather than rigid adherence to eruption stage alone.

## OBJECTIVES

Secondary alveolar bone grafting (SABG) using autogenous iliac crest bone is the gold standard for alveolar cleft reconstruction, restoring maxillary continuity, facilitating permanent canine eruption, and closing oronasal fistulae.

Optimal timing is before canine eruption, when the root is ½–¾ developed, as this improves graft integration and eruption outcomes. However, SABG is sometimes performed after eruption due to delayed referral or limited access to multidisciplinary cleft care.

Prior studies suggest post-eruption grafting may reduce spontaneous canine eruption and increase orthodontic complexity, though evidence is limited by small sample sizes and variable protocols.

The objective of this study is comparing outcomes of pre-eruption vs post-eruption SABG in a large institutional cohort.

## METHODS

This retrospective cohort study was conducted in the Department of Oral and Maxillofacial Surgery at Mayo Clinic and included patients treated between 2005 and 2025. Electronic medical records were reviewed for demographic, surgical, and postoperative data.

Patients aged 6–18 years with unilateral or bilateral alveolar clefts who underwent SABG with documented canine eruption timing and preoperative imaging were included. Exclusion criteria comprised primary, adult, or tertiary grafting, syndromic craniofacial anomalies, and incomplete records.

Patients were classified as pre-eruption SABG (unerupted canine, root  $\leq$ ¼ developed) or post-eruption SABG (clinically or radiographically erupted canine). Outcomes included graft success, spontaneous canine eruption, complications, revision grafting, and additional surgery.

Cox regression analysis was used to evaluate outcomes, with  $p < 0.05$  considered statistically significant.

## RESULTS 1

A total of 88 patients underwent SABG, including 67 pre-eruption and 21 post-eruption cases. Demographic data are summarized in Table 1, and clinical outcomes by group are shown in Table 2, with pre-eruption characteristics detailed in Table 3.

Univariate Cox regression (Table 4) showed higher rates of additional and non-complication surgeries in pre-eruption cases.

Multivariate analysis (Tables 5–6), adjusting for age, sex, smoking, comorbidities, orthodontic intervention, and graft success, identified SABG timing and postoperative orthodontics as predictors of additional surgery, while age, orthodontic intervention, and graft success predicted non-complication procedures. A representative treatment timeline is shown in Figure 1.

## RESULTS 2

TABLE 1. Demographics comparison based on canine eruption

Variable		Overall N = 88	After N = 21	Before N = 67	P-value
Age	Mean	9.71 (9.05, 11.59)	13.60 (11.59, 14.98)	9.34 (8.77, 10.13)	<0.001*
	F	39 (44%)	10 (48%)	29 (43%)	
	M	49 (56%)	11 (52%)	38 (57%)	0.7
ASA	I	61 (69%)	16 (76%)	45 (67%)	
	II	26 (30%)	5 (24%)	21 (31%)	0.7
	III	1 (1.1%)	0 (0%)	1 (1.5%)	
BMI	Mean	16.81 (15.38, 19.00)	18.65 (17.24, 19.57)	16.50 (15.19, 18.30)	0.04*
	Standard deviation	2.33	2.33	2.33	
Laterality	Bilateral	23 (26%)	10 (48%)	13 (20%)	
	Unilateral	64 (74%)	11 (52%)	53 (80%)	0.01*
Unilateral side	Left	42 (66%)	8 (55%)	36 (68%)	
	Right	22 (34%)	5 (45%)	17 (32%)	0.5
Prior cleft surgery	No	18 (20%)	6 (29%)	12 (18%)	
	Yes	70 (80%)	15 (71%)	55 (82%)	0.4
Prior oronasal fistula	No	13 (15%)	3 (14%)	10 (15%)	
	Yes	75 (85%)	18 (86%)	57 (85%)	>0.9
Lateral incisor status	Agensis	61 (69%)	13 (62%)	48 (72%)	
	Extraction before surgery	9 (10%)	3 (14%)	6 (9.0%)	0.6
	Present	18 (20%)	5 (24%)	13 (19%)	
Pre orthodontic treatment status	Arch expansion	30 (34%)	7 (33%)	23 (34%)	
	Arch expansion + leveling	11 (13%)	3 (14%)	8 (12%)	
	Leveling	5 (5.7%)	2 (9.5%)	3 (4.5%)	0.3
	No treatment	33 (38%)	5 (24%)	28 (42%)	
Ongoing treatment	9 (10%)	4 (19%)	5 (7.5%)		

TABLE 2. Outcomes comparison based on canine eruption

Variable		Overall N = 88	After N = 21	Before N = 67	P-value
Postoperative orthodontic intervention	No	29 (34%)	8 (38%)	21 (32%)	
	Yes	52 (60%)	13 (62%)	39 (60%)	0.6
Graft success < 1	Failure	9 (10%)	1 (4.8%)	8 (12%)	
	Success	79 (90%)	20 (95%)	59 (88%)	0.7
Dehiscence in SABG site	No	78 (89%)	19 (90%)	59 (88%)	
	Yes	10 (11%)	2 (9.5%)	8 (12%)	>0.9
Fistula	No	76 (87%)	19 (90%)	57 (86%)	
	Yes	11 (13%)	2 (9.5%)	9 (14%)	>0.9
Graft loss	No	11 (13%)	1 (4.8%)	10 (15%)	
	Yes	77 (88%)	20 (95%)	57 (85%)	0.4
Root resorption	No	83 (95%)	19 (90%)	64 (97%)	
	Yes	4 (4.6%)	2 (9.5%)	2 (3.0%)	0.2
Additional surgery type	Other	36 (41%)	3 (14%)	33 (49%)	0.004*
	Graft revision	3 (3.4%)	1 (4.8%)	2 (3.0%)	0.6
	Dehiscence surgery	1 (1.1%)	0 (0%)	1 (1.5%)	>0.9
	Regraft	2 (2.3%)	0 (0%)	2 (3.0%)	>0.9
	Fistula closure	3 (3.4%)	0 (0%)	3 (4.5%)	>0.9
	Tissue surgery	2 (2.3%)	0 (0%)	2 (3.0%)	>0.9

TABLE 3. Characteristic outcomes in pre-canine eruption group

Variable	Count	Percentage	
Canine Erupt Status <2y	Ectopic eruption	8	16%
	No eruption (Impaction or fail)	20	40%
	Ortho-eruption	3	6%
	Spontaneous eruption	19	38%
Canine Ever Erupt	No	5	8.33%
	Yes	55	91.67%
Root Development Status <1y	Complete or open apex	9	25.71%
	Incomplete or two/third	26	74.29%

TABLE 4. Univariate Cox regression for outcomes

Variable	SABG status	Events	Univariate logistic Odds Ratio (95% CI)	Univariate COX Hazard Ratio (95% CI)	P-value
Graft success	Before canine eruption	58		0.369 (0.019, 2.194)	0.36
	After canine eruption	20		1.0 (reference)	
	Overall	78			
Wound infection in SABG site	Before	2		1.618 (0.143, 18.313)	0.7
	After	1		1.0 (reference)	
	Overall	3			
Dehiscence in SABG site	Before	8	1.288 (0.291, 9.025)	>100 (0.00, inf)**	0.76
	After	1		1.0 (reference)	
	Overall	9			
Oronasal fistula	Before	9		0.683 (0.137, 3.417)	0.64
	After	2		1.0 (reference)	
	Overall	11			
Graft loss	Before	10		0.252 (0.023, 2.784)	0.26
	After	1		1.0 (reference)	
	Overall	11			
Graft exposure	Before	4	1.27 (0.175, 25.608)	>100 (0.00, inf)**	0.84
	After	1		1.0 (reference)	
	Overall	5			
Root resorption	Before	2		1.618 (0.143, 18.313)	0.7
	After	2		1.0 (reference)	
	Overall	4			
Additional surgery needed	Before	34		6.182 (1.874, 28.171)	0.01*
	After	3		1.0 (reference)	
	Overall	37			
Complication surgeries	Before	15		0.266 (-0.044, 0.576)	0.09
	After	1		1.0 (reference)	
	Overall	16			
Non-complication surgeries	Before	33		5.824 (1.765, 26.536)	0.01*
	After	3		1.0 (reference)	
	Overall	36			
Post operative orthodontic intervention	Before	38		0.923 (0.325, 2.507)	0.88
	After	13		1.0 (reference)	
	Overall	51			

TABLE 5. Multivariate Cox regression for additional surgery

Predictor	Odds Ratio (95% CI)	P-value
Age	1.01 (0.95_1.07)	0.77
Post operative orthodontic intervention	1.42 (1.11_1.83)	0.008*
Graft success	0.57 (0.31_1.03)	0.06
Graft loss	0.97 (0.56_1.69)	0.92

TABLE 6. Multivariate Cox regression for non-complication surgery

Predictor	Odds Ratio (95% CI)	P-value
Age	1.05 (1.01_1.08)	0.005*
Post operative orthodontic intervention	0.81 (0.69_0.95)	0.01*
Graft success	1.83 (1.08_3.11)	0.02*
Fistula	0.96 (0.72_1.27)	0.76
Graft loss	1.2 (0.73_1.98)	0.46

## RESULTS 3

FIGURE 1. An alveolar cleft patient underwent SABG before canine eruption (9 years old)



## DISCUSSION

The study suggests that SABG timing relative to canine eruption did not significantly affect graft success or complication rates. However, pre-eruption SABG was associated with a higher likelihood of additional surgeries, largely reflecting planned, non-complication interventions.

Spontaneous canine eruption occurred in most pre-eruption cases, supporting early grafting for favorable eruption patterns, particularly when the lateral incisor is present. Postoperative complications were uncommon and similar between groups, suggesting that standardized surgical technique and preoperative orthodontic preparation yield predictable outcomes regardless of timing.

The higher rate of additional procedures in pre-eruption cases likely reflects institutional protocols favoring early intervention rather than increased surgical risk.

Limitations include the retrospective design, smaller post-eruption cohort, and low complication rates, which restricted multivariable analyses for some outcomes.

## CONCLUSIONS

In this large, standardized cohort, SABG performed before or after canine eruption showed comparable graft success and low complication rates. Pre-eruption grafting was associated with more non-complication-related procedures but supported favorable canine eruption. These findings support the feasibility of both approaches while emphasizing individualized surgical planning and orthodontic coordination.

## REFERENCES

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