Maxillofacial Growth in Children with Unilateral Cleft Lip and Palate following Secondary Alveolar Bone Grafting: An Interim Evaluation

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This study evaluates the effect of alveolar bone grafting on the maxillofacial growth in children of mixed dentition with unilateral complete cleft lip–cleft palate. Twenty patients received an iliac crest alveolar bone graft between the ages of 6 years 10 months and 10 years 10 months, whereas 20 matched controls between the ages of 6 years 11 months and 10 years 6 months did not. Geometric morphometric assessments were used to localize alterations between the initial and final cephalographs in the two groups of cleft children, using Procrustes analysis and thin-plate spline analysis, in addition to conventional cephalometric techniques. It is concluded that no statistically significant difference in maxillofacial growth was found between the cleft children having received secondary alveolar bone grafting and the nongraft controls in general during the first to third postoperative years. Further investigation will be undertaken to determine the long-term effects after the age of skeletal maturity. (*Plast. Reconstr. Surg.* 115: 687, 2005.)

Boyne and Sands[1,2] introduced secondary alveolar bone grafting as a procedure for repair of alveolar defects in patients with cleft lip–cleft palate. This procedure has gained increased popularity since then and is currently the standard of care in most cleft palate and craniofacial centers. The goals and benefits of bone grafting are well recognized and include the creation of bony support for subsequent tooth eruption, elimination of oronasal fistulas, improved status of oral hygiene by separating the nasal cavity from the oral cavity, reconstruction of the hypoplastic piriform aperture and soft-tissue nasal base support, and stabilization of the maxillary arch.[1–8]

However, the belief that surgical intervention has a traumatic effect is well established, and the adverse effect on maxillofacial growth of the various surgical techniques of lip and palate repair has been demonstrated in the literature.[9–11] Nevertheless, there is no consensus in the literature pertaining to secondary alveolar cleft bone grafting of unilateral complete cleft lip–cleft palate as to whether this procedure causes disruption of maxillofacial growth. Ross,[12] in a comparative study of three centers, noted that bone grafting during the period of late mixed dentition adversely affects the vertical dimensions of the anterior maxilla and, indirectly, the lower face. However, Semb[13] found no statistically significant difference in either anteroposterior or vertical maxillary growth when comparing children with unilateral complete cleft lip–cleft palate who had alveolar bone grafts during the period of

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mixed dentition to a control group of children with unilateral complete cleft lip–cleft palate who had no alveolar bone grafts. The results of the studies by Daskalogiannakis and Ross[14] and Levitt et al.[15] are in agreement with the findings by Semb.[13]

Conventional cephalometrics, based on angular and linear measurements, has shown an increasing number of limitations,[16] and the actual sites of putative craniofacial skeletal change are insufficiently evidenced in traditional cephalometric analysis.[17] Recently, newer disciplines of geometric morphometrics have evolved, enabling a more thorough analysis of form change. These disciplines include Procrustes analysis,[18,19] thin-plate spline analysis,[20,21] and other methods using landmark data. All these methods are coordinate-free and insusceptible to translation or rotation, which offers a great advantage over conventional cephalometrics.

This study evaluates the maxillofacial growth of children with unilateral complete cleft lip–cleft palate who had secondary alveolar bone grafting to determine whether the maxillofacial growth was disturbed by this procedure. This was conducted to carry out geometric morphometric assessments to localize alterations between the initial and final cephalographs in children with cleft lip–cleft palate, both with and without secondary alveolar bone grafting, using Procrustes analysis and thin-plate spline analysis, in addition to conventional cephalometric techniques.

Patients and Methods

Sample

All patients were born with unilateral complete cleft lip–cleft palate. At 1 to 2 weeks after birth, the infants underwent nasoalveolar molding therapy,[22] using an acrylic intraoral molding plate with a nasal stent rising from the labial vestibular flange. The effectiveness of therapy using an intraoral molding plate with a nasal stent is enhanced by adequately supporting the presurgical orthopedic appliance against the palatal tissues and by strapping the lip segments together across the cleft with 3M (St. Paul, Minn.) tape. This treatment modality includes as its objectives the active molding and repositioning of the deformed nasal cartilages and alveolar processes, in addition to the correction of the nasal tip and the alar base on the affected side and the position of the philtrum and columella.[22]

At 3 to 4 months of age, the infants had a Millard rotation-advancement cheiloplasty,[23,24] followed by a one-stage two-flap palatoplasty[25,26] at the age of 9 to 18 months. At 5 years of age, the patients underwent open tip rhinoplasty[27] with or without lip revision. If velopharyngeal insufficiency had occurred, sphincter pharyngoplasty[28] was also performed at 5 years of age. All patients underwent passive preoperative orthodontic treatment. They were treated at approximately the same time with the same technique in the sequence by the same surgeons and orthodontists on the cleft palate team.[29]

Details of the sample are presented in Table I. The grafted group consisted of 20 children (13 boys and seven girls) who underwent an iliac crest alveolar bone graft. The alveolar bone grafting procedure used was that described by Hall and Posnick,[8] with minor modifications.[29] The control nongrafted group consisted of 20 children (13 boys and seven girls) who did not receive an alveolar bone graft. The control group was chosen randomly from nongrafted cleft subjects with similar chronologic age, skeletal age (cervical vertebral bone age),[30,31] sex, and observation period (Table I). Because the two groups were not individually matched, the statistical analysis was based on two independent groups.

TABLE I
Summary of Sample Data

	Grafted Group	Nongrafted Group
Sex distribution		
Female	7	7
Male	13	13
Age at graft (ABG), year, month		
Mean	8, 2	—
Range	6, 10–10, 10	—
Stage of examination, year, month		
Younger (pre-ABG)		
Mean	7, 11	7, 11
Range	6, 9–10, 8	6, 11–10, 6
Older (follow-up)		
Mean	11, 4	11, 2
Range	8, 7–14, 3	8, 8–14, 2
Observation period, year, month		
Mean	3, 2	3, 3
Range	1, 11–4, 4	1, 10–4, 2
Time period treated	1996–2000	1986–1987

ABG, iliac crest alveolar bone graft.

Methods

Lateral cephalometric radiographs were obtained at two different times: at the younger or pre–iliac crest alveolar bone graft stage and at the older or follow-up stage. The magnification of each cephalograph used in this study was 10 percent. Each cephalograph was traced by one investigator and checked by another investigator. An appropriate software package[32] was used to digitize 14 homologous landmarks on the craniofacial complex (Fig. 1). The landmarks were used to compare 10 angles and three distances.

To assess errors involved in cephalometric tracing and digitizing, 30 randomly selected lateral cephalographs were traced and digitized. The same cephalographs were retraced and redigitized under the same conditions after an interval of 1 week. Correlations between the double measurements were then analyzed for both angular and linear measurements. The correlation coefficients between the double measurements were over 0.9.[33]

Conventional cephalometric analysis. The paired *t* test was used to evaluate any statistically significant differences between the younger or pre–iliac crest alveolar bone graft stage and the older or follow-up stage in the two groups. After this univariate analysis, measurements were compared by a multivariate Hotelling's T^2 test[34] so that the results derived from the Procrustes analysis could be corroborated. The Hotelling's T^2 test was used on these 10 angular and three linear variables to determine whether the overall mean differences in outcome were beyond chance.

The analysis of covariance was performed to investigate the statistical significance of differences attributable to sex and presence or absence of a bone graft, using the younger values as a covariate. In this way, any differences that existed between the two groups at the younger or pre–iliac crest alveolar bone graft stage would be taken into account in the comparison of the later differences at the older or follow-up stage.

Procrustes analysis. A generalized least-squares Procrustes analysis[18,19] procedure was used to compute the average configuration of the younger or pre–iliac crest alveolar bone graft stage and the older or follow-up stage of two groups. Each subject's coordinates were translated, rotated, and scaled iteratively until the least-squares fit of all configurations was no longer improved. Craniofacial configurations were registered with respect to one another and scaled to equivalent areas, which eliminated any difference

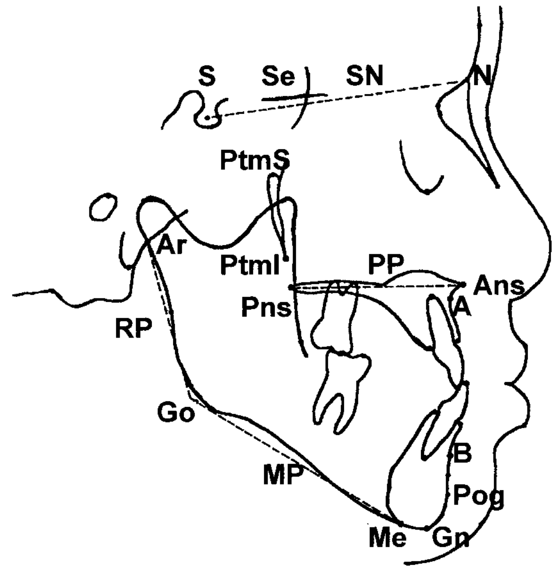

FIG. 1. Cephalometric landmarks: *S*, sella; *Se*, spheno-ethmoidale; *N*, nasion; *PtmS*, pterygomaxillare superius; *PtmI*, pterygomaxillare inferius; *Pns*, posterior nasal spine; *Ans*, anterior nasal spine; *A*, subspinale; *B*, supramentale; *Pog*, pogonion; *Gn*, gnathion; *Me*, menton; *Go*, gonion interceptive; *Ar*, articulare. Cephalometric planes or lines: *SN*, sella-nasion plane; *PP*, palatal plane; *MP*, mandibular plane; *RP*, ramal plane.

related to size. The procedure was repeated for each stage to produce a mean geometric configuration. To determine whether craniofacial configurations differed between stages, mean geometries were statistically compared using analysis of variance.[18,19,35]

Thin-plate spline analysis. After the mean geometric configurations for each group were computed using Procrustes analysis,[18,19] they were subjected to thin-plate spline analysis.[20,21,36] Thin-plate spline analysis facilitates the construction and display of transformation grids that capture the shape change between forms. The biological shape change is modeled as a deformation, and the spatial changes between the compared morphologies can be seen as deformation grids.[37] This conceptually simple maneuver quickly shows the

TABLE II

Procrustes Analysis of Mean Craniofacial Configurations in the Grafted and Nongrafted Groups between Younger or Pre-ABG and Older or Follow-Up Stages

Group	Procrustes Analysis Residual	F Test	p*
Grafted	0.000109	0.2264	>0.05
Nongrafted	0.000588	0.1351	>0.05

ABG, iliac crest alveolar bone graft.
* $p > 0.05$, nonsignificant.

location and extent of the deformation. Separate transformation grids were obtained for the younger or pre–iliac crest alveolar bone graft stage and the older or follow-up stage comparisons in the grafted and nongrafted groups.

Results

Procrustes Analysis

Residuals computed from the Procrustes analysis were compared using an *F* distribution.

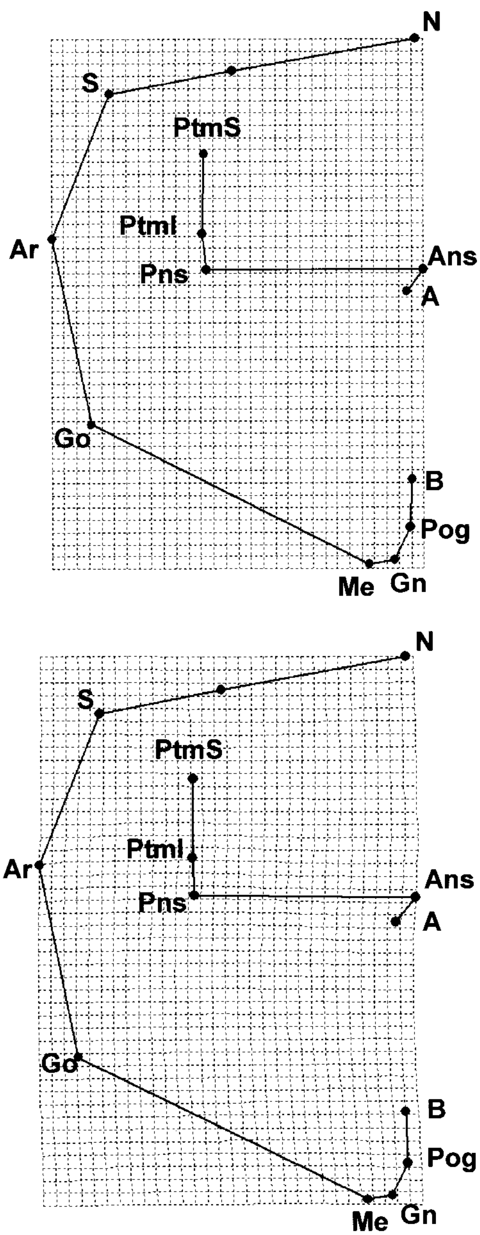

FIG. 2. Thin-plate splines (*above*) generated from mean craniofacial configuration in the nongrafted group at a younger stage in untransformed space and (*below*) generated from mean differences in shape coordinates between younger and older stages in the nongrafted group. *S*, sella; *N*, nasion; *PtmS*, pterygomaxillare superius; *PtmI*, pterygomaxillare inferius; *Pns*, posterior nasal spine; *Ans*, anterior nasal spine; *A*, subspinale; *B*, supramentale; *Pog*, pogonion; *Gn*, gnathion; *Me*, menton; *Go*, gonion interceptive; *Ar*, articulare.

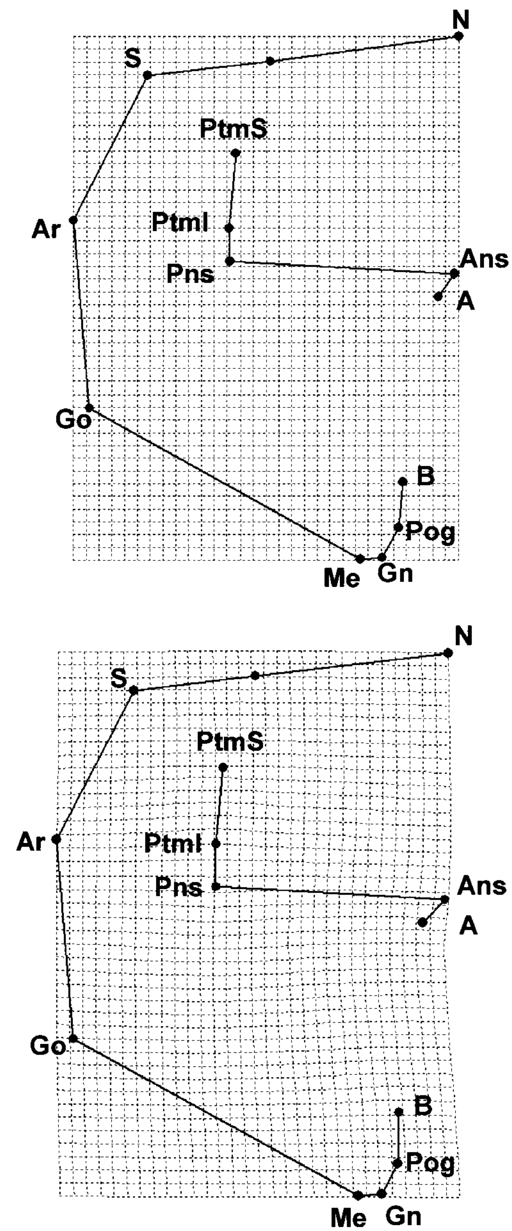

FIG. 3. Thin-plate splines (*above*) generated from mean craniofacial configuration in the grafted group at the pre–iliac crest alveolar bone graft alveolar bone graft stage in untransformed space and (*below*) generated from mean differences in shape coordinates between pre–iliac crest alveolar bone graft stage and follow-up stage in the grafted group. *S*, sella; *N*, nasion; *PtmS*, pterygomaxillare superius; *PtmI*, pterygomaxillare inferius; *Pns*, posterior nasal spine; *Ans*, anterior nasal spine; *A*, subspinale; *B*, supramentale; *Pog*, pogonion; *Gn*, gnathion; *Me*, menton; *Go*, gonion interceptive; *Ar*, articulare.

Differences in the craniofacial configurations between the younger or pre–iliac crest alveolar bone graft stage and the older or follow-up stage were considered not significant at the $p >$ 0.05 level for both the grafted and nongrafted groups (Table II).

Thin-Plate Spline Analysis

The total spline showed little change of the grafted and nongrafted groups at the end of the observation periods (Figs. 2 and 3). Point A (subspinale) was relatively backward in both groups.

Conventional Cephalometric Analysis

The grafted group revealed a significant change only in the mean palatal length (posterior nasal spine–anterior nasal spine distance) between the younger and the older stages (Table III). The mean palatal length increased 2.1 mm in this group. However, the nongrafted group showed no significant change in all linear and angular measurements studied between the two stages, even though the mean palatal length increased 2.0 mm (Table IV).

At the younger stage compared with the nongrafted group, the grafted group exhibited a statistically significantly longer palatomaxillary complex (as evidenced by posterior nasal spine–anterior nasal spine, subspinale–posterior nasal spine, and subspinale–pterygomaxillare inferius/palatal plane distances), more retruded mandible with more vertical ramus (as shown by sella-nasion-supramentale, sella-nasion-pogonion, subspinale-nasion-supramentale, gonial, and sella-nasion/ramal plane angles), and more proclined lower incisors (as evidenced by the L1/mandibular plane angle) (Table V). The multivariate Hotelling's T^2 tests confirmed that statistically significant differences existed between the two groups at the younger stage, although only for angular measurements (Table VI).

However, at the end of the observation periods, the differences in 15 of the 18 cephalometric measurements were not statistically significant between the two groups. The only three measurements that did reach statistical significance were sella-nasion-supramentale, sella-nasion-pogonion, and sella-nasion/palatal plane angles, which appeared to have differences of an average of −1.37, −1.36, and 1.24 degrees, respectively, in the grafted group compared with the nongrafted group (Table VII). However, they were of little clinical significance.

Discussion

Secondary bone grafting of the alveolar cleft during the period of mixed dentition, in conjunction with orthodontic treatment, has become a well-accepted treatment modality for patients with unilateral complete cleft lip–cleft palate. Most cleft palate and craniofacial centers support the use of secondary bone grafting because of the detrimental effects of primary alveolar grafting on maxillary growth.[3–6] Primary bone grafting also has a more severe impact on vertical than on sagittal growth of the maxilla.[38] Nevertheless, a few advocates of primary bone grafting remain.[39–42]

TABLE III

Comparison of Means for the Grafted Group between Pre–Iliac Crest Alveolar Bone Graft and Follow-Up Stages

Variable	Pre–Iliac Crest Alveolar Bone Graft Stage (mean ± SD)	Follow-Up Stage (mean ± SD)	Paired *t* Test (*p*)
SNA, degrees	78.53 ± 4.20	77.80 ± 4.67	0.6074
SNB, degrees	75.85 ± 3.81	77.08 ± 4.40	0.3517
SNPog, degrees	76.07 ± 4.01	77.58 ± 4.66	0.2810
ANB, degrees	2.67 ± 3.81	0.72 ± 4.03	0.1235
SN/MP, degrees	36.50 ± 6.00	35.82 ± 6.47	0.7326
SN/PP, degrees	10.19 ± 3.38	10.15 ± 4.11	0.9780
PP/MP, degrees	26.31 ± 5.38	25.67 ± 5.58	0.7118
LI/MP, degrees	93.89 ± 9.03	90.20 ± 9.45	0.2146
SN/RP, degrees	92.18 ± 4.60	92.03 ± 4.36	0.9182
Gonial, degrees	124.32 ± 5.21	123.78 ± 5.39	0.7532
ANS-PNS, mm	46.56 ± 2.81	48.66 ± 3.03	0.0285*
A-PtmI/PP, mm	44.75 ± 2.91	46.18 ± 3.08	0.1395
A-PNS, mm	43.73 ± 2.94	44.56 ± 2.85	0.3677

S, sella; N, nasion; PtmI, pterygomaxillare inferius; PNS, posterior nasal spine; ANS, anterior nasal spine; A, subspinale; B, supramentale; Pog, pogonion; SN, sella-nasion plane; PP, palatal plane; MP, mandibular plane; RP, ramal plane; LI, lower incisor.
* $p < 0.05$.

Ideally, secondary bone grafting should be performed at the early transitional dentition stage, after the eruption of the permanent incisors but before the eruption of the permanent maxillary canines.[1,4,43–45] The optimal time for performing secondary alveolar bone grafting is probably between 7 and 12 years of age,[46] and the dental age needs to be considered. Bone grafting should be performed before eruption of the canine in the cleft region when the root is one-fourth to two-thirds formed.[47] At this period, the procedure would be able to create an osseous environment that permits the spontaneous eruption or orthodontic adjustment of the canine tooth. Because sagittal and transverse growth is largely finished by 8 to 9 years of age,[44,45] the chances of interfering with maxillary growth are minimal after this age; however, vertical growth of the alveolar process is still going on. The beneficial effect of bone grafting before eruption of the canine is that, as the canine erupts, it induces deposition of bone on the alveolar crest and adds to the vertical height of the maxilla.[47] However, extensive mobility of the palatal mucosa during surgery may result in reduced vertical development of the maxilla.[48,49] Pearl and Kaplan[50] and Semb and Shaw[51] failed to substantiate a significant effect of pharyngeal flaps on midfacial growth, whereas Long and McNamara[52] and Ren et al.[53] found increased vertical growth direction following surgery. The latter found the changes to be temporary and stated that the influence of a pharyngeal flap on facial growth had no long-term clinical importance.

Based on principles suggested by Boyne and Sands,[1,2] the technique of secondary alveolar bone grafting was introduced in Taiwan in 1982 and in southern Taiwan in 1987. Since then, most of the unilateral complete cleft lip–cleft palate cases with an average to favorable growth pattern have been recommended for bone grafting. Cases that exhibit a severe skeletal discrepancy that would warrant orthognathic surgery at skeletal maturity are generally not considered for secondary alveolar bone grafting, because these patients could have maxillary advancement surgery with bone grafting at a later age. To prevent the introduction of bias, the nongrafted group for this study was selected from patient records before 1987.

Thin-plate spline analysis shows the shape difference or deformation, which appears as

TABLE IV

Comparison of Means for the Nongrafted Group between Younger and Older Stages

Variable	Younger Stage (mean ± SD)	Older Stage (mean ± SD)	Paired *t* Test (*p*)
SNA, degrees	77.84 ± 4.09	77.21 ± 3.89	0.6176
SNB, degrees	79.25 ± 2.86	79.34 ± 3.21	0.9312
SNPog, degrees	79.11 ± 3.08	79.55 ± 3.57	0.6758
ANB, degrees	–1.41 ± 4.10	–2.13 ± 4.31	0.5926
SN/MP, degrees	37.23 ± 6.07	37.03 ± 6.12	0.9175
SN/PP, degrees	10.25 ± 3.28	11.46 ± 3.82	0.2882
PP/MP, degrees	26.98 ± 6.10	25.57 ± 6.51	0.4837
LI/MP, degrees	88.11 ± 8.46	86.19 ± 8.10	0.4687
SN/RP, degrees	88.39 ± 3.13	89.21 ± 3.78	0.4614
Gonial, degrees	128.84 ± 6.02	127.82 ± 5.72	0.5865
ANS-PNS, mm	44.07 ± 3.44	46.10 ± 4.03	0.0963
A-PtmI/PP, mm	42.35 ± 3.56	44.11 ± 4.29	0.1670
A-PNS, mm	40.97 ± 3.53	42.26 ± 4.06	0.2903

S, sella; N, nasion; PtmI, pterygomaxillare inferius; PNS, posterior nasal spine; ANS, anterior nasal spine; A, subspinale; B, supramentale; Pog, pogonion; SN, sella-nasion plane; PP, palatal plane; MP, mandibular plane; RP, ramal plane; LI, lower incisor.

TABLE V

Comparison of Means for the Grafted and Nongrafted Groups at Younger or Pre–Iliac Crest Alveolar Bone Graft Stage

Variable	Grafted (mean ± SD)	Nongrafted (mean ± SD)	Paired *t* Test (*p*)
SNA, degrees	78.53 ± 4.20	77.84 ± 4.09	0.6056
SNB, degrees	75.85 ± 3.81	79.25 ± 2.86	0.0028*
SNPog, degrees	76.07 ± 4.01	79.11 ± 3.08	0.0108†
ANB, degrees	2.67 ± 3.81	–1.41 ± 4.10	0.0023*
SN/MP, degrees	36.50 ± 6.00	37.23 ± 6.07	0.7029
SN/PP, degrees	10.19 ± 3.38	10.25 ± 3.28	0.9511
PP/MP, degrees	26.31 ± 5.38	26.98 ± 6.10	0.7157
LI/MP, degrees	93.89 ± 9.03	88.11 ± 8.46	0.0435†
SN/RP, degrees	92.18 ± 4.60	88.39 ± 3.13	0.0042*
Gonial, degrees	124.32 ± 5.21	128.84 ± 6.02	0.0152†
ANS-PNS, mm	46.56 ± 2.81	44.07 ± 3.44	0.0169†
A-PtmI/PP, mm	44.75 ± 2.91	42.35 ± 3.56	0.0252†
A-PNS, mm	43.73 ± 2.94	40.97 ± 3.53	0.0105†

S, sella; N, nasion; PtmI, pterygomaxillare inferius; PNS, posterior nasal spine; ANS, anterior nasal spine; A, subspinale; B, supramentale; Pog, pogonion; SN, sella-nasion plane; PP, palatal plane; MP, mandibular plane; RP, ramal plane; LI, lower incisor.

* $p < 0.01$.

† $p < 0.05$.

TABLE VI

Hotelling's T^2 of Mean Craniofacial Configurations in the Grafted and Nongrafted Groups at Younger or Pre–Iliac Crest Alveolar Bone Graft Stage*

Variable	Hotelling's T^2	*p*
Linear	15.8308	0.0578
Angular	41.2763	0.0073†

* Mean values of 10 angular and three linear measurements for the nongrafted and grafted groups at younger or pre–iliac crest alveolar bone graft stage listed in Table V.

† $p < 0.05$.

TABLE VII
Analysis of Covariance Tests for Growth of Craniofacial Variables in the Grafted and Nongrafted Groups at Older or Follow-Up Stages

Variable	Parameter Estimate	SE	*t* Ratio	*p*
SNA, degrees				
Grafted versus nongrafted	0.04	0.65	0.06	0.9547
Male versus female	–0.08	0.70	–0.11	0.9115
SNA at T1	0.08	0.08	0.98	0.3335
SNB, degrees				
Grafted versus nongrafted	–1.37	0.52	–2.62	0.0128*
Male versus female	–0.24	0.49	–0.48	0.6310
SNB at T1	–0.07	0.07	–0.94	0.3522
SNPog, degrees				
Grafted versus nongrafted	–1.36	0.47	–2.92	0.0061†
Male versus female	–0.07	0.45	0.16	0.8752
SNPog at T1	–0.10	0.06	–1.60	0.1174
ANB, degrees				
Grafted versus nongrafted	1.11	0.60	1.86	0.0713
Male versus female	–0.04	0.55	–0.08	0.9406
ANB at T1	0.03	0.07	0.44	0.6602
SN/MP, degrees				
Grafted versus nongrafted	0.49	0.58	0.84	0.4075
Male versus female	–0.70	0.62	–1.14	0.2606
SN/MP at T1	0.01	0.05	0.21	0.8372
SN/PP, degrees				
Grafted versus nongrafted	1.24	0.60	2.07	0.0460*
Male versus female	0.79	0.63	1.25	0.2181
SN/PP at T1	–0.05	0.09	–0.54	0.5919
PP/MP, degrees				
Grafted versus nongrafted	–0.71	0.86	–0.82	0.4152
Male versus female	–1.62	0.91	–1.78	0.0840
PP/MP at T1	0.08	0.08	1.08	0.2892
LI/MP, degrees				
Grafted versus nongrafted	0.73	1.77	0.41	0.6829
Male versus female	–0.16	1.82	–0.09	0.9306
L1/MP at T1	0.18	0.10	1.77	0.0853
SN/RP, degrees				
Grafted versus nongrafted	0.70	0.66	1.07	0.2937
Male versus female	–0.35	0.62	–0.56	0.5781
SN/RP at T1	0.07	0.08	0.88	0.3861
Gonial angle, degrees				
Grafted versus nongrafted	0.00	0.78	0.00	0.9985
Male versus female	–0.59	0.78	–0.76	0.4493
Gonial angle at T1	0.11	0.07	1.60	0.1182
ANS-PNS, mm				
Grafted versus nongrafted	–0.20	0.68	–0.30	0.7695
Male versus female	–0.01	0.66	–0.01	0.9886
ANS-PNS at T1	0.05	0.10	0.47	0.6399
A-PNS, mm				
Grafted versus nongrafted	0.20	0.68	0.29	0.7722
Male versus female	0.35	0.65	0.54	0.5926
A-PNS at T1	0.09	0.10	0.96	0.3446
A-PtmI/PP, mm				
Grafted versus nongrafted	0.22	0.71	0.31	0.7565
Male versus female	–0.31	0.70	–0.44	0.6640
A-PtmI/PP at T1	0.04	0.11	0.41	0.6877

S, sella; N, nasion; PtmI, pterygomaxillare inferius; PNS, posterior nasal spine; ANS, anterior nasal spine; A, subspinale; B, supramentale; Pog, pogonion; SN, sella-nasion plane; PP, palatal plane; MP, mandibular plane; RP, ramal plane; LI, lower incisor. T1, younger or pre-ABG stage.

* $p < 0.05$.

† $p < 0.01$.

vertical compression/extension and/or horizontal compression/extension of the grids on the graphical displays when the younger and the older stage lateral cephalographs are superimposed and the landmark configurations compared.[32] Although the thin-plate spline analysis is unable to determine whether there is a statistical difference between mean configurations, it allows the visualization of the differences as a transformation grid, whether these are statistically significant or not. Therefore, to determine whether the craniofacial configurations between the younger or pre–iliac crest alveolar bone graft and the older or follow-up stages are morphologically different, we relied on the residuals of homologous landmarks from Procrustes analysis.[18,19,37]

As can be seen, the measured variables of palatomaxillary complex length demonstrated significant differences between the two groups at the younger stage. There were also significant differences found in the variables of mandibular position. These findings represent a preexisting difference between the group to receive bone grafts and their matched controls. On the contrary, there was lack of significant difference between the two groups in the measured variables of palatomaxillary complex length at the older stage. However, inspection of thin-plate spline transformation grids in Figures 2 and 3 would suggest a trend for the grafted group to become more relatively maxillary retrusive after grafting.

Even in a successfully treated complete unilateral cleft lip–cleft palate patient, the characteristics of the cleft face are always there. The patients with clefts clearly exhibit the underlying potential for class III growth or midfacial deficiency as the result of the original deformity and subsequent multiple operations necessary for its repair. It has been suggested that growth deficiencies of children with unilateral cleft lip–cleft palate do not become manifest until adolescence. In this study, the final cephalometric film was obtained 1 to 3 years after the repair procedure, which was before the cessation of the patient's growth. The long-term effects of both the intrinsic growth and the external therapies applied to remedy the craniofacial deficiencies in the unilateral complete cleft lip–cleft palate patient are especially evident during the pubertal growth period.[49] Therefore, the possibility of a significant difference becoming evident if the patients had been examined once they had grown through adolescence and had reached skeletal maturity cannot be ruled out.

Conclusions

Secondary alveolar cleft bone grafting at the mixed dentition stage seems to cause no deleterious effects on the growth of the midface and maxillary growth in general after a 1- to 3-year observation period. Thin-plate spline analysis may show the degree of transformation within the craniofacial geometric configuration attributable to maxillofacial growth changes, primarily caused by intrinsic growth and surgically induced scar tissues, as seen on lateral cephalometric radiographs. Longitudinal studies of patients are required to fully appreciate the long-term implications, using Procrustes analysis and thin-plate spline graphical analysis corroborated by conventional cephalometric analysis.

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