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Early alveolar bone grafting has a negative effect on maxillary dental arch dimensions of pre-school children with complete unilateral cleft lip and palate

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Structured Abstract

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Objective – To evaluate maxillary dental arch dimensions in pre-school children with a complete unilateral cleft lip and palate (CUCLP) after early alveolar bone grafting.

Material and Methods – Intercanine and intermolar widths, length of dental arch and mesiopalatal inclination of both maxillary segments were measured directly on the dental casts of 42 children (27 boys and 15 girls; mean age = 5.2 years, SD 0.5; *Early-grafted* group), 30 children (18 boys and 12 girls; mean age = 5.8 years, SD 0.8; *Non-grafted* group), and 40 children (25 boys and 15 girls, mean age = 5.8, SD 0.4; non-cleft *Control* group). Children from *Early-grafted* and *Non-grafted* groups had a CUCLP repaired with a one-stage closure of the entire cleft. An alveolar bone grafting was performed in the *Early-grafted* group between 2 and 4 years (mean = 2.4, SD 0.6). A one-way ANOVA model with *post hoc* Tukey's multiple comparison procedures were used to identify intergroup differences.

Results – The mesiopalatal inclination of the lesser segment in the *Early-grafted* group was decreased in comparison with the *Non-grafted* and *Control* groups. The intercanine width had a tendency to be reduced in the *Early-grafted* group relative to *Non-grafted* group.

Conclusions – Early bone grafting results in a larger collapse of the lesser segment than bone grafting carried out between 9 and 12 years of age.

Key words: alveolar bone graft; cleft palate; dental arch; early bone grafting; maxilla; surgery; treatment outcome; unilateral cleft lip and palate

Introduction

Alveolar bone grafting (ABG) has long been recognized as an important element of treatment of cleft lip and palate. Its aim is to provide support for cleft-adjacent teeth, to stabilize the maxillary segments, to eliminate the notched alveolar ridge, to support the alar bases, and to enable expansion of the interpremaxillary suture (1).

Initially, ABG was performed at or around the time of lip repair (2). Increasing evidence that bone grafting performed at this age (so called, *primary bone grafting*) causes maxillofacial growth derangement (3, 4) resulted in a reduction in the number of cleft centers using primary ABG.

Instead, bone grafting carried out prior to eruption of the cleft-adjacent canine (5) became widely accepted. This method was based on the assumption that growth of the anterior region of the maxilla is largely complete by 8 years of age (6) and a repair of the cleft alveolus with bone graft at 9–11 years, invariably associated with a growth-inhibiting scarring, should not compromise future maxillary development. Little deficiency of maxillofacial growth after this approach was confirmed later (7–9).

An ABG, however, also offers the opportunity to close oronasal fistulas, which have a negative effect on speech. Because speech development starts in the first year of life, early ABG might demonstrate beneficial influence on language skills. Furthermore, it could provide a bony environment for eruption and maintenance of cleft-adjacent lateral incisors, when present. Provided that facial growth is comparable to that following ABG performed during a mixed-dentition period, early ABG could offer advantages of mixed-dentition ABG without disadvantages of primary bone grafting. Unfortunately, there are no published data regarding growth effect of an early ABG, performed before the timing recommended by Boyne and Sands (5). Thus, the aim of this study is to evaluate maxillary dental arch dimensions after ABG performed between 2 and 4 years of age.

Material and methods

Subjects

This was a retrospective three-group comparative study. Maxillary dental arch dimensions were assessed in two groups of children with a complete unilateral cleft lip and palate (CUCLP) and a group consisting of non-cleft children with normal occlusion. The principles outlined in the Helsinki Declaration have been followed during the current investigation.

In the subjects with a cleft, CUCLP was repaired with a one-stage closure of the cleft of the lip and the palate in the 1st year of life.

The *Early-grafted* group consisted of 42 children (27 boys and 15 girls) at the age of 5.2 years (Table 1) taken from a series of 85 consecutive non-syndromic patients operated on from July 1999 to June 2006. There were the following inclusion criteria for the *Early-grafted* group: alveolar bone grafting carried out between 2 and 4 years of age, presence of full complement of primary dentition (except lateral incisor on the cleft side), and availability of good quality dental study casts taken at the age of approximately 5 years. In this series, 67 of 85 children (78.8%) received an alveolar bone graft between 2 and 4 years of age, whereas in the remaining 18 children, the bone-grafting procedure was not performed. A maxillary arch constriction (cross-bite) was the reason for postponement of ABG in 8 of 18 children; in 10 children, other reasons caused postponement of ABG. Of the 67 children who had received alveolar bone grafts, only 42 subjects had dental casts taken at 5 years available.

The *Non-grafted* group comprised 30 children (18 boys and 12 girls) at the age of 5.5 years (Table 1) taken from a series of 61 consecutive non-syndromic patients operated on from May 1993 to August 1996. The outcome in this group had been evaluated previously (10–12). The inclusion criterion for the *Non-grafted* group was the availability of good quality dental study casts taken at 5 years with a full complement of primary dentition (except lateral incisor on the cleft side).

In children from the *Early-grafted* and *Non-grafted* groups, no infant orthopedic (IO) treatment was carried out. During one operation lip, hard palate and soft palate were closed according to the following protocol:

Table 1. **Characteristics of the *Early-grafted*, *Non-grafted*, and *Control* groups**

	Early-grafted (E)	Non-grafted (N)	Control (C)	Intergroup difference
Proportion of boys and girls (%)	64.4/35.6	60/40	62.5/37.5	$p > 0.1$
Age in months at one-stage repair (SD)	6.0 (1.6)	8.9 (2.3)	N/A	$p = 0.000$ (E–N)
Age in years at alveolar bone grafting (SD)	2.4 (0.6)	N/A	N/A	N/A
Age in years at collection of dental casts (SD)	5.2 (0.5)	5.5 (0.8)	5.8 (0.4)	$p = 0.000$ (E–C)

SD, standard deviation. N/A, not applicable.

lip closure was undertaken using a triangular flap; for hard palate repair, an extended vomer flap with a tight closure of the anterior palate was performed. During the soft palate repair, all abnormal muscle insertions were dissected from the posterior edge of the hard palate up to the hamuli, which were always fractured; subsequently, the palatal muscles were reconstructed and sutured in the midline. No primary nose surgery was performed at the time of operation. However, in the *Early-grafted* group, a secondary nose surgery (open rhinoplasty) was carried out at the time of bone grafting.

The mean age at one-stage repair of CUCLP was 6 months (SD 1.6; range 4.0–13.2 months) and 8.9 months (SD 2.3; range 4.8–15.8 months) for the *Early-grafted* and *Non-grafted* groups, respectively (Table 1). One experienced surgeon operated on all children from the *Non-grafted* group, and three experienced surgeons (including the one, who carried out surgical repairs in the *Non-grafted* group) performed one-stage repairs and alveolar bone grafting in the *Early-grafted* group.

The timing of alveolar bone-grafting procedure was different in the *Early-grafted* and *Non-grafted* groups. In the former group, iliac-crest solid bone grafting was performed at 2.4 years (SD = 0.6; range: 1.4–4.1 years). The latter group received alveolar bone grafts between 9 and 12 years. The surgical technique described by Boyne and Sands (5) was used in all subjects.

The *Control* group consisted of 40 pre-school children (25 boys and 15 girls) at the age of 5.8 years without malocclusion. The detailed description of this group is given elsewhere (13). To summarize, 141 pre-school children (69 boys and 72 girls) at the age of 5–6 years were examined and 50 children (27 boys and 23 girls), who met the following inclusion criteria: 1) complete primary dentition, 2) absence of proximal caries or restorations, and 3) normal occlusion, were selected for further investigation. To match gender proportion of the *Early-grafted* and *Non-grafted* groups, 25 boys and 15 girls were selected at random for the purpose of this study.

Methods

The method of assessment of maxillary dental arch dimension was partly based on the study of Wojtaszek-Slominska et al. (14).

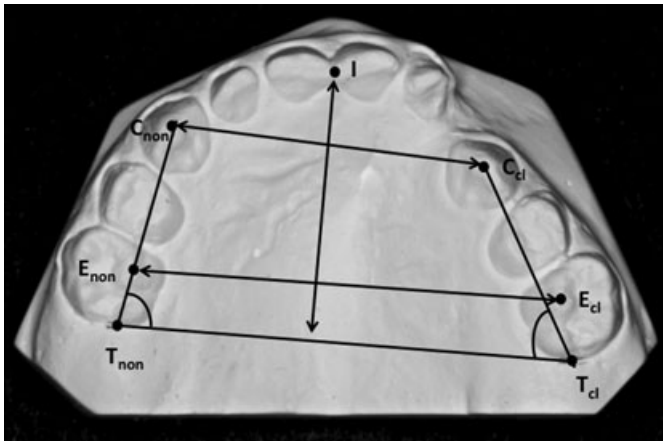

Fig. 1. Reference points and measurements.

The following reference points were marked directly on maxillary dental casts: tuberosity points (T_{cl} and T_{non}, where T_{cl} means the cleft side and T_{non} – non-cleft side), incisal point (I), and the mesiopalatal cusps of the second deciduous molars (E_{cl} and E_{non}) and the cusps of the deciduous canines (C_{cl} and C_{non}) – Fig. 1. In children from the *Control* group, the analogous reference points were designated as right or left (for example, T_r and T_l).

The measurements of dental arch dimensions were carried out by one investigator directly on the casts with the aid of a digital caliper or protractor. The following distances and angles were measured:

(1) anterior width of the dental arch – from C_{cl} to C_{non},
(2) posterior width of the dental arch – from E_{cl} to E_{non},
(3) length of the dental arch – from the line connecting the tuberosity point (T_{cl} and T_{non}) to incisal point (I),
(4) mesiopalatal inclination of the major (I) and lesser (i) segments relative to the tubercular plane (T_{cl}–T_{non}). A mesiopalatal inclination of the major segment was the angle between T_{cl}–T_{non} and a line passing through C_{non} and T_{non}. A mesiopalatal inclination of the lesser segment was the angle between T_{cl}–T_{non} and a line passing through C_{cl} and T_{cl} (Fig. 1).

To determine the intra-observer reliability of measurements, 30 dental casts were selected at random and measured twice. Repeatability of the measurements was calculated according to Bland and Altman (15). The interpretation of the repeatability coefficient (CR) was carried out according to the guidelines of the British Standards Institution (16), which states that 95% of all measurements should be within two standard

deviations of the mean of the combined 1st and 2nd measurements.

Statistical analysis

The drop-out analysis in the *Non-grafted* group included independent *t*-tests to compare the dropouts with the remaining subjects regarding dental arch relationship at the age of 11.2 years (SD = 1.7) (11).

Descriptive statistics (means, standard deviation, and ranges) were computed for each group. A one-way ANOVA model was used to test the intergroup differences in measurements. When a difference was detected, pair wise comparisons were made using the Tukey's multiple comparison procedure to control the Type 1 error rate.

A regression analysis was performed to investigate an association between dental arch measurements (dependent variables) and sex, age at one-stage repair of CUCLP, presence/absence of alveolar bone graft, and age when records were taken (independent variables). The difference was considered significant for $p < 0.05$.

Table 2. **Results of evaluation of the error of method**

Variable	CR	SD of 1st and 2nd measurements
Intercanine width (C-C)	0.85	3.16
Intermolar width (E-E)	1.01	2.89
Length of dental arch (L)	1.19	2.26
Inclination of the larger segment (I)	2.82	4.16
Inclination of the smaller segment (i)	2.93	6.92

CR, coefficient of repeatability; SD, standard deviation.

Results

Boys and girls were relatively equally distributed in the groups (Table 1). The timing of repair of CUCLP was different in the *Early-grafted* and *Non-grafted* groups (at 6 and 9 months, respectively), and the difference was statistically significant. The dental casts in the *Early-grafted* group were made approximately 7 months earlier than in the *Control* group, and the difference was significant.

The value of CR, not exceeding the double standard deviation of the mean of the combined duplicate measurements, suggests good intra-observer reliability (Table 2).

The drop-out analysis in the *Non-grafted* group showed that the dental arch relationship in the drop-outs and the remaining patients was comparable ($p > 0.1$).

There was a tendency that anterior width of the dental arch (C_{cl}–C_{non}) in the *Early-grafted* group was smaller in comparison with the *Non-grafted* group but the difference did not reach statistical significance (Table 3). The posterior width (E_{cl}–E_{non}) and length of the dental arch (L) in the *Early-grafted* and *Non-grafted* groups were comparable. The mesiopalatal inclination of the major segment (I) in both cleft groups was comparable as opposed to the mesiopalatal inclination of the lesser segment (i), which was reduced by 5.6° in the *Early-grafted* group relative to the *Non-grafted* group.

The measurements in the *Control* group demonstrated differences in comparison with the *Early-grafted* and *Non-grafted* groups (Table 3). In general, the dental arch in 5 year olds without cleft was longer, wider in the anterior region, and both right and left segments had larger mesiopalatal inclination (angles I

Table 3. **Results of intergroup comparison of dimensions of the maxillary dental arches**

	Early-grafted (E)	Non-grafted (N)	Control (C)		
	Mean (SD)	Mean (SD)	Mean (SD)	*p*-Value	Intergroup difference
Intercanine width (C_{cl}–C_{non})	27.2 (3.1)	28.5 (3.6)	29.6 (1.8)	0.001	E–C
Intermolar width (E_{cl}–E_{non})	35.5 (2.6)	36.1 (3.0)	34.7 (2.0)	0.091	
Length of dental arch (L)	26.2 (2.4)	25.6 (2.3)	27.1 (1.6)	0.011	N–C
Inclination of the major segment (I)	77.4 (3.7)	77.9 (4.1)	80.0 (2.8)	0.004	E–C; N–C
Inclination of the lesser segment (i)	62.2 (6.6)	67.8 (6.6)	80.7 (2.9)	0.000	E–N; E–C; N–C

Table 4. **Association between the inclination of the lesser fragment *i* (dependent variable) and sex, age at cleft repair, bone grafting, and age when records were taken (independent variables) evaluated with the aid of multiple regression analysis**

Variable	Regression coefficient	SE	*p*-Value
Intercept	58.183	7.382	0.000
Sex (0 = males; 1 = females)	–0.098	1.691	0.954
Age at cleft repair (in years)	10.180	5.080	0.049
Bone grafting (0 = Early-grafted; 1 = Non-grafted)	4.247	1.793	0.021
Age at taking records (in years)	–0.373	1.304	0.776

Adjusted R^2 = 0.150; SE, standard error.

and i) in comparison with children with a cleft. Only the posterior width of the dental arch (E_{cl}–E_{non}) showed no intergroup differences.

The regression analysis (Table 4) demonstrated that the mesiopalatal inclination of the smaller segment (i) was influenced by bone-grafting procedure and age of repair of CUCLP (p = 0.021 and 0.049, respectively).

Discussion

The timing of ABG in the current study was defined as *early*. This is rather a general term but the nomenclature employed to classify ABG on the basis of timing is confusing. According to Eppley and Sadove (17), the terms *primary* (<2 years of age), *early secondary* (from 2 to 5 years of age), and *secondary* (> 5 years of age) are used most frequently. Grisius et al. (18) additionally divide secondary ABG into *early secondary* (2–5 years), *secondary* (6–12 years), and *late secondary* (> 12 years) alveolar grafting, and Kuijpers-Jagtman and Long (1) use the term *early secondary* ABG when they refer to grafting carried out around 10 years of age. When the stages of dental development are utilized for the classification, ABG is termed *primary* when the procedure is carried out in the deciduous dentition, *secondary* – in the mixed dentition, and *tertiary* – when a patient is in the permanent dentition during ABG (19). Because of existing controversy regarding classification of timing of ABG, we decided to use the broad term *early* to indicate relatively early placement of ABG and to emphasize that it is carried out independently from a repair of the cleft.

Our findings suggest that dimensions of the maxillary dental arch are less favorable than in subjects who did not receive early alveolar bone grafts. We observed a larger collapse of the lesser segment and a tendency toward a reduction in the anterior width of the maxilla (C_{cl}–C_{non} distance) in the *Early-grafted* group in comparison with the *Non-grafted* group. This was despite the fact that the dental arch in 2-year-old children from the *Early-grafted* group was likely to be wider than in children from the *Non-grafted* group. Prior to ABG, the dental arch relationship had been evaluated, and several children with a cross-bite in the region of deciduous canines on the cleft side were not eligible for an early ABG. Consequentially, only children with a favorable shape of the maxillary dental arch were bone grafted, hence, included in the *Early-grafted* group. Therefore, it may be assumed that if all children treated from June 1997 to June 2006 were bone grafted irrespective of a presence of the cross-bite, the inhibitory effect of early ABG on maxillary growth would have been more pronounced. Although the current study design does not allow to identify a specific element of the protocol influencing the outcome, it could be considered that palatal scarring after the bone grafting performed at the age of 2–4 years was a main factor affecting the shape of the maxillary dental arch.

Very few reports on the effects of a repair of the alveolus performed between 2 and 5 years of age have been published to date. Meazzini et al. (20–22) presented a long-term outcome of the Milan protocol that combines a hard palate closure performed between 18 and 36 months with a gingivo-alveoloplasty (GAP). GAP differs from ABG, because instead of grafting bone, formation of new bone is induced by a creation of a tunnel of mucoperiosteal flaps sealing off the alveolar defect from both oral and nasal cavities (20). Nevertheless, the timing, design of the flaps, and potential to create palatal scars in ABG and GAP procedures seem comparable. The findings by Meazzini et al. are generally in agreement with our results – the authors noticed an inhibition of maxillary growth in patients who had had GAP compared with patients who had been treated with a conventional bone grafting between 9 and 11 years of age.

Our methodology was similar to that employed by Wojtaszek-Slominska et al. (14), who examined 5 year olds with the same ethnic background as our patients, treated with or without Skoog's gingivoperiosteoplasty

(GP). Primary GP according to Skoog (23) was demonstrated to negatively affect maxillofacial growth and was discontinued in the Uppsala center where it had been developed (24). A comparison of the findings of Wojtaszek-Slominska et al. with ours shows a gradation of severity of growth impairment, with the protocol including GP demonstrating the least favorable outcome – the largest reduction of intercanine width and the most pronounced collapse of the lesser segment – and the *Non-grafted* group showing the most advantageous outcome. The intercanine width and mesiopalatal inclination of the lesser segment in the *Early-grafted* group tended, however, to be more favorable than in both groups evaluated by Wojtaszek-Slominska et al. This suggests that the amount of growth deficiency following early bone grafting may ultimately not be severe.

A regression model showed that a timing of one-stage surgery influenced the mesiopalatal inclination of the lesser segment *i* (Table 4). In the *Early-grafted* group, one-stage repair of CUCLP was performed at 6 months whereas in the *Non-grafted* group at 9 months. The present study design – retrospective analysis of treatment outcome – does not allow identification of elements of the protocol affecting the final results. However, growth impairment after cleft surgery is associated with scar formation. The later the surgery, the less growth deficiency should be observed. One can suppose that a later closure of CUCLP in the *Non-grafted* than in *Early-grafted* group might have resulted in better outcome. It should be emphasized, however, that variables identified with a regression analysis as associated with mesiopalatal inclination of the maxillary lesser segment were responsible for only 15% of variation of the results (adjusted $R^2 = 0.150$).

Conclusions

Based on the current findings, the following can be concluded:

(1) Early bone grafting seems to result in larger collapse of the lesser segment than bone grafting carried out between 9 and 12 years of age;
(2) The timing of one-stage repair of CUCLP as employed in this series of patients might have contributed to less favorable outcome;
(3) Present results should be considered preliminary because this evaluation was performed only 3 years after ABG

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