Cone beam computed tomography in the assessment of alveolar bone grafting in children with unilateral cleft lip and palate

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SUMMARY
OBJECTIVES: To quantify the treatment outcome of secondary alveolar bone grafting (SABG) in individuals with unilateral cleft lip and palate using cone beam computed tomography (CBCT) and to reveal needs for improvement in surgical technique.

MATERIAL AND METHODS: CBCT images taken 6 months after SABG of 35 patients were analysed. Vertical and horizontal bone supports of the grafted bone at three levels of the roots of the adjacent teeth were classified, the height of the nasal floor was compared with the unaffected side, and the inter- and intra-examiner reproducibility of these evaluations was assessed.

RESULTS: The grafted bone filled the defect in all three vertical measurement levels in 34 per cent. The labiopalatal thickness of the grafted bone was good in at least one-third of the root length in 66 per cent and fair in 34 per cent. Typically, the bone graft was deficient in the apical and palatal direction. Clear asymmetry in the nasal floor was found in 72 per cent. Kappa values indicated excellent agreement for all but one measured parameter.

LIMITATIONS: This is a preliminary study involving only a limited number of study subjects.

CONCLUSIONS: Our results showed mainly a good or fair treatment outcome. Deficiency of the bone graft was observed mostly in the apical and palatal areas of the defect. Asymmetry of the nasal floor was observed frequently. Careful insertion of the bone graft towards the palatal and apical direction of the cleft is recommended.

Introduction

Secondary alveolar bone grafting (SABG) in patients with cleft lip and palate, first described by Boyne and Sands (1972), has become an essential part of the surgical management of cleft lip and palate patients. The timing of SABG at the age of 9–11 years is based on the assumption that growth of the anterior region of the maxilla is largely complete by 8 years of age so that scarring would not compromise future maxillary growth (Björk and Skiller, 1976). On the other hand, SABG does not seem to have much effect on growth (Semb, 1988; Levitt et al., 1999).

A successful ABG gives bony support to the teeth adjacent to the cleft, stabilizes the maxillary arch particularly in bilateral clefts, closes of oronasal fistulae, and enhances the orthodontic treatment (Boyne and Sands, 1972; Abyholm et al., 1981; Bergland et al., 1986a,b; Kuijpers-Jagtman and Long, 2000; Trindade et al., 2005). It also allows placement of osseointegrated implants.

Outcome criteria for SABG such as eruption of the cleft teeth, periodontal status (Tan et al., 1996) or alveolar height (Enemark et al., 1987), alar base support (Kokkinos et al., 1997), and the revision rate (Abyholm et al., 1981; Bergland et al., 1986a; Collins et al., 1998; Goudy et al., 2009) have been advocated. A more precise way is to analyse the bone graft with radiographic examination (Bergland et al., 1986a; Kindelan et al., 1997; Newlands, 2000; Witherow et al., 2002; Hynes and Earley, 2003; Felstead et al., 2010). Periapical radiographic measures of interalveolar septum height as a grading system were popularized by Bergland et al. (1986a). This grading classifies the height of crestal bone as type I (height approximately normal), type II (at least 3/4 of normal height), type III (less than 3/4 of normal height), and as type IV (failure). A drawback of this system is that the canine has had to erupt (Witherow et al., 2002). Also, the Bergland scale does not measure the amount of bone in the most apical region of the cleft (Witherow et al., 2002; Trindade et al., 2005). In spite of its limitations, the Bergland grading system has remained the golden standard for 2D assessments of bone graft success. However, the use of intraoral radiographs only in assessing the graft does not permit adequate quantitative measurement (Lee et al., 1995; Zybutz et al., 2000).
Therefore, 3D imaging has been used to better determine the grafted bone volume and spatial placement and to monitor the orthodontic treatment of the cleft-adjacent teeth, the subsequent eruption of the canine or incisor, and the prosthetic treatment with dental implants (Hamada et al., 2005; Wörtche et al., 2006; Oberoi et al., 2010; Economopoulos et al., 2012; Garib et al., 2012; Quereshy et al., 2012). 3D imaging has first been achieved by the use of conventional computed tomography (CT) and, more recently, with lower radiation dose by cone beam CT (CBCT; Mozzo et al., 1998; Scarfe and Farman, 2008).

ABG is not a simple surgical procedure. The success rate has been reported to vary from 42 per cent before the centralization of services in the UK to 91 per cent success rate in a Norwegian centre with one surgeon (Abyholm et al., 1981; Bergland et al., 1986b; Williams et al., 2001). In the UK, the Clinical Standards Advisory Group on Cleft Lip and Palate audited ABG. The success of ABG seemed to be related to surgeon’s experience (Williams et al., 2001). After centralization of services in the UK, the success rate has increased up to 94 per cent (Felstead et al., 2010).

The purpose of the current retrospective study was to quantify the outcome of SABG in children with unilateral cleft lip and palate using CBCT and to find out clinical recommendation for surgery. The vertical height of bone graft and labiopalatal thickness verified on CBCT slices of three root levels: cervical, middle, and apical third of the roots of the adjacent teeth. Also, the height of the nasal floor support for alar base at the inferior portion of the pyriform aperture in the operated side was compared with the unaffected side. The inter- and intraexaminer reproducibility of these evaluations was assessed.

The research protocol was approved by the Ethics Committee of Helsinki University Central Hospital.

Materials and methods

Patients

Our team performs approximately 30 SABG operations annually. The study population of the present study consists of altogether 35 consecutive patients (20 boys and 15 girls) with unilateral cleft lip and palate (57 per cent left sided), operated in our unit during the 20 month study period and imaged with CBCT. The mean age of the study subjects at the SABG operation was 9.9 years (±1.1 years). Lateral cleft incisor was missing in 14/35 cases and in 9 cases extra numeral lateral incisor was found. The lateral cleft incisor was erupted in 3/35 cases and cleft cuspid in 2/35 cases. The apical development of cleft cuspid had reached one-third of length in 8/35, half of length in 11/35, and 13/35 two-thirds of length and in three cases apex was closed.

Preoperatively, the upper arch was expanded and upper teeth were aligned using fixed orthodontic appliances in all patients. Harvesting cancellous bone from anterior iliac crest and grafting into alveolar crest were performed by one of the four surgeons involved in the study. Wide mucoperiosteal flaps were raised to cover the bone graft on the nasal, buccal, and lingual sides according to the technique described by Bergland et al. (1986b). Bio-Guide® resorbable bilayer membrane was used in 54 per cent of cases. The effect of Bio-Guide® membrane, the size of the cleft or the presence of erupting teeth, or other factors possibly influencing the results was not evaluated due to small sample size. The CBCT examination was performed mean 6.3 (±1.2 months) months postoperatively.

Imaging

The CBCT examinations were performed with a Promax 3D® scanner (Planmeca, Helsinki, Finland) using the common imaging and image reconstruction protocol used for these patients. The imaging conditions were: 84 kV tube voltage, 14 mA tube current; 12 s exposure time; 80 mm (diameter) and 50 mm (height) field of view (FOV); 0.16 mm voxel size. Axial and coronal reconstructions of 2 mm were used for the evaluations. Axial slices were reconstructed parallel to the hard palate and coronal slices were reconstructed perpendicular to the hard palate, which are the well-known planes used in 3D imaging. Also, 1 mm paracoronal slices were reconstructed perpendicular to the alveolar crest on the cleft side. Volume Viewer 3.1 program of GE Healthcare’s Advantage Workstation was used for these reconstructions using DICOM (Digital Imaging and Communications in Medicine) images sent from the CBCT device. This program is used in our hospital because of the fast and effective processing of the CBCT examinations. After these reconstructions have been made, they are sent to our PACS (Picture Archiving and Communication Systems) system and are also available for clinicians.

The vertical dimension of grafted bone was evaluated at three different levels of the roots of the adjacent teeth using paracoronal images: 1 = cervical third of the root, 2 = middle third of the root, and 3 = apical third of the root (Figure 1). In health, the distance of the interdental bone from the cement-enamel junction is 1.0 mm and increases with age to 2.8 mm (Gargiulo et al., 1961). Because of the young age of the study subjects, the 1.0 mm distance from the cement-enamel junction level was used in this study. The vertical dimension of bone in each of these three sections was classified into: 1 = poor (i.e. no detectable bone), 2 = fair (i.e. the bony bridge extends in part to the height of the given section of the roots of the adjacent teeth), 3 = good (i.e. the bony bridge fills the total height of the given section), or NA = not assessable due to artefacts caused by metallic orthodontic appliances (Figure 2a and 2b). The simple ‘good–fair–poor’ categorizing used in this study derives from the popular 2D study by Bergland et al. (1986b).
Similarly, the thickness of bone in horizontal, i.e. labio-palatal dimension was classified into categories in these three levels of the root length using axial slices. The categories were: 1 = poor (i.e. no detectable bone; Figure 3a and 3b), 2 = fair (i.e. bone width in horizontal dimension is less than the width of the roots of the teeth adjacent to the cleft; Figure 4a and 4b), and 3 = good (i.e. the width of the bony bridge is as wide as or wider than the width of the roots of the teeth adjacent to the cleft; Figure 5a and 5b). The cases, where the measurements could not be done, are marked as NA.

To localize bony bridge in labiopalatal direction, both the labial and palatal contours of bony bridge in middle third of the adjacent roots were classified as good, i.e. the contour was even and continuous, fair, i.e. minor deformity in the labial contour, and poor, i.e. major deformity or NA.

The vertical height of nasal floor support for alar base on grafted and unaffected side was compared. The modified classifications presented by Iino et al. (2005) were used for these previously mentioned evaluations. The symmetry was measured in the coronal slice in the apical level of the upper incisors (Figure 6). The symmetry was classified into five categories according to the difference of the level of the nasal floors on grafted and the unaffected side. The categories were: 0 = difference was ≥10 mm, i.e. major difference; 1 = difference was 7–9 mm, i.e. obvious difference; 2 = 4–6 mm, i.e. intermediate difference; 3 = 1–3 mm, i.e. minor difference; and 4 = 0 mm, i.e. no difference.

The images were evaluated by three researchers (KH, AS, and TÅ) together as a consensus reading. In addition, one of the researchers (AS) evaluated the images after that twice. The first reading was 3 weeks and the second reading 13 weeks after the consensus reading.
Statistical methods

Kappa values were calculated for inter- and intraobserver agreement. Prevalence-adjusted bias-adjusted kappa was used for the interdental bone height and interdental bone width comparisons. Bias-adjusted kappa was used for the comparison of the difference in the height of the nasal floor. A κ value of <0.40 was considered to indicate poor, 0.40–0.59 fair, 0.60–0.74 good, and 0.75–1.00 excellent agreement. WinPepi 6.9 (Abramson, 2004) software was used for calculations.

Results

The presented results are the results of the consensus reading.

Bone support in vertical dimension

In 34 per cent (12/35 patients), the bone support was good in all three root portions. In 46 per cent (16/35), the bone support was good in cervical and middle third of the roots, but fair in the apical third of the roots. Together these cases presented 80 per cent of the all cases. In one case (3 per cent), there was no bone at the apical third. The results are presented in detail in Table 1. In Figure 7, the bone support

Figure 3 (a) The labiopalatal thickness of the grafted bone was assessed using an axial view. The drawing illustrates poor labiopalatal bone support of the roots of the teeth adjacent to the grafted site, i.e. no detectable grafted bone. (b) Poor labiopalatal bone support of the roots of the adjacent teeth in a representative axial cone beam computed tomography image.

Figure 4 (a) The drawing illustrates fair labiopalatal bone support of the roots of the teeth adjacent to the grafted site. (b) Fair labiopalatal bone support of the roots of the teeth adjacent to the grafted site in a representative axial cone beam computed tomography image.
in vertical dimension is presented as the sum of the bone support in the three sections of the root length classified into three categories (score 1, 2, and 3). Thus, the maximum score is 9.

**Bone support in horizontal direction**

Horizontal, i.e. labiopalatal thickness of grafted bone was evaluated in three sections using axial slices (Table 2). In 66 per cent (23/35), the interdental bone support in horizontal direction was good at least in one-third of the root length and fair at least in one-third of the root length in 34 per cent (12/35). Because of the artefacts due to metal fixed orthodontic appliances, the horizontal bone support in the cervical third of the root could be assessed only in 20 per cent (7/35) of cases in the consensus reading.

In the apical third, the success of bone grafting was good (15/35), fair (19/35), and poor in a case (1/35). In the middle third, the bone support was good (19/35), fair (15/35), and in one case it was NA. In the cervical third, only seven cases were horizontally assessable, of these one was good and six were fair.

In **Figure 7**, the bone support in horizontal dimension is presented as the sum of the bone support in the two sections (middle and apical third) of the root length classified into three categories (score 1, 2, and 3). The maximum score is 6.

Our observations to localize bony bridge in labiopalatal direction showed that grafted bone fulfilled labial side of
alveolar cleft frequently while deficiency in bone graft was seen on the palatal direction. In 40 per cent (14/35), the craft fulfilled the defect in middle third of the adjacent roots both labially and palatinally and the labial contour was good. In 14 per cent (5/35), the craft fulfilled the defect but there was minor deformity in the labial contour. In 31 per cent (11/35), the labial bone support was good and palatinally fair and in one patient it was good labially and poor palatinally. In three patients, the bone support was fair and in one patient it was NA.

Nasal floor level

Comparison between vertical levels of the nasal floor on grafted and unaffected side showed wide diversity in symmetry (Table 3). In 88.6 per cent of the study subjects, an intermediate or minor difference was found. The difference
in the height of the nasal floor in comparison with the unaffected side is presented in Figure 7 (scale 0–4).

**Inter- and intraobserver agreement**

The kappa values indicated excellent agreement except for the interexaminer horizontal bone support measurements in the middle third of the root, which indicated fair agreement (Table 4). Because of the artefacts, the horizontal bone support measurements in the cervical third of the root could be done only occasionally and kappa values for inter- and intraobserver agreement could not be calculated for these measurements.

**Discussion**

Our study shows that CBCT provides a reproducible and practical clinical method to evaluate the presence and position of grafted bone. Our study showed mainly good or at least fair treatment outcome of thickness and location of grafted bone interdentally. The grafted bone adequately filled the labial side of the alveolar cleft in most cases, whereas deficiencies in bone filling were noticed in palatal or apical areas. The nasal floor was lower on the operated cleft side in all except one case.

3D assessment of the outcome of bone grafting as used in this study may differ markedly from 2D imaging. Lee et al. found that root coverage may be overestimated by as much as 25 percent on dental radiographs compared with CT scans. Rosenstein et al. (1997) found that root coverage may be overestimated by as much as 25 percent on dental radiographs compared with CT images.

Table 4 Kappa (κ) values for inter- and intraobserver agreement.

<table>
<thead>
<tr>
<th>Monitored object</th>
<th>Interexaminer agreement (κ)</th>
<th>Intraexaminer agreement (κ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(agreement/evaluations)</td>
<td>(agreement/evaluations)</td>
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<tr>
<td>Vertical bone support</td>
<td></td>
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<tr>
<td>Cervical third of the root</td>
<td>0.82 (31/34)</td>
<td>0.82 (31/34)</td>
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<tr>
<td>Middle third of the root</td>
<td>0.89 (33/35)</td>
<td>0.94 (34/35)</td>
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<tr>
<td>Apical third of the root</td>
<td>0.87 (32/35)</td>
<td>0.96 (34/35)</td>
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<tr>
<td>Horizontal bone support</td>
<td></td>
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<tr>
<td>Middle third of the root</td>
<td>0.53 (26/34)</td>
<td>0.83 (32/35)</td>
</tr>
<tr>
<td>Apical third of the root</td>
<td>0.96 (34/35)</td>
<td>0.83 (31/35)</td>
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<tr>
<td>Nasal floor</td>
<td></td>
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<tr>
<td>Millimetre difference in the height</td>
<td>0.91</td>
<td>0.94</td>
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Prevalence-adjusted bias-adjusted kappa was used for the vertical and horizontal bone support comparisons. Bias-adjusted kappa was used for the comparison of the difference in the height of the nasal floor. In parenthesis are presented the numerical consensus of the monitored objects. Obviously, it is indicated to use a method like the one presented in our study, providing the precise location of the alveolar bone graft in three dimensions, not just the location in two dimensions or the volume of the bone graft, as has been done in, e.g. the CBCT study by Economopoulos et al. (2012). In addition, artefacts that were found in our study would not allow reliable volume measurements.

CT images have been used to measure the height of the nasal floor after bone grafting. Forte et al. (2012). Iino et al. (2005) reported that in 27/29 cases the constructed nasal floor was at the same height as on the unaffected side. Our results were not as good and we found great variance in the postoperative height of the nasal base. Iino et al. (2005) studied axial CT slices while in our study coronal CBCT slices were used, which may in part explain the difference in the results.

As with conventional CT, artefacts are found in CBCT examinations. Artefacts can be classified according to their cause and they can be physics based, patient related, scanner based, or cone-beam related. Scarfe and Farman, 2008. In the present study, orthodontic appliances caused unavoidable artefacts. Whenever possible, metallic material in the imaging area should be removed. Unfortunately, our patients had fixed orthodontic appliances that could not be removed before imaging. In addition, a correct head position and avoidance of movement during exposure are important (Scarfe and Farman, 2008). To minimize these artefacts, manufacturers have already introduced artefact reduction algorithms and in particular attention has been given to further develop these techniques (Schulze et al., 2011). The radiation doses from dental CBCT are generally higher than those from conventional dental radiography (intraoral and panoramic), but lower than those from multislice computed tomography (MSCT) scans. While the current imaging method of choice for the assessment of cleft palate is MSCT, CBCT may be preferable, if the radiation dose is lower (Sedentexct, 2011). The smallest FOV compatible with the situation should be selected to reduce the radiation dose. The tube current of the CBCT examinations used in this study was higher than what we currently use. The reason for the previous use of a higher tube current was that it is difficult to visualize cancellous bone taken from of the iliac crest immediately after the operation.

One weakness in our study is that the consensus reading was done among three persons—two orthodontists and one specialist in oral and maxillofacial radiology—and the latter read the images twice after that. Because the orthodontists do not routinely evaluate CBCT images, we decided to choose a consensus reading in order to avoid variation caused by less experienced readers. Also, 12 months might be a better follow-up time than the 6 months used in this study. According to Feichtinger et al. (2007), the mean bone loss after SAG using CT during the first year after surgery was 49.5 per cent, and the transplants remained almost constant for the following 2 years.
Conclusions

In the present study, we present a standardized method to quantify the outcome of SABG in individuals with unilateral cleft lip and palate using CBCT. The vertical height, thickness, and localization of the bone graft were possible to evaluate although artefacts due to metal orthodontic appliances caused problems in the cervical region of the teeth. The treatment outcome following the SABG operation was in general good or fair. However, since some deficiency was detected in the vertical height and thickness of the bone grafts, and asymmetry of the nasal floor was observed frequently, a clinical recommendation for surgery emphasizes careful insertion of the bone graft towards the palatal and apical direction of the cleft.

CBCT permits to assess the presence and spatial location of the alveolar bone graft and there is a need to create standardized outcome criteria for SABG when using CBCT.

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References


