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ORIGINAL ARTICLE

Assessing the Interdental Septal Thickness in Alveolar Bone Grafting Using Cone Beam Computed Tomography

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Objective: **To assess the interdental septal thickness of grafted bone bridges using cone beam computed tomography (CBCT).**

Patients: **Of 71 patients with cleft lip and/or palate having undergone alveolar bone grafting for the first time at least 6 months previously, 52 patients with 57 grafted sites rated type I or II based on the Bergland scale using occlusal radiographs were selected.**

Interventions: **CBCT was performed for each bone-grafted alveolar cleft within 1 week after the occlusal radiographs were taken.**

Main Outcome Measures: **The thickness of the grafted bone bridge was evaluated using CBCT according to the relationship between crest thickness and the root width of cleft-adjacent teeth, and the results were classified into four categories, with scores of 1 to 4 indicating that the thickness of the bony bridge was ≥100%, ≥75%, ≥50%, and <50% of the root width of the cleft-adjacent teeth, respectively.**

Results: **Of the 34 grafted sites rated type I on the Bergland scale, 15 (44.12%), 10 (29.41%), 4 (11.76%), and 5 (14.71%) clefts were scored 1 to 4 on interdental septal thickness using CBCT, respectively. Of the 23 cases of type II, 3 (13.04%), 9 (39.13%), 1 (3.45%), and 10 (43.48%) clefts were scored 1 to 4, respectively.**

Conclusions: **The interdental septal thickness of grafted bone bridges with clinically successful heights based on the Bergland scale (type I or II) using occlusal radiographs varied significantly in the evaluation using CBCT.**

KEY WORDS: *alveolar bone grafting, cone beam computed tomography (CBCT), thickness*

Alveolar cleft is commonly seen in patients with cleft lip and/or palate (CL/P). It frequently leads to oronasal fistulas and failures in tooth development and is often associated with collapse of the upper arch. Thus, there is a need to repair such alveolar defects to provide better outcomes in tooth development, orthodontic and prosthetic treatment, and oronasal fistula closure (Hall and Posnick, 1983; Bergland et al., 1986b). Secondary alveolar bone grafting for repair of the residual alveolar cleft, first described by Boyne and Sands (1972), has become an essential step in the management of patients with CL/P.

Traditionally, the bone bridges constructed have been evaluated on intraoral radiographs (Abyholm et al., 1981; Hall and Posnick, 1983; Sindet-Pedersen and Enemark, 1985; Bergland et al., 1986b; Enemark et al., 1987; Paulin et al., 1988; Amanat and Langdon, 1991; Kalaaji et al., 1994). The scale described by Bergland et al. (1986b) has gained worldwide acceptance and remains the gold standard. However, intraoral radiographs can only provide two-dimensional (2D) information, failing to present comprehensive three-dimensional (3D) views of the object (Dado et al., 1997; Rosenstein et al., 1997; Santiago et al., 1998). Rosenstein et al. (1997) found that the dental radiographs significantly overestimated bony coverage of the roots of cleft-adjacent teeth after alveolar bone grafting, by up to 25%, compared with computed tomography (CT). Lee et al. (1995) assessed the diagnostic accuracy of dental radiographs in determining the success of secondary alveolar bone grafting by analyzing dental radiographs and CT in selected cases. They found differences of up to 17% between 2D calculations from dental radiographs and 3D calculations from CT for evaluating the clinical success of alveolar bone grafting. Moreover, the 2D method can assess only the height of the alveolar bone bridge, not the

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FIGURE 1 Bergland grading scale used in the radiographic assessment of bone-grafted alveolar clefts. Type I = septal height approximately normal. Type II = septal height at least three-quarters of normal.

alveolar thickness. From the standpoint of full dental rehabilitation, the thickness of the bone bridge is important for orthodontic tooth movement and for the application of dental implants. Insufficient thickness of the grafted bone bridge is likely to result in failure of orthodontic or prosthodontic treatment. Lee et al. (1995) stated that intraoral dental radiography was an inaccurate gauge of clinical orthodontic decisions because it failed to detail the depth and volume of the bony bridge. Iino et al. (2005) indicated that in 41% of cases where, based on intraoral radiographs, the interdental bone height was regarded as a successful surgical outcome the labiolingual thicknesses were actually revealed to be less than the root width of the cleft-adjacent teeth on CT. Inconsistent findings in patients after bone grafting, with success in short-term radiographic examinations and less satisfactory clinical results in later follow-up, were reported by Enemark et al. (1987), who found that the successful rate of alveolar bone grafting in intraoral radiographs was 90%, whereas orthodontic cleft closure succeeded in fewer than half the patients. Thus, the 3D evaluation of the outcome of alveolar bone grafting is important for full oral and dental rehabilitation, especially in terms of the interdental septal thickness.

With the development of computed tomography technology, especially the emergence of cone beam computed tomography (CBCT), which provides a lower radiation dose and higher resolution than spiral computed tomography (Arai et al., 1999; Murthy and Lehman, 2005; Ludlow and Ivanovic, 2008), it is possible to develop a better scale for grading alveolar bone. Recently, several studies have assessed the status of bone grafting using CT—including grafted bone amount or volume, bone resorption, and bone density or quality (maturation) (Van der Meij et al., 1994; Lee et al., 1995; Dado et al., 1997; Santiago et al., 1998; Honma et al., 1999; Tai et al., 2000; Van der Meij et al., 2001; Feichtinger et al., 2006, 2007). However, the interdental septal thickness of grafted bone bridge with ratings of type I or II on the Bergland scale using occlusal radiographs regarded as a satisfactory result (Bergland et al., 1986a) has not been specifically evaluated using a 3D method, particularly using CBCT.

In this study, we assessed the thickness of bone-grafted alveolar clefts using CBCT, rating the height as type I or II on the Bergland scale using occlusal radiographs, and determined the status of the grafted bone bridges.

Materials and Methods

Subjects

From May 2014 to December 2014, 71 patients with cleft lip and/or palate (CL/P) were recruited from the Department of Orthodontics at Peking University School and Hospital of Stomatology. All of the patients had undergone alveolar bone grafting for the first time using cancellous iliac bone by the same maxillofacial surgeon at least 6 months earlier (Boyne and Sands, 1972). Additionally, the patients had no history of chemotherapy or radiotherapy, and also had no restorations, root canal treatment, evident root resorption, or any apical surgery. Standardized anterior maxillary occlusal radiographs were taken through the cleft line in these patients, and the postoperative interdental septal height was evaluated using the Bergland scale (Bergland et al., 1986b).

Of 92 grafted sites in the 71 patients who underwent alveolar bone grafting, 57 grafted sites in 52 patients were rated type I or II based on the Bergland scale using occlusal radiographs. In the other 19 patients, 35 grafted sites were rated type III or IV. According to the Bergland scale (Bergland et al., 1986b), type I indicated that the septal height was approximately normal, and type II indicated that it was at least three-quarters normal height. Occlusal radiographs rated type I or II on the Bergland scale are shown in Figure 1. From a clinical point of view, both types I and II were regarded as clinical success. These 52 patients (36 males, 16 females) with sites rated type I or type II were recruited

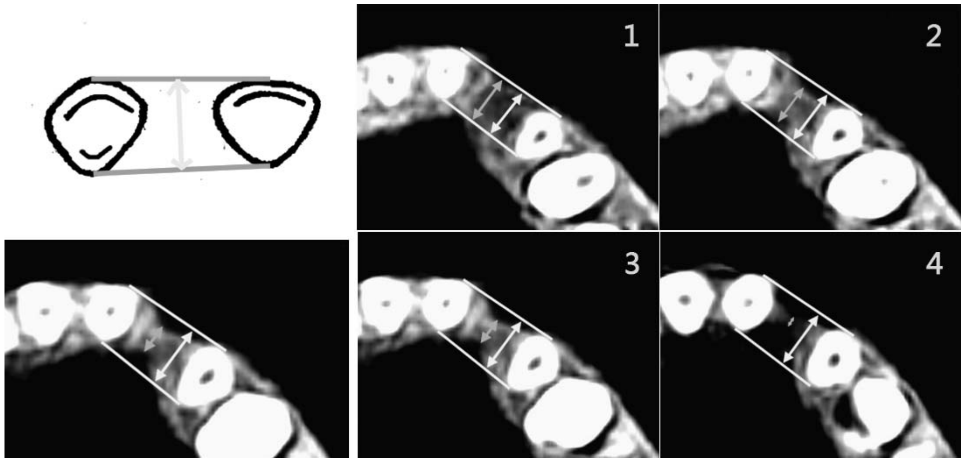

FIGURE 2 The grading scale used to assess the interdental bone thickness on cone beam computed tomography (compared with the root width of the cleft-adjacent teeth). DICOM images were displayed with window level of 1150 Hu and window width of 2000 Hu. Score 1 = the labiolingual thickness of the bony bridge is at least equal to the root width of the teeth adjacent to the cleft (≥100%). Score 2 = the thickness of the bony bridge is at least three-quarters as great as the root width of the cleft-adjacent teeth (≥75%). Score 3 = the thickness of the bony bridge is at least half as great as the root width of the cleft-adjacent teeth (≥50%). Score 4 = the thickness of the bony bridge is less than half the root width of the cleft-adjacent teeth (<50%).

for further analysis using CBCT. The other 19 patients with sites rated type III or type IV were excluded.

Of the 52 patients included in the study, 39 had unilateral cleft lip and palate (UCLP), 4 had bilateral cleft lip and palate (BCLP), 8 had unilateral cleft lip and alveolus (UCLA), and 1 had bilateral cleft lip and alveolus (BCLA). The mean age at the time of bone grafting was 14.07 years (range, 11 to 26).

This study protocol followed the Declaration of Helsinki on medical protocols and ethics. It was approved by the Ethics Committee of Peking University School and Hospital of Stomatology (PKUSSIRB-201413031).

Evaluation of Interdental Septal Thickness Using CBCT

Cone beam computed tomography was performed for each bone-grafted alveolar cleft within 1 week after occlusal radiographs were taken. There was an average of 8.60 months (range, 6 to 27) from the time of the operation to the CBCT examination (Appendix Table 1). All CBCT images were obtained by an experienced technician using a DCT Pro (Vatech, Yongin-Si, South Korea) with a voxel size of 0.3 mm. Scans were made from the maxillary occlusal plane to slightly above the nasal floor with 1-mm slice thicknesses, parallel to the maxillary occlusal plane. Mimics software (ver. 10.01; Materialise HQ, Leuven, Belgium) was used to create the 3D images, which were transformed to digital imaging and communications in medicine (DICOM) format.

The thickness of the grafted bone bridge was evaluated using CBCT (Fig. 2). The minimum labiolingual width of the grafted bone bridge was defined as the interdental septal thickness at the height level. Interdental bone thickness at all height levels along the cleft-adjacent roots were evaluated by comparing the thickness with the root width of the cleft-adjacent teeth at the same height level, and these measurements were classified into four categories based on scores of 1 to 4: 1, the labiolingual thickness of the bony bridge was at least equal to the root width of the teeth adjacent to the cleft (≥100%); 2, the thickness of the bony bridge was at least three-quarters as great as the root width of the teeth adjacent to the cleft (≥75%); 3, the thickness of the bony bridge was at least half as great as the root width of the teeth adjacent to the cleft (≥50%); and 4, the thickness of the bony bridge was less than half the root width of the teeth adjacent to the cleft (<50%). The score of the minimum thickness at all of the levels along the whole interdental height was defined as the final result of interdental bone thickness in the grafted bone bridge. Additionally, the height of the grafted sites from the cemento-enamel junction to the root apex of the cleft-adjacent tooth was divided into three parts to locate the minimum thickness of the grafted bone bridge: the top third (close to the cervix of the neighboring teeth), the middle third, and the bottom third (close to the apex). Then, we determined in which part the minimum thickness at all height levels was found.

To assess inter- and intra-operator agreement and reliability, two experienced orthodontists evaluated all of the CBCT images based on the scores of the interdental bone thickness twice at 2-week intervals.

Results

According to occlusal radiographs, 34 and 23 of the 57 bone-grafted alveolar clefts were rated types I and II, respectively, based on the Bergland scale. Of the 34 type I

TABLE 1 Interdental Septal Thickness of Grafted-Bone Alveolar Clefts Assessed From Cone Beam Computed Tomography (CBCT)

Occlusal Radiography (Bergland Scale)	*CBCT (Internal Bone Thickness)*	*Cleft Type**				*Grafted Sites*	*Ratio (%)*
		UCLP	*BCLP*	*UCLA*	*BCLA*		
Type I	Score 1	5	3	5	2	15	44.12
	Score 2	9	0	1	0	10	29.41
	Score 3	3	1	0	0	4	11.76
	Score 4	3	2	0	0	5	14.71
	Total	20	6	6	2	34	100
Type II	Score 1	3	0	0	0	3	13.04
	Score 2	7	2	0	0	9	39.13
	Score 3	1	0	0	0	1	3.45
	Score 4	8	0	2	0	10	43.48
	Total	19	2	2	0	23	100
Total		39	8	8	2	57	100%

* Cleft type: UCLP = unilateral cleft lip and palate; BCLP = bilateral cleft lip and palate; UCLA = unilateral cleft lip and alveolus; BCLA = bilateral cleft lip and alveolus.

grafted sites, 15 (44.12%), 10 (29.41%), 4 (11.76%), and 5 (14.71%) clefts scored 1 to 4, respectively, for interdental septal thickness using CBCT. Of the 23 cases of type II, 3 (13.04%), 9 (39.13%), 1 (3.45%), and 10 (43.48%) clefts scored 1 to 4, respectively (Table 1).

Among the 57 sites evaluated, the minimum thickness was located in the top third in 34 (59.65%) sites (19 cases scored 2 in the interdental septal thickness, 5 scored 3, and 10 scored 4); in the bottom third in 5 sites (8.77%; all scored 4); and at all height levels in the remaining 18 (31.58%) sites, all of which scored 1 in interdental septal thickness.

Interoperator reliability, assessed by the kappa value, was 0.893, while the intra-operator reliability was 0.984 (operator A) and 0.998 (operator B). These values indicated that the 3D method of assessing interdental bone thickness using CBCT was reliable.

Discussion

Secondary alveolar bone grafting is an integral part of the overall management of patients with CL/P. Its major objectives include orthodontic closure of the gap in the dental arch with no prosthesis (Boyne and Sands, 1972; Paulin et al., 1988; Tai et al., 2000) and endosseous dental implant(s) embedded in the graft site (LaRossa et al., 1995; Ronchi et al., 1995; Takahashi et al., 1997). The most important clinical use of imaging of alveolar bone grafting is to evaluate whether the bone bridge can support prosthetic treatment with dental implants, orthodontic treatment of the cleft-adjacent teeth, or subsequent eruption of the canine or incisor (Hamada et al., 2005). Thus, precise evaluation of the bony bridge after secondary alveolar bone grafting is clinically necessary from the viewpoint of occlusal reconstruction.

Standard imaging methods for assessing bone bridges after alveolar bone grafting are routine dental radiographic techniques, including panoramic, periapical, and occlusal radiographs (Bergland et al., 1986b; Long et al., 1995; Kindelan et al., 1997). The 2D scale described by Bergland et al. (1986b) has been used widely to assess the success or failure of alveolar bone grafting. Sufficient height of the postoperative bone bridge is rated type I or II on the Bergland scale. However, it is not possible to obtain the labiolingual thickness of the grafted alveolar cleft from routine dental radiographs.

In this study, we used CBCT to evaluate the interdental septal thickness of bone-grafted alveolar clefts according to the relationship between crest thickness and the root width of cleft-adjacent teeth. Although the interdental septal height of some cases were rated type I or II on the Bergland scale using occlusal radiographs, there were obvious differences of interdental bone thickness on CBCT. Of the 34 grafted sites rated type I on the Bergland scale, 11.76% and 14.71% of clefts showed interdental septal thicknesses that were at least half of the root width of cleft-adjacent teeth and less than half of the root width, respectively (Table 1).

These findings suggest that it is not sufficient to evaluate the bone support of adjacent teeth after alveolar bone grafting in three dimensions using dental radiographs alone. Lee et al. (1995) argued that dental radiography alone was inadequate as a basis of clinical orthodontic decisions because (1) it failed to provide detailed information about the thickness and volume of bone deposited in the cleft, (2) it was inconsistent and often late in showing graft trabeculation, and (3) it failed to show the buccolingual position of adjacent or erupting teeth relative to the bone graft.

However, the thickness of the alveolar bone bridge is an important determinant of the success of full oral and dental rehabilitation in patients with cleft lips and palates (Enemark et al., 1987; Lee et al., 1995; Iino et al., 2005). Studies about dental implant prostheses have indicated that a minimum thickness of 1.5 mm is necessary at the surface where dental implants are to be placed so as to provide additional protection and coverage of implants in buccolingual sites (Abyholm et al., 1981; Kim et al., 2013). As Tarnow et al. (2000) demonstrated, bone resorption around implants occurs not only in the vertical direction but also horizontally, in the range of 1.3 to 1.4 mm. Spray et al. (2000) also showed that as labial bone thickness approaches 1.8 to 2 mm, bone loss decreases significantly.

When implants are placed in the esthetic zone, the labial bone thickness should be at least 2 mm to avoid the loss of the labial bone plate and the consequent risk of soft-tissue recession (Grunder et al., 2005). To meet this requirement, the diameter of dental implants is as small as possible in the narrow alveolar bone. According to recent reports, the minimum diameter of implants used in the knife edge ridge of the anterior zone is 3.3 mm (Rajput et al., 2013). Thus, the thickness of alveolar bone in which the dental implants can be inserted is at least 7.3 mm. With regard to orthodontic tooth movement, Bergland et al. (1986a) considered the interdental septal height of Bergland types I and II to be satisfactory results because the bone responded normally to the movement of teeth in the grafted area and gave adequate support to the dental roots. However, Enemark et al. (1987) reported some cases in which orthodontic closure of the cleft was not achieved in late follow-up among patients with early dental radiographic results showing apparently successful alveolar bone graft of type I or II.

To date, there has been no reported study about how thick a grafted bone bridge must be able to support orthodontic movement of the cleft-adjacent teeth into the grafted area. According to previous studies suggesting that orthodontic tooth movement is a stimulating factor for bone apposition, it may not be necessary for the thickness of the grafted bone bridge to be at least the root width of the cleft-adjacent teeth (Vardimon et al., 2001; Lei et al., 2010). Vardimon et al. (2001) revealed that the total bony apposition was 6.5-fold larger with orthodontic tooth movement into surgical bony defects in rats. It was also shown that enhanced bone healing occurred following orthodontic movement, where the defect involved periodontal structures (Nemcovsky et al., 2004). With proper biomechanics to move the root slowly toward the centerline, this allowed the bone to remodel (Lei et al., 2010). Given the interdental septal thickness, postoperative orthodontic movement of the teeth and the application of dental implants around the grafted area must be performed carefully, even if the interdental septal height is satisfactory.

Although routine dental radiographs have been used to evaluate secondary alveolar bone grafting for many years, the obvious shortcoming of this approach is the possible inaccuracy of extracting 3D information from a 2D record. This is likely to result in the failure of full oral and dental rehabilitation due to lack of detailed thickness information in dental radiographs. Although the assessment methods using standard dental radiographs have become increasingly objective and sophisticated, none is capable of circumventing this underlying limitation (Dado et al., 1997). With the development of CT, the shortcomings of dental radiographs have been overcome. Feichtinger et al. (2006) obtained reliable 3D information on alveolar clefts from CT images and 3D reconstructions that compared pre- and postoperative CT images of alveolar clefts, particularly the interdental septal thickness. Van der Meij et al. (2001) successfully used CT to assess whether sufficient bone, especially in the buccopalatal direction, was present to facilitate eruption of the permanent canine into the bone bridge. The thickness and volume of the grafted bone bridge can be determined only by using a 3D method of assessment rather than 2D radiography.

The 3D method of assessing alveolar bone thickness used in this study was based on the relationship between crest thickness and the root width of cleft-adjacent teeth. Four categories were defined based on the scale of interdental septal thickness using CBCT, as shown in Figure 2. As a semiquantitative evaluation method on 3D radiography, it can be readily and conveniently used. In addition, this study used an advanced CBCT technique, which has the advantage of low radiation compared with multi-slice CT (Arai et al., 1999; Murthy and Lehman, 2005; Ludlow and Ivanovic, 2008).

The radiation dose for a single CBCT scan is 3 to 7 times that of panoramic radiography (Ludlow et al., 2003), and the effective dose from a standard dental protocol scan with multidetector CT is 1.5 to 12.3 times greater than that of comparable CBCT scans (Ludlow and Ivanovic, 2008). To reduce the radiation dose without jeopardizing evaluation of the area of interest, the CBCT field of view and image resolution need to be considered.

The radiation dose of CBCT is influenced by two major factors: the field of view (FOV) and the voxel dimension. The radiation dose increases when the FOV is greater or the voxel dimension is smaller (Garib et al., 2014). Thus, the FOV of CBCT should be carefully restricted to cover the area of interest so as to minimize radiation exposure following the "as low as reasonably achievable" (ALARA) principle. Additionally, CBCT scans with high resolution (0.1 or 0.2 mm voxel size) are appropriate for the diagnosis of delicate structures, such as mild root resorption and tooth fractures. Voxel sizes of 0.3 and 0.4 mm should be used when a high level of detail is not needed (Menezes et al., 2010). It is recommended that the lowest resolution possible should be used without jeopardizing evaluation (American Academy of Oral Maxillofacial Radiology, 2013). Because the 3D method in this study involved only the grafted alveolar cleft, the area scanned using CBCT was only the local alveolar bone in the maxilla. Thus, CBCT can be requested with a small ($<$10 cm) field of view. Moreover, for a semiquantitative evaluation of interdental bone thickness on CBCT, a voxel size of 0.3 mm should be appropriate. Thus, it is feasible to evaluate the thickness of grafted bone bridges using CBCT.

Conclusions

In this study, the interdental septal thickness of grafted bone bridges with clinically successful heights according to the Bergland scale (type I or II) based on occlusal radiographs differed significantly from the evaluation using

CBCT. Because interdental bone thickness is closely related to orthodontic and prosthetic treatments, CBCT can provide a reference and assistance for patients with bone-grafted alveolar clefts in determining the labiolingual thickness.

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References

Abyholm FE, Bergland O, Semb G. Secondary bone grafting of alveolar clefts. A surgical/orthodontic treatment enabling a non-prosthodontic rehabilitation in cleft lip and palate patients. *Scand J Plast Reconstr Surg*. 1981;15:127–140.

Amanat N, Langdon JD. Secondary alveolar bone grafting in clefts of the lip and palate. *J Craniomaxillofac Surg*. 1991;19:7–14.

American Academy of Oral Maxillofacial Radiology. Clinical recommendations regarding use of cone beam computed tomography in orthodontics. Position statement by the American Academy of Oral and Maxillofacial Radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2013;116:238–257.

Arai Y, Tammisalo E, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. *Dentomaxillofac Radiol*. 1999;28:245–248.

Bergland O, Semb G, Abyholm F, Borchgrevink H, Eskeland G. Secondary bone grafting and orthodontic treatment in patients with bilateral complete clefts of the lip and palate. *Ann Plast Surg*. 1986a;17:460–474.

Bergland O, Semb G, Abyholm FE. Elimination of the residual alveolar cleft by secondary bone grafting and subsequent orthodontic treatment. *Cleft Palate J*. 1986b;23:175–205.

Boyne PJ, Sands NR. Secondary bone grafting of residual alveolar and palatal clefts. *J Oral Surg*. 1972;30:87–92.

Dado DV, Rosenstein SW, Alder ME, Kernahan DA. Long-term assessment of early alveolar bone grafts using three-dimensional computer-assisted tomography: a pilot study. *Plast Reconstr Surg*. 1997;99:1840–1845.

Enemark H, Sindet-Pedersen S, Bundgaard M. Long-term results after secondary bone grafting of alveolar clefts. *J Oral Maxillofac Surg*. 1987;45:913–919.

Feichtinger M, Mossbock R, Karcher H. Evaluation of bone volume following bone grafting in patients with unilateral clefts of lip, alveolus and palate using a CT-guided three-dimensional navigation system. *J Cranio Maxill Surg*. 2006;34:144–149.

Feichtinger M, Mossbock R, Karcher H. Assessment of bone resorption after secondary alveolar bone grafting using three-dimensional computed tomography: a three-year study. *Cleft Palate Craniofac J*. 2007;44:142–148.

Garib DG, Calil LR, Leal CR, Janson G. Is there a consensus for CBCT use in orthodontics? *Dental Press J Orthod*. 2014;19:136–149.

Grunder U, Gracis S, Capelli M. Influence of the 3-D bone-to-implant relationship on esthetics. *Int J Periodontics Restorative Dent*. 2005;25:113–119.

Hall HD, Posnick JC. Early results of secondary bone grafts in 106 alveolar clefts. *J Oral Maxillofac Surg*. 1983;41:289–294.

Hamada Y, Kondoh T, Noguchi K, Iino M, Isono H, Ishii H, Mishima A, Kobayashi K, Seto K. Application of limited cone beam computed tomography to clinical assessment of alveolar bone grafting: a preliminary report. *Cleft Palate Craniofac J*. 2005;42:128–137.

Honma K, Kobayashi T, Nakajima T, Hayasi T. Computed tomographic evaluation of bone formation after secondary bone grafting of alveolar clefts. *J Oral Maxillofac Surg*. 1999;57:1209–1213.

Iino M, Ishii H, Matsushima R, Fukuda M, Hamada Y, Kondoh T, Seto K. Comparison of intraoral radiography and computed tomography in evaluation of formation of bone after grafting for repair of residual alveolar defects in patients with cleft lip and palate. *Scand J Plast Reconstr Surg Hand Surg*. 2005;39:15–21.

Kalaaji A, Lilja J, Friede H. Bone-grafting at the stage of mixed and permanent dentition in patients with clefts of the lip and primary palate. *Plast Reconstr Surg*. 1994;93:690–696.

Kim JW, Cho MH, Kim SJ, Kim MR. Alveolar distraction osteogenesis versus autogenous onlay bone graft for vertical augmentation of severely atrophied alveolar ridges after 12 years of long-term follow-up. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2013;116:540–549.

Kindelan JD, Nashed RR, Bromige MR. Radiographic assessment of secondary autogenous alveolar bone grafting in cleft lip and palate patients. *Cleft Palate Craniofac J*. 1997;34:195–198.

LaRossa D, Buchman S, Rothkopf DM, Mayro R, Randall P. A comparison of iliac and cranial bone in secondary grafting of alveolar clefts. *Plast Reconstr Surg*. 1995;96:789–797; discussion 798–789.

Lee C, Crepeau RJ, Williams HB, Schwartz S. Alveolar cleft bone grafts: results and imprecisions of the dental radiograph. *Plast Reconstr Surg*. 1995;96:1534–1538.

Lei WY, Rabie AB, Wong RW. Repair of a defect following the removal of an impacted maxillary canine by orthodontic tooth movement: a case report. *Cases J*. 2010;3:62.

Long RE Jr., Spangler BE, Yow M. Cleft width and secondary alveolar bone graft success. *Cleft Palate Craniofac J*. 1995;32:420–427.

Ludlow JB, Davies-Ludlow LE, Brooks SL. Dosimetry of two extraoral direct digital imaging devices: NewTom cone beam CT and Orthophos Plus Ds panoramic unit. *Dentomaxillofac Radiol*. 2003;32:229–234.

Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2008;106:106–114.

Menezes CCd, Janson G, Massaro CdS, Cambiaghi L, Garib DG. Reproducibility of bone plate thickness measurements with cone-beam computed tomography using different image acquisition protocols [in Portuguese]. *Dental Press J Orthod*. 2010;15:143–149.

Murthy AS, Lehman JA. Evaluation of alveolar bone grafting: a survey of ACPA teams. *Cleft Palate Craniofac J*. 2005;42:99–101.

Nemcovsky CE, Beny L, Shanberger S, Feldman-Herman S, Vardimon A. Bone apposition in surgical bony defects following orthodontic movement: a comparative histomorphometric study between root- and periodontal ligament-damaged and periodontally intact rat molars. *J Periodontol*. 2004;75:1013–1019.

Paulin G, Astrand P, Rosenquist JB, Bartholdson L. Intermediate bone grafting of alveolar clefts. *J Craniomaxillofac Surg*. 1988;16:2–7.

Rajput NS, Bhaskar J, Valiathan M, Chandrasekaran SC, Alam MN. Placement of dental implant in a knife edge ridge in anterior aesthetic zone. *J Clin Diagn Res*. 2013;7:2376–2377.

Ronchi P, Chiapasco M, Frattini D. Endosseous implants for prosthetic rehabilitation in bone grafted alveolar clefts. *J Craniomaxillofac Surg*. 1995;23:382–386.

Rosenstein SW, Long RE Jr., Dado DV, Vinson B, Alder ME. Comparison of 2-D calculations from periapical and occlusal radiographs versus 3-D calculations from CAT scans in determining bone support for cleft-adjacent teeth following early alveolar bone grafts. *Cleft Palate Craniofac J*. 1997;34:199–205.

Santiago PE, Grayson BH, Cutting CB, Gianoutsos MP, Brecht LE, Kwon SM. Reduced need for alveolar bone grafting by presurgical orthopedics and primary gingivoperiosteoplasty. *Cleft Palate Craniofac J*. 1998;35:77–80.

Sindet-Pedersen S, Enemark H. Comparative study of secondary and late secondary bone-grafting in patients with residual cleft defects. Short-term evaluation. *Int J Oral Surg*. 1985;14:389–398.

Spray JR, Black CG, Morris HF, Ochi S. The influence of bone thickness on facial marginal bone response: stage 1 placement through stage 2 uncovering. *Ann Periodontol*. 2000;5:119–128.

Tai CC, Sutherland IS, McFadden L. Prospective analysis of secondary alveolar bone grafting using computed tomography. *J Oral Maxillofac Surg*. 2000;58:1241–1249; discussion 1250.

Takahashi T, Fukuda M, Yamaguchi T, Kochi S. Use of endosseous implants for dental reconstruction of patients with grafted alveolar clefts. *J Oral Maxil Surg*. 1997;55:576–583.

Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. *J Periodontol*. 2000;71:546–549.

Van der Meij AJ, Baart JA, Prahl-Andersen B, Valk J, Kostense PJ, Tuinzing DB. Computed tomography in evaluation of early secondary bone grafting. *Int J Oral Maxillofac Surg*. 1994;23:132–136.

Van der Meij AJ, Baart JA, Prahl-Andersen B, Valk J, Kostense PJ, Tuinzing DB. Bone volume after secondary bone grafting in unilateral and bilateral clefts determined by computed tomography scans. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2001;92:136–141.

Vardimon AD, Nemcovsky CE, Dre E. Orthodontic tooth movement enhances bone healing of surgical bony defects in rats. *J Periodontol*. 2001;72:858–864.

Appendix

APPENDIX TABLE 1 The Time of Cone Beam Computed Tomography (CBCT) Scan After the Alveolar Bone Grafting

Time of CBCT After Operation (Months)	*Sex*		*Cleft Type**				*Number of Patients*	*Ratio (%)*
	Male	*Female*	*UCLP*	*BCLP*	*UCLA*	*BCLA*		
6	25	13	28	3	6	1	38	73.08
7	1	0	1	0	0	0	1	1.92
8	2	0	2	0	0	0	2	3.85
12	2	2	3	0	1	0	4	7.69
15	1	0	0	0	1	0	1	1.92
17	1	0	1	0	0	0	1	1.92
20	1	0	0	1	0	0	1	1.92
21	1	0	1	0	0	0	1	1.92
24	1	1	2	0	0	0	2	3.85
27	1	0	1	0	0	0	1	1.92

* Cleft type: UCLP = unilateral cleft lip and palate; BCLP = bilateral cleft lip and palate; UCLA = unilateral cleft lip and alveolus; BCLA = bilateral cleft lip and alveolus.