Alveolar Bone Graft Evaluation Agreement using Cone Beam Computed Tomography in Cleft Lip and Palate Patients: A Pilot Study

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Objective: To develop and test assessor agreement using a new cone beam computed tomography (CBCT) examination method for evaluating the outcome of alveolar bone grafts in cleft lip and palate patients.
Material and Method: Twenty patients with complete cleft lip and cleft palate who had undergone alveolar bone grafting with CBCT follow-up 3-6 months postoperative at the Faculty of Dentistry, Khon Kaen University were recruited into the study. Four trained clinical assessors (two orthodontists, an oral surgeon and an oral radiologist) had made a judgment of three outcome measurements: 1) cemento-enamel junction (CEJ) to marginal bone level of the teeth adjacent to the cleft site, 2) marginal bone level to root apex of the teeth adjacent to the cleft site, 3) labio-lingual alveolar bone grafted thickness. Repeat measurements were made by the same assessors.
Results: The Kappa values of intra-assessor agreements of each assessor were 0.82, 0.91, 0.91 and 1, respectively, while the inter-assessor agreements for the first and second time of determinations were 0.81 and 0.74.
Conclusion: This CBCT method for scoring alveolar bone graft outcomes produced good agreement among four assessors, which suggests its potential use to evaluate the success of alveolar bone grafting. In the future, this new method of alveolar bone graft evaluation should be compared with the standard method for testing validity.

Keywords: Alveolar bone graft, Cone beam computed tomography, Cleft lip and palate

The treatment of cleft patients is a multi-disciplinary team approach. Alveolar bone grafting is an integral part of the overall management of patients with cleft lip and palate (CLP)[1]. The objectives of alveolar bone graft are to stabilize the upper dental arch, to give a bony support for the teeth adjacent to the alveolar cleft area, to support the lip and nose, and to close a possible residual oronasal fistula[2].

Evaluation of alveolar bone grafts for patients with cleft alveolus is important to enable clinicians to assess graft prognosis, determine the treatment plan to close a missing lateral incisor space orthodontically, or restore the space with an osseo-integrated dental implant or fixed partial denture, or to decide if re-graft surgery is necessary. Assessment of the result needs an accurate method. The inability to assess the facial and lingual aspects of alveolus and inherent overlap of bony structures is the main disadvantage of the dental radiographic methods of evaluation[3]. Peamkaroonrath[4] developed a clinical method for assessing the alveolar bone graft condition, combining probing depth, and residual defects at alveolar bone graft site. She also did a pilot study to evaluate the agreement of those clinical criteria and radiographic scales. However, her study had only a small sample size so she could not reach an adequate statistical conclusion. Pirmsinthavee[5] applied the same clinical methods for assessing the alveolar bone graft subsequently. It produces good level of agreement between radiographic methods and clinical methods. However, they do attempt a 3D assessment although by direct visual observation and probing of the grafted region but this method does not show true

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morphological quantification.

CBCT enables construction of images that provides measurable maxillary sections in any plane, demonstrating all the anatomical structures in depth[6]. It also enables construction of a three-dimensional (3D) visualization and measurement of the amount of grafted bone around the tooth roots that is not possible with conventional radiography[7]. These capabilities enhance the information to make more accurate diagnostic and treatment decisions.

Hamada et al[7] compared CBCT with dental occlusal and panoramic radiographs in evaluating bone grafts of the alveolar cleft. They found that the CBCT provided more precise information about 3D morphology of the bone bridge at the cleft site and 3D relationships between the bone bridge and the roots of the teeth adjacent to the cleft. This type of imaging also offers more information about the bony bridge, bone support of teeth adjacent to the cleft, and better assessment of the alveolar bone graft for placement of dental implants[8].

However, there have been few objective studies determining success of alveolar bone grafting by CBCT. Therefore, the aim of the present study was to develop and test assessor agreement of a cone beam computed tomography (CBCT) examination method for evaluating the outcomes of alveolar bone graft in cleft lip and palate patients.

Material and Method

The present study is a pilot study which comprised a group of patients with complete cleft lip and cleft palate who had received alveolar bone grafting follow-up at the Faculty of Dentistry, Khon Kaen University between February 2012 and June 2012. The inclusion criteria for the present study were alveolar bone grafting 3-6 months previously. Patients who had systemic disease which interfere with bone formation were excluded from the study. The research was reviewed and approved by Ethics Committee of Khon Kaen University (HE551063).

Cone beam computed tomography was performed using the WhiteFox Cone beam 3D system (WhiteFox, WhiteFox Imaging, Italy). The technical parameters for image acquisition were 105 kv, 9 mA, field of view (FOV) in 60 mm x 60 mm (half arch) and voxel size of 0.2 mm³. During the CBCT imaging, patients were stood so that Frankfort plane was parallel to the floor with sagittal plane perpendicular. Measurements of the CBCT images were performed digitally using the WhiteFox imaging software version

3.0. All constructions and measurements were executed on a Samsung computer with a graphic card (NVDIA GeForce GT330M Series) and 14.1 inch Generio PnP Monitor with solution 1,366 x 768 pixels and zoom level 150%.

The CBCT data were evaluated by four assessors: two orthodontists, an oral surgeon and an oral radiologist, to make a judgment about the alveolar bone graft outcome. The assessor scores of alveolar bone graft outcomes are as follows:

1. Cemento-enamel junction (CEJ) to marginal bone level of the teeth adjacent to the cleft site (Fig. 1).

Mid-distal of mesial tooth adjacent to the cleft and mid-mesial of distal tooth adjacent to the cleft were measured. Scoring the alveolar bone graft outcomes as follows:

1 = CEJ to marginal bone ≥75% root length.
2 = CEJ to marginal bone 50-74% root length.
3 = CEJ to marginal bone 25-49% root length.
4 = CEJ to marginal bone <25% root length.

2. Marginal bone level to the root apices of the teeth adjacent to the cleft site (Fig. 2).

Mid-distal of mesial tooth and mid-mesial of distal tooth adjacent to the cleft were measured. Scoring the alveolar bone graft outcomes as follows:

1 = Marginal bone level to the root apex of the tooth ≤25% root length.

2 = Marginal bone level to the root apex of the tooth 26-50% root length.

3 = Marginal bone level to the root apex of the tooth 51-75% root length.

4 = Marginal bone level to the root apex of the tooth >75% root length.

3. Labiolingual alveolar bone graft thickness (Fig. 3).

Fig. 1   Scoring the alveolar bone graft outcomes. A) CEJ to marginal bone was less than 25% of root length. Score of distal marginal bone of mesial tooth adjacent to the cleft was 4. B) the mesial marginal bone of distal tooth adjacent to the cleft was scored 4.
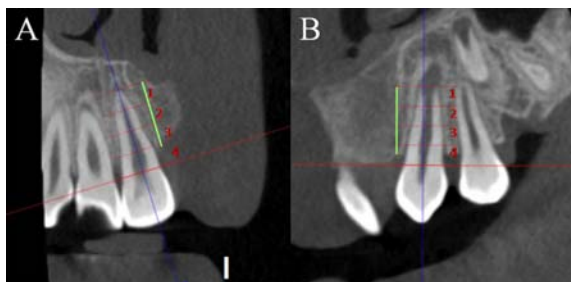
Fig. 2 Scoring the alveolar bone graft outcomes. A) marginal bone to the root apex of the mesial tooth adjacent to the cleft was more than 75% of root length. Score of distal marginal bone of mesial tooth adjacent to the cleft was 4. B) the mesial marginal bone to the root apex of distal tooth adjacent to the cleft was scored 4.
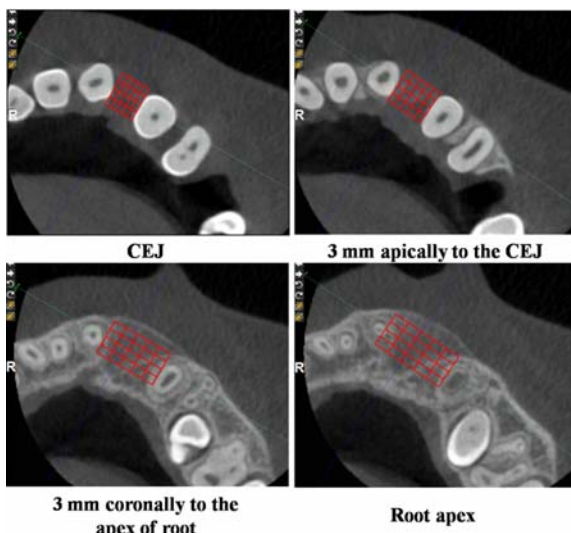

Fig. 3 These are the CBCT images 3 months after alveolar bone graft of one patient. The score of labiolingual alveolar bone grafted thickness at CEJ level = 1, 3 mm apically to the CEJ = 1, 3 mm coronally to the apex of root = 4 and the root apex = 4.

This was measured on axial sections parallel to CEJ of the mesial tooth adjacent to the cleft passing CEJ, 3 mm apically to the CEJ, 3 mm coronally to the apex of root and the root apex. A grid was created between the teeth adjacent to the cleft in each level. Scoring the alveolar bone graft outcomes as follows:

1 = Labiolingual alveolar bone graft thickness ≤25% of bone graft site.

2 = Labiolingual alveolar bone graft thickness 26-50% of bone graft site.

3 = Labiolingual alveolar bone graft thickness 51-75% of bone graft site.

4 = Labiolingual alveolar bone graft thickness >75% of bone graft site.

These three sets of assessment criteria were incorporated into a scoring chart for the assessors (Table 1).

Examination procedures were reassessed one week later, to allow an estimate of inter- and intra-observer reliability. All examiners were first trained to achieve acceptable reproducibility for 3 criteria. Reliability testing used for the CBCT assessments were Kappa statistics from Stata Software.

The assessors were also given a questionnaire about their experiences in using this new method of evaluating alveolar bone graft outcomes using CBCT as follows:

Questionnaire

1. What were your experiences for use CBCT in cleft patient?

2. What were your experiences with use of Criterion 1 (CEJ to marginal bone level of the teeth adjacent to the cleft site)?

3. What were your experiences with use of Criterion 2 (Marginal bone level to the root apices of the teeth adjacent to the cleft site)?

4. What were your experiences with use of Criterion 3 (Labiolingual alveolar bone graft thickness)?

5. Was it easy? If not, then why?

6. Were the images sufficiently clear to give confidence in measurement accuracy?

7. Did you think that, together, the 3 criteria covered the requirements for a useful assessment?

8. Does the CBCT give greater confidence in diagnostic judgment?

9. What was your overall impression?

Results
General characteristics of the study subjects

The descriptive statistics for the 20 patients are shown in Table 2. The mean age was 11.5 years with a range 9 to 17 years. The study subjects included 14 males and 6 females. The patients comprised 14 unilateral cleft cases and 6 bilateral cleft cases.

Reliability of the CBCT scoring alveolar bone graft outcomes

The Kappa[9] values of intra-assessor agreement in combining Criteria 1, 2 and 3 were 0.82, 0.91, 0.91 and 1, respectively, while the inter-assessors agreement between first and second assessment were

Table 1. Recording table for CBCT scoring alveolar bone graft outcomes

Subject's Study number: Site for judgement outcomes	Assessor's score			
	1	2	3	4
1. CEJ to marginal bone level of the teeth adjacent to the cleft site (coronal section)				
1.1 Mid distal of the mesial tooth adjacent to the cleft				
1.2 Mid mesial of the distal tooth adjacent to the cleft				
2. Marginal bone level to the root apices of the teeth adjacent to the cleft site (coronal section)				
2.1 Mid distal of the mesial tooth adjacent to the cleft				
2.2 Mid mesial of the distal tooth adjacent to the cleft				
3. Labiolingual alveolar bone graft thickness (4 levels of axial section)				
3.1) CEJ				
3.2) 3 mm apically to CEJ				
3.3) 3 mm coronally to apex of root				
3.4) The apex of root				
Sum of Criteria 3				
Overall CBCT score				

Table 2. General characteristics of the subjects

Patient No.	Sex	Side of grafted/ cleft type	Age at the time of alveolar bone graft (years-months)	Interval between alveolar bone graft and CBCT exam (months)
1	Male	L/BCLP	9-8	6
2	Male	L/UCLP	10-4	4
3	Male	L/UCLP	10-5	6
4	Male	L/UCLP	10-10	5
5	Male	L/UCLP	11-6	6
6	Male	L/UCLP	12-0	5
7	Male	L/UCLP	12-1	3
8	Male	L/BCLP	12-10	3
9	Male	L/UCLP	13- 4	6
10	Male	L/UCLP	13-3	6
11	Male	L/UCLP	14-0	6
12	Male	R/BCLP	9-8	4
13	Male	R/BCLP	11-5	4
14	Male	R/UCLP	11-6	3
15	Female	L/UCLP	9-0	3
16	Female	L/UCLP	9-2	6
17	Female	L/UCLP	10-0	4
18	Female	L/BCLP	10-8	5
19	Female	L/BCLP	17-6	3
20	Female	R/UCLP	12-10	5

L = left, R = right, UCLP = unilateral cleft lip and palate, BCLP = bilateral cleft lip and palate

0.81 and 0.74. This indicated very good intra- and inter-observer agreement (Tables 3 and 4).

    The four assessors performed the CBCT examination for the subjects in order to test their reliability. It showed that the intra-assessor (Kappa value) for Criteria 1 and 2 had very good agreement,

Table 3. Intra-assessor scoring for CBCT alveolar bone graft outcomes (Kappa value at 95% confidence interval)

Site for judgement outcomes	Assessor 1	Assessor 2	Assessor 3	Assessor 4
1. CEJ to marginal bone level of the teeth adjacent to the cleft site	0.92 (0.84-1.00)	1	0.95 (0.75-1.00)	1
2. Marginal bone level to the root apices of the teeth adjacent to the cleft site	0.92 (0.81-1.00)	1	0.95 (0.88-1.00)	1
3. Labiolingual alveolar bone graft thickness	0.83 (0.79-0.92)	0.91 (0.77-1.00)	0.91 (0.80-1.00)	1
Overall intra-assessor	0.82 (0.53-0.92)	0.91 (0.81-1.00)	0.91 (0.90-1.00)	1

Table 4. Inter-assessors scoring for CBCT alveolar bone graft outcomes (Kappa value of 4 assessors at 95% confidence interval)

Site for judgement outcomes	Kappa1 (First time)	Kappa2 (Second time)
1. CEJ to marginal bone level of the teeth adjacent to the cleft site	0.87 (0.70-0.91)	0.80 (0.65-0.89)
2. Marginal bone level to the root apices of the teeth adjacent to the cleft site	0.87 (0.69-0.95)	0.80 (0.71-0.93)
3. Labiolingual alveolar bone graft thickness	0.96 (0.91-1.00)	0.87 (0.69-0.96)
Overall inter-assessors	0.81 (0.60-0.85)	0.74 (0.66-0.81)

ranging from 0.92 to 1 while sum of components of Criterion 3 ranged from 0.83 to 1. Criterion 3 showed less agreement compared with Criteria 1 and 2 (Table 3).

The Kappa value of inter-assessors for Criteria 1 and 2 were 0.87 at the first assessment while for the second assessment they were 0.80. The sum of Criterion 3 presented Kappa values of 0.96 and 0.87, respectively (Table 4).

The questionnaire responses

The experiences of three assessors using CBCT for cleft patients were 1 to 5 years, while one assessor did not have prior experience. The first three had used Criterion 1 (CEJ to marginal bone level of the teeth adjacent to the cleft site) and Criterion 2 (marginal bone level to the root apices of the teeth adjacent to the cleft site) to evaluate alveolar bone graft outcomes in both 2D and 3D images. Use of assessment components of Criterion 3 (Labio-lingual alveolar bone graft thickness) were new, all having relied on direct clinical examination.

All assessors stated that the images were sufficiently clear to give confidence in measurement accuracy, thus giving greater confidence in diagnostic judgment. The 3 criteria covered the requirements for a useful assessment. They were satisfied with the result

of this CBCT assessment method. Prior experiences of assessors in use CBCT in cleft patient is considered to be essential.

Discussion

2-dimensional (2-D) radiographic methods have been used for evaluating the outcome allowing only measurement of the inter-alveolar bone height[2,10,11]. Only recently, CBCT has been introduced as a method for assessing the outcomes of alveolar bone graft in cleft patients, permitting clinicians to determine the bucco-palatal width of bone, morphology of bone bridge, relationship between the bone bridge and root of neighboring teeth and their periodontal condition[7].

There are several factors which should be considered concerning CBCT images. Firstly, the possible effect of artifacts from a metallic orthodontic appliance which may be present on the quality of CBCT images of alveolar bone graft. The soft tissue attenuation and patient motion also affect accuracy of measurement distance in CBCT image[12]. From the personal experience of the author, the CEJ level presents the most likely artifact images so this assessment criterion may lead to some assessor variability in scoring alveolar bone graft outcomes. Secondly, a good quality image is related to smaller voxel size (<0.2 mm^3) and

smaller field of view. This would create clearer images for evaluating the graft but would involve more radiation exposure.

Each subject investigated in the present study received only one-time CBCT scan for clinical evaluation and a selected FOV of 60 mm x 60 mm (half-arch) with high resolution for minimizing radiation exposure of the patients. The decision to take any radiograph must follow the ALARA (As Low As Reasonably Achievable) principle[13] and in accordance with US Food and Drug Administration guidelines[14]. In the present study, the effective dose was 36.11 μSv per scan which is higher than any one of the intraoral radiography (8.3 μSv)[15]. The scientific evidence supports CBCT imaging of specific cases where its use has been substantiated to enhance diagnosis and treatment planning and in which its benefits exceed the possible risks. CBCT imaging of other types of cases in which it is likely to provide valuable diagnostic information can also be performed following determination of a positive value-proposition[16].

The present study shows that this CBCT scoring method for assessing alveolar bone graft outcomes indicated very good intra- and inter-observer agreement. Additionally, CBCT provides good accuracy for quantitative analyses of buccal and lingual alveolar bone thickness at different vertical levels[17].

Nightingale et al[18] stated that the intra-observer Kappa scores were an average of 0.67 for the Bergland Scale[2], 0.61 for the Chelsea Scale[10], and 0.70 for the Kindelan Scale[19]. Inter-observer Kappa values averaged 0.48 for the Bergland Scale, 0.50 for the Chelsea Scale, and 0.49 for the Kindelan Scale. The results indicated that there was little difference in reliability between the scales and only moderate agreement between observers, supporting opinions about deficiencies of 2-D intraoral radiography for assessing bone graft outcomes[7].

Ruppel[11] reported testing of the Standardized Way of Assessing Grafts (SWAG) assessment method (Americleft Project of the American Cleft Palate-Craniofacial Association), based on intraoral radiography by five orthodontists experienced in cleft palate care and one trainee orthodontist on 82 consecutively completed grafts, and found mean overall kappa scores for intra- and inter-assessor agreements of 0.79 and 0.71, respectively.

A possible variable that could influence difference in reliability testing could be the small sample size available for the present study. This size offered low variability of graft outcomes for adequate testing a range of qualities of graft outcomes.

Most previous studies used CBCT to evaluate bone graft by comparing postoperative grafted bone volume with pre-operative alveolar bony defect[20-23]. Oberoi et al[20] and Honma et al[21] measured the volume of the preoperative bony defect and postoperative bone fill. Kim et al[22] similarly evaluated changes in the grafted bone after secondary alveolar bone graft by measuring the height, labio-lingual thickness (LLT), and volume of the grafted bone at the time before bone graft compared with three and 12 months after bone graft. Zhang et al[23] also evaluated the resorption of alveolar bone grafting by assessing the graft volume at one month and six months. The merit of these studies may be obscured because they all involved doubling the radiation exposure of the subjects.

The subject number for the present study was insufficient for adequate statistical significance testing, because locating and calling back subjects was difficult. The problem extended to the absence of a wide variety of bone grafts representing an ordinal range of excellent or very good to poor and unsatisfactory. Thus this assessment method leaves open the question of its validity in covering the possible range of graft outcomes. There is the hypothetical question as to how this method would have compared with the results of any evaluative surveys that included a record of graft failures.

Conclusion

Cone beam computed tomography (CBCT) is one method for providing quantifiable information to evaluate alveolar bone graft outcome which has some indications of use for improving diagnostic and treatment planning accuracy of subsequent orthodontic treatment of the teeth adjacent to the cleft or eruption of embedded canine into the bone graft. The presently tested CBCT method of scoring alveolar bone graft outcomes produced good agreement among four clinical assessors and offers potential benefit for both patients and clinician to evaluate the success of alveolar bone graft.

Potential conflicts of interest

None.

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ความเที่ยงของการประเมินผลของการปลูกกระดูกเบ้ารากฟันโดยวิธีการใช้ภาพถ่ายรังสีอาศัยส่วนตัดคอมพิวเตอร์ชนิดโคนบีมในผู้ป่วยปากแหว่งเพดานโหว่: การศึกษานำร่อง

ทัศนีย์ วังศรีมงคล, มนเทียร มโนสุดประสิทธิ์, พูนศักดิ์ ภิเศก, ภิภพ สุทธิประภาภรณ์,
ธณัชช์ปิยา สมสุข

วัตถุประสงค์: เพื่อพัฒนาและทดสอบความเที่ยงของผู้ตรวจ โดยการใช้ภาพถ่ายรังสีอาศัยส่วนตัดคอมพิวเตอร์ชนิดโคนบีม (ซีบีซีที) ในการตรวจประเมินผลของการปลูกกระดูกเบ้ารากฟันในผู้ป่วยปากแหว่งเพดานโหว่

วัสดุและวิธีการ: ผู้ป่วยปากแหว่งเพดานโหว่จำนวน 20 ราย ที่ได้รับการติดตามผลการปลูกกระดูกเบ้ารากฟัน ภายหลังจากการผ่าตัดปลูกกระดูกเบ้ารากฟันไปแล้ว 3-6 เดือน ด้วยซีบีซีที ที่คณะทันตแพทยศาสตร์ มหาวิทยาลัยขอนแก่น ได้ถูกเลือกเข้ามาในการศึกษานี้ ผู้ตรวจที่ได้รับการฝึกการประเมินทางคลินิก 4 ราย (ทันตแพทย์จัดฟัน 2 ราย, ศัลยแพทย์ช่องปาก 1 ราย และทันตแพทย์รังสี 1 ราย) ทำการพิจารณาเกณฑ์การวัด 3 ค่า คือ 1) ระยะห่างของรอยต่อของเคลือบรากฟันและเคลือบฟัน (ซีอีเจ) ถึงระดับขอบกระดูกของฟันที่อยู่ติดกับร่องโหว่ 2) ระยะห่างของระดับขอบกระดูกถึงปลายรากฟันของฟันที่อยู่ติดกับร่องโหว่ 3) ความหนาของกระดูกที่ปลูกในแนวข้างแก้มและข้างลิ้น และทำการวัดซ้ำโดยผู้ตรวจกลุ่มเดิม

ผลการศึกษา: ค่าแคปปาภายในตัวผู้ตรวจแต่ละคน มีค่า 0.82, 0.91, 0.91 และ 1 ตามลำดับ ในขณะที่ค่าแคปปาระหว่างผู้ตรวจในการวัดครั้งที่ 1 และครั้งที่ 2 มีค่า 0.81 และ 0.74

สรุป: การประเมินผลของการปลูกกระดูกเบ้ารากฟันด้วยซีบีซีทีมีค่าความเที่ยงในระดับดี ในผู้ตรวจ 4 คน จึงแนะนำให้ใช้เป็นแนวทางในการประเมินผลสำเร็จของการปลูกกระดูกเบ้ารากฟัน ในอนาคตวิธีการประเมินการปลูกกระดูกเบ้ารากฟันวิธีใหม่นี้ควรเปรียบเทียบกับวิธีการมาตรฐานเพื่อทดสอบความเที่ยงตรง