Comparison of a Clinical Method with Two Radiographic Methods for Assessing Quality of Alveolar Bone Grafts

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The aim of the present study was to test the agreement between a new developed clinical examination method and two commonly used radiographic scales (Bergland and Chelsea) for assessing alveolar bone graft outcomes in the cleft lip and palate patients. This new clinical method consisted of: (1) Probing depth for the teeth adjacent to the cleft and (2) Residual defects at the bone graft site. Two trained examiners examined the subjects in the present study. The inter- and intra-reliability tests of the two clinical criteria and the two radiographic scales produced the excellent agreement level of Kappa values (0.85-1.00). Comparison of the "acceptable-unacceptable" proportions between clinical and radiographic examination methods using McNemar's Chi-square showed non-significant differences (p-values 0.317-1.00), and good level Kappa values (0.68-0.77). It is suggested that the new clinical examination method could be used as an alternative screening tool for alveolar bone graft assessment.

Keywords: *Alveolar bone graft, Clinical evaluation, Radiographic evaluation*

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Alveolar bone grafting is an important procedure for reconstruction of the alveolar cleft defects. There are several objectives and benefits of bone grafting in the cleft patients[1-3]: to obtain maxillary arch continuity which is a universal goal in cleft management; to provide better bone support for the dentition; to stabilize the maxillary segments following orthodontic treatment, especially the mobile primary palate of bilateral clefts; to close oronasal fistulas; to provide nasal alar cartilage support; to help improvement of facial growth; and, to provide adequate bone volume sufficient for any future endosteal implant placement or other prosthesis, if needed. In order to meet these objectives, a sufficient height and volume of bone must be provided by bone grafting. The method to evaluate the graft must attempt to assess the actual quantity of bone-fill so that the efficacy of bone grafting can be more critically evaluated. Several methods of evaluation have been developed, but all with limitations in their use.

Radiographic examination, used in conjunction with various radiographic scales[3-10], is the mostly performed method. However, this method still has some limitations and disadvantages, such as cost, radiation exposure, patient accessibility, and quality of the image and its interpretation. The Bergland scale is the most widely used scale, which was considered to be the "gold standard[9]". A four-point semi-quantitative radiographic scale measuring interdental septal bone height compared with the cemento-enamel junction. However, Witherow and co-workers[9], in noting limitations of the Bergland scale, developed their "Chelsea scale" intending to take more account of wide clinical variations compared with the Bergland scale.

The clinical examination has been introduced into the assessment as well, based on the desirability of three-dimensional visualization and evaluation[11]. Computed tomography offers a means of three-dimensional assessment but has the significant disadvantages of undesirable radiation risk and high cost.

Peamkaroonrath[12] developed a combination of two clinical methods for assessing the alveolar bone graft condition: probing depth, and residual defects at alveolar bone graft site. She did a pilot study to evaluate the agreement of those clinical criteria and two widely

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used radiographic scales, Bergland[3] and Chelsea[9]. However, her study had only a small sample size so she could not reach an adequate statistical conclusion. Therefore, the present study aimed to test the agreement between the new clinical examination method which had been developed by Peamkaroonrath[12] and the Bergland and Chelsea radiographic methods for assessing secondary alveolar bone grafting.

Material and Method

Patients, with complete unilateral or bilateral cleft lip and palate and having mixed or permanent dentitions with or without prior eruption of the permanent canine adjacent to the cleft, who underwent alveolar bone grafting at Srinagarind Hospital Faculty of Medicine and Faculty of Dentistry in Khon Kaen University not less than 3 months earlier, were recruited for the present study. Patients who were undergoing orthodontic space closure at the cleft site and/or had systemic disease which may interfere with bone formation were excluded from the present study. Intraoral occlusal radiographs of the grafted region using a standardized technique were obtained for all subjects.

The clinical examination method used for evaluation of bone graft outcomes in the present study used two criteria as follows:

1. Probing depth: The distance from the gingival margin to the base of the probable gingival sulcus or periodontal pocket.

2. Residual defects at alveolar bone graft site: a qualitative assessment of the facio-lingual depth of the labial vestibular at the approximate levels of the root apices of the teeth on either side of the cleft graft.

The two clinical examiners were trained to achieve acceptable reproducibility for criterion 2 of the clinical using sample clinical photographs. Illustrations of the Bergland and co-workers[3] and Witherow and co-workers[9] assessment scales were used to achieve acceptable reproducibility.

The clinical examination recording chart and scoring system are shown in Table 1. The radiographs of the grafts were assessed by the same examiners using the Bergland and Chelsea scales.

Reliability testing used for the clinical and radiographic scales assessments were intraclass correlation coefficient (ICC) and Kappa statistics.

From the clinical examination criteria, the descriptives "Excellent" and "Good" were interpreted as "acceptable grafts", while the other three were considered as "unacceptable grafts". The scores using Bergland and Chelsea radiographic scales were converted as follows:

Bergland scale

Type I and II = Acceptable result (+)

Type III and IV = Unacceptable result (-)

Chelsea scale

Type A and Type C = Acceptable result (+)

Type B, D, E & F = Unacceptable result (-)

The "acceptable-unacceptable" proportional comparisons between the clinical and radiographic evaluation results were calculated using Kappa statistics and McNemar's Chi-square in order to determine whether these two methods provided the same proportions.

Results

General characteristics of the study subjects

The descriptive statistics for the 37 patient (45 cleft sites) are shown in Table 2. The subjects consisted with 15 males and 22 females. If categorized by cleft type, there were 9 bilateral cleft cases and 28 unilatreal cases. In one bilateral case, the space at right cleft side was closed by orthodontic tooth movement so only the left cleft site was measured.

Reliability of the clinical assessments

Intraclass correlation coefficients for Criterion 1 in both mesial and distal teeth ranged from 0.88 to 1.00, which was interpreted as very good agreement. Kappa values of Criterion 2 and the combining of Criterion 1 and Criterion 2 also showed very good agreement at kappa values 0.89 to 1.00 and 0.84 to 1.00, respectively. It can be concluded that the two examiners in the present study had the same standard for all clinical criterion measurements (Table 3).

Reliability of the radiographic assessments

For radiographic examination, the Kappa value for the Bergland scale assessment was in very good agreement, with Kappa value 0.93 for intra-examiner, and 0.86 to 1.00 for inter-examiner comparisons. Also, there was very good agreement with use of the Chelsea scale, 0.88 to 1.00 for intra-examiner, and 0.85 to 0.88 for inter-examiner scores (Table 4).

Comparison of the "acceptable-unacceptable" proportions between clinical and radiographic examination methods

From the clinical examination and the radiographic examination, the scores were converted

Table 1. Recording table for Index for clinical scoring bone graft outcome

Probing depth	Right side cleft						Left side cleft					
	Mesial tooth*			Distal tooth**			Mesial tooth*			Distal tooth**		
	B	M	Pa	B	M	Pa	B	M	Pa	B	M	Pa
≤ 3 mm (Score 5) 4-5 mm (Score 3) ≥ 6 mm (Score 1) Final point***	Mesial tooth =			Distal tooth =			Mesial tooth =			Distal tooth =		
	Final point*** =			(a)			Final point*** =			(c)		

Abbreviations: B = Buccal, D = Distal, Pa = Palatal, M = Mesial

Residual defects at alveolar bone graft site	Right side cleft			Left side cleft		
	Labial surface	Alveolar ridge	Palatal surface	Labial surface	Alveolar ridge	Palatal surface
No or slight depression (1 scores) Moderate depression (3 scores) Marked depression (5 scores) Residual fistula (8 scores)						
	Final point*** =		(b)	Final point*** =		(d)
	Final score : Right = (a) + (b) =			Left = (c) + (d) =		
				Overall result/outcome for one cleft site: Excellent: 2 Good: 3-4 Fair: 5-6 Poor: 7-8 Very Poor: 9-13		
	Category of the graft result : Right =			Left =		

* “Mesial tooth” means “The tooth which is in the mesial position of the cleft area”
** “Distal tooth” means “The tooth which is in the distal position of the cleft area”
*** “Final point” means “The worst score selected from the two or three columns of one side of cleft defect or the topic”

into “acceptable” and “unacceptable” graft results as mentioned earlier in order to provide the matching proportions. The McNemar Chi-square test and the Kappa statistic were used to compare those two methods which had been matched in the pairs as shown in Table 5 and Table 6.

Table 5 shows that all paired proportions were not significantly different which means that the proportions between the clinical examination methods compared with each of the two radiographic methods were not different.

From Table 6, the Kappa values of the clinical examination method and two radiographic methods of examiner 1 showed good agreement, 0.77, compared with the Bergland and 0.72 compared with Chelsea. For examiner 2, the Kappa values showed lower level of

Table 2. General characteristics of the subjects

Characteristics	n (percentage)	
	Patient	Cleft sites
Gender		
Male	15 (40.54)	20 (44.44)
Female	22 (59.46)	25 (55.56)
Cleft type		
Unilateral cleft	9 (24.32)	17 (37.78)*
Bilateral cleft	28 (75.68)	28 (62.22)
Age at the time of alveolar bone graft		
8-11 yrs old	16 (43.24)	18 (40.00)
More than 11 yrs old*	21 (56.76)	27 (60.00)
Age at the time of clinical examination		
8-11 yrs old	9 (24.32)	11 (24.44)
More than 11 yrs old	28 (75.68)	34 (75.56)
Total	37 (100.00)	45 (100.00)

* The one subject with a bilateral cleft who had orthodontic space closure on the right cleft side, so the measurement was done only on the left cleft site

Table 3. Reliability for clinical examination

Criteria selected	Agreement			
	Examiner 1A vs. 1B	Examiner 2A vs. 2B	Examiner 1A vs. 2A	Examiner 1B vs. 2B
Criterion 1 (ICC value)				
Mesial tooth	0.94	0.94	0.97	0.88
Dsital tooth	1.00	0.96	1.00	0.96
Criterion 2 (Kappa value)				
Residual defect	0.89	0.89	1.00	0.89
Criterion 1 + 2 (Kappa values)	0.85	0.90	1.00	0.84

Note: n = 37 patients (45 cleft sites)
Examiner 1A = The first examination of the first examiner
Examiner 1B = The repeated examination of the first examiner
Examiner 2A = The first examination of the second examiner
Examiner 2B = The repeated examination of the second examiner

agreement but still in the range of good agreement.

Discussion

Comments on the clinical examination criteria

From previous study of Peamkaroonrath[12], the clinical examination criteria were developed based on an idea of enabling a topographical 3-D assessment of the graft outcome, compared with the 2-D radiographic methods. In the present study, two clinical criteria were used as follows:

Probing depth

Use of this criterion was suggested by Bragger and co-workers[13], since it was a simple technique to indicate the periodontal status of each subject. The level of periodontal attachment measured by periodontal probing relates directly to bone level achieved with the graft. Therefore, the probing depth indicator was considered to be an appropriate measure for determining the adequacy of the grafted bone support for the teeth on either side of the cleft.

Table 4. Reliability for radiographic examination

Radiographic method	Agreement			
	Examiner 1A vs. 1B	Examiner 2A vs. 2B	Examiner 1A vs. 2A	Examiner 1B vs. 2B
Bergland scale	0.93	0.93	1.00	0.86
Chelsea scale	0.88	1.00	0.88	0.85

Note: n = 37 patients (45 cleft sites)
Examiner 1A = The first examination of the first examiner
Examiner 1B = The repeated examination of the first examiner
Examiner 2A = The first examination of the second examiner
Examiner 2B = The repeated examination of the second examiner

Table 5. Comparison of the "acceptable-unacceptable" proportions between clinical and radiographic examination methods using McNemar's Chi-square test

Matched pair	p-value
Examiner 1 clinic	
Examiner 1 Bergland scale	0.317
Examiner 1 Chelsea scale	0.655
Examiner 2 clinic	
Examiner 2 Bergland scale	1.000
Examiner 2 Chelsea scale	1.000

Table 6. Comparison of the "acceptable-unacceptable" proportions between clinical and radiographic examination methods using Kappa statistic

Matched pair	Kappa
Examiner 1 clinic	
Examiner 1 Bergland scale	0.77
Examiner 1 Chelsea scale	0.72
Examiner 2 clinic	
Examiner 2 Bergland scale	0.68
Examiner 2 Chelsea scale	0.68

In the present study, "probing depth" was defined as the distance from the gingival margin to the base of the probable gingival sulcus or pocket. It was found in the present study that in some cases there was horizontal bony deficiency together with gingival recession which resulted in a small and satisfactory probing depth, but not recording what may have been a significant level of bone loss below the cementoenamel junction of the teeth abutting the cleft.

It is essential to have training for the clinical examiners to practice using the same method of assessment. This would help to maximize the reliability of the examination and increase the precision of the methods used in the present study.

Residual defects at alveolar bone graft side

This criterion was newly introduced by Peamkaroonrath[12] in the clinical examination method to evaluate the result of alveolar bone grafting. Although the nature of characteristics of the defects cannot be evaluated quantitatively, Peamkaroonrath[12] provided guideline pictures exemplifying a range of defects to enable the examiner to match the test subjects with her rankings for this criterion. In the present study, the same guideline pictures combined with Peamkaroonrath's score rating definitions were used in order to help the examiners more easily score the graft outcome. However, there were some subjects in the present study who did not match with the guideline pictures, because there lacked clear distinction as to the scoring level for some of the residual defects.

Comments on the radiographic examination criteria

The Bergland scale has been claimed by several authors as a "gold standard" method in the radiographic assessment of alveolar bone graft, but it still has some drawbacks in its use. Witherow et al[9] stated that this scale needs the eruption of the permanent canine or/and fissural tooth if present, so it could not be used to evaluate the graft failure in the mixed dentition stage. It also did not determine the amounts of bone-fill in the cleft site: *e.g.*, between 25% of bone and 100% of bone in the cleft site. Trindade et al[14] also claimed some limitations in the Bergland scale, since it did not specify the amount of vertical bone resorption or the absence of bone in the most apical

region of the cleft. In order to reduce limitations of the Bergland scale, Witherow and co-workers[9] introduced the Chelsea scale, aiming to assess the condition of the bone in relation to the roots of the teeth abutting the cleft.

In the present study, use of the Bergland scale gave very good intra-examiner agreement (0.93 and 0.93) and slightly higher agreement for inter-examiner comparisons (1.00 and 0.86) (Table 4). Other studies, such as Nightingale et al[15] showed lower level of both intra-observer (0.65 and 0.72) and inter-observer reliability (0.45 and 0.51), Peamkaroonrath[12] showed good intra-examiner agreement (0.64 and 0.73), but with 0.77 and 0.86, for inter-examiner agreement. For the Chelsea scale, the reliability testing showed very good levels of agreement, ranging from 0.85 to 1.00 (Table 4), which was in close agreement with Peamkaroonrath[12] whose Kappa values ranged from 0.80 to 1.00. There was a higher level of agreement compared with the present study of Witherow et al[9] where the agreement ranged from 0.64 to 0.95.

Nightingale and co-workers[15] reported that the Chelsea scale was easier to use and provided more detailed information on the condition of grafted bone than the Bergland scale. Furthermore, comparing these two scales obviously showed that the Chelsea scale produced higher level of agreement than that of Bergland. But there were no differences in the present study. However, in some subjects using either of the radiographic grading systems, it was still difficult to interpret the grafted results, such as for subjects with the canine erupting into the cleft site, with overlapping image of the canine within the alveolar bone masking periodontal bone level or any possible bony bridge.

The timing for radiographic evaluation after alveolar bone grafting varies from only a few months to several years with no clear indications[3,5-7,9,10]. The surgical protocol for timing of grafting at the Khon Kaen University Cleft Palate Center (KKUCPC) is based on prediction of the timing of canine eruption. It is expected that when a dental radiograph shows half to two-thirds root development of the canine, imminent commencement of the final phase of eruption can be expected. As part of this protocol with the usually required pre-grafting orthodontics anticipates taking six to nine months, radiographic check of the amount of root development of the permanent canine is required. A half to two-thirds indicates that eruption of the canine can be anticipated within the next nine to twelve months. This lag period is used to carry out the usually necessary pre-grafting orthodontics occupying six to nine months, followed by grafting. This then leaves a short period for eruption of the canine into the newly reorganizing grafted bone. The canine may or may not have completed eruption three months after grafting, but will have shown significant eruptive movement. Any timing that is longer than 6 months after grafting is likely to be after eruption of the canine. If there is lengthy delay in checking the graft and there is a poor outcome, it will most likely be after the canine is erupted. In such a circumstance, a regrafting is less likely to achieve the desired success. Moreover, Bergland and co-worker[3] also claimed that the appearance of trabecular pattern of the grafted bone had been seen by 3 months post operatively, so that further delaying evaluation was not necessary. So in the present study, the timing to evaluate the alveolar bone grafting is "not less than 3 months after alveolar bone grafting procedure".

In following the above protocol for timing of radiography to check for canine eruption it is necessary to avoid radiographic re-checks. Thus, it is appropriate to base this timing on chronological age of expected canine eruption, say 11 to 12 years.

Comparison of the "acceptable-unacceptable" proportions between clinical and radiographic examination methods

According to Peamkaroonrath's assessment method[12], the total score from the clinical examination table (Table 2) was converted to one or other category of excellent, good, fair, poor and very poor. The "Excellent" and "Good" were interpreted as "acceptable" grafts, while the other three were considered as "unacceptable".

The way to categorize "acceptable-unacceptable" using the radiographic scale was based on Bergland and co-workers' study[3]; they concluded that Bergland Types I and II were "successful or acceptable" grafted outcomes, Types III and IV were "failed or unacceptable" results. But for the Chelsea scale, Witherow et al did not indicate how they distinguished between acceptable or unacceptable outcomes[9]. So in the present study, the decision was made according to that of the Bergland determination: Types A and C were acceptable results, while the others (Types B, D, E and F) were unacceptable.

In the present study, the proportional comparisons of the clinical examination and radiographically recorded outcome showed that they were not significantly different, p-value ranging from 0.317 to 1.000. The comparison using Kappa values

also showed acceptable agreement, ranging from 0.68-0.77.

Problems encountered in the clinical examination

Probing Depth

In a few cases, the large amount of mucosal flap thickness covering the bone-grafted alveolus made it difficult to measure the probing depth. Moreover, the thick flap was flabby and non-keratinized so that the consistency of repeated probing was difficult.

Residual defects at alveolar bone graft site

Even though there were the guideline pictures for evaluate this second criterion, it was found that, in the case of some defects, it was difficult to determine which score was appropriate. This was due to the lack of adequate clarified description of each score.

In some cases, scar contraction and frenum attached to the site made measurement difficult.

Conclusion

A way to interpret the result of alveolar bone graft by a clinical evaluation method without the use of radiographs is presented in the present study. This new clinical evaluation method is easy to use and produced good agreement with the commonly used Bergland and Chelsea radiographic methods for the assessment of the quality of alveolar cleft bone grafting. Thus, it provides an acceptable method without the need of radiographic confirmation of bone graft quality, at least for cases that will be followed with orthodontic space closure at the graft site. A desirable benefit of this clinical assessment method is that it would remove the health risks associated with repeated radiation exposure and reduce financial burdens of the patient's family. On the basis of this study, there should only be a need for radiographic assessment in cases where there is disagreement between the clinical judgments of the examining orthodontist and surgeon.

A further study would be useful to compare the agreement between this new clinical examination method and CT which has more recently been claimed to be a gold standard for alveolar bone graft evaluation. The results of such comparison could determine how useful this clinical evaluation method will be in the future.

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Potential conflicts of interest

None.

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การเปรียบเทียบวิธีการตรวจทางคลินิกกับวิธีการตรวจทางภาพถ่ายรังสีสองวิธีเพื่อประเมินผลการปลูกกระดูกเบ้าฟันในผู้ป่วยปากแหว่งเพดานโหว่

ทัศนีย์ วังศรีมงคล, มนเทียร มโนสุดประสิทธิ์, ศศิบุษบา เพิ่มสินทวี

การศึกษานี้มีวัตถุประสงค์ในการเปรียบเทียบความแตกต่างระหว่าง วิธีการตรวจทางคลินิกที่ได้รับการพัฒนาขึ้นมาใหม่ กับวิธีการตรวจทางภาพถ่ายรังสี (วิธีเบิร์กแลนสเกลและเซลซีสเกล) ในการประเมินผลการปลูกกระดูกเบ้าฟันในผู้ป่วยปากแหว่งเพดานโหว่ วิธีการตรวจทางคลินิกประกอบด้วย 1) การวัดร่องลึกปริทันต์ และ 2) ลักษณะของร่องโหว่ที่ยังหลงเหลืออยู่ โดยใช้ผู้ตรวจ 2 ราย ได้ผลว่าเกณฑ์การประเมินทางคลินิกทั้ง 2 เกณฑ์และวิธีการตรวจทางภาพถ่ายรังสีทั้ง 2 วิธีมีค่าความเที่ยงในระดับสูง (แคปปา 0.85-1.00) ส่วนการทดสอบความแตกต่างระหว่างวิธีการตรวจทางคลินิกที่ได้รับการพัฒนาขึ้นมาใหม่ และวิธีการตรวจทางภาพถ่ายรังสีนั้นพบว่าไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ (พี-แวลู 0.317-1.00) และมีค่าความเที่ยงระหว่างสองวิธีอยู่ในระดับดี (แคปปา 0.68-0.77) แนะนำให้ใช้วิธีการตรวจทางคลินิก ที่นำเสนอในการศึกษานี้เป็นวิธีประเมินการปลูกกระดูกเบ้าฟันในเบื้องต้นได้