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RESEARCH ARTICLE

# A six-site method for the evaluation of periodontal bone loss in cone-beam CT images

[1]Yu-Jiao Guo, [1]Zhi-pu Ge, [1]Ruo-han Ma, [2]Jian-xia Hou and [1]Gang Li

[1]*Department of Oral and Maxillofacial Radiology, Peking University, School and Hospital of Stomatology, Beijing, China;* [2]*Department of Periodontology, Outpatient Center, Peking University, School and Hospital of Stomatology, Beijing, China*

**Objectives:** In contrast to two-dimensional planar images, a measuring point is hardly repeatedly determined in a CBCT image when alveolar bone loss is assessed. Thus, the aim of the present study was to propose a six-site measuring method, which is closely related to anatomical structure, for the evaluation of alveolar bone loss in CBCT images.
**Methods:** 150 measuring points in 11 molars and 14 premolars from 6 patients (2 males and 4 females) were included. CBCT images of the teeth were acquired prior to periodontal surgery. Four observers measured the distances between cemento–enamel junctions and the apical bases of the periodontal bone defect at the mesio–buccal, mid-buccal, disto–buccal, mesio–lingual/palatal, mid-lingual/palatal and disto–lingual/palatal sites in CBCT images. Direct measurements of the six sites were correspondingly obtained in the subsequent periodontal surgeries. Differences between the distances measured in the CBCT images and during the surgery were analysed. Interobserver and intraobserver variances were tested.
**Results:** No statistically significant difference was found between the surgical and CBCT measurements ($p = 0.84$). Diagnostic coincidence rates of four observers were 86.7%, 87.3%, 88.7% and 88.0%, respectively. The interobserver ($p = 0.95$) and intraobserver ($p = 0.30$) variances were not significant.
**Conclusions:** The six-site measuring method validated in the present study may be a useful three-dimensional measuring method for the evaluation of periodontal disease.
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**Keywords:** periodontitis; alveolar bone level; three-dimensional imaging; CBCT

## Introduction

Radiographic evaluation of periodontal bone loss is important for the diagnosis, treatment planning and prognosis evaluation of periodontitis.[1] Commonly used radiographic examinations employ bitewing, periapical and panoramic radiographs.[1,2] However, the methods suffer from the inherent drawbacks of plain radiographs, such as magnification, distortion and superimposition of adjacent anatomical structures.[2–4] These drawbacks often limit the usefulness of these radiographs.[1]

CBCT is a recently developed imaging technique that can provide three-dimensional (3D) images similar to spiral CT images but gives a relatively low radiation dose to patients and a relatively high-quality image of the hard tissue.[2,5] Since CBCT overcomes the inherent drawbacks from plain radiograph, it has been widely used in dentistry including periodontics.[5,6] Because alveolar bone loss is an important index for the progress of periodontitis, many studies have focused on CBCT assessments of alveolar bone heights and bony defects and concluded that CBCT images are acceptable for the measurement of alveolar bone changes.[7–10] These studies only identified the usefulness of CBCT images in staging periodontitis but did not further investigate

Correspondence to: Dr Gang Li. E-mail: kqgang@bjmu.edu.cn

Dr Gang Li and Dr Jian-xia Hou contributed equally to the article.

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whether these measurements could be repeatedly carried out in follow-up CBCT images since the same measuring point has rarely been determined in different 3D images.[11,12] Furthermore, there are no specific guidelines about how to analyse this type of 3D images.[11]

To get a relatively accurate measurement of alveolar bone changes from a series of CBCT images, a six-site measuring method has been proposed in the present study. This method was established on the basis of clinical probing locations that are commonly used in the assessment of the alveolar bone level.[13,14] Thus, the aim of the present study was to investigate the accuracy and repeatability of the method for alveolar bone level evaluation in CBCT images.

## Methods and materials

*Subjects*

Patients who visited the Department of Periodontology at Peking University School and Hospital of Stomatology from May 2009 to October 2010 and had a diagnosis of chronic periodontitis or aggressive periodontitis were included in the study. Patients who had severe systematic disease or patients who smoked more than 10 cigarettes per day and had stopped smoking for less than 2 years were excluded. Basic therapy included oral hygiene instruction, plus scaling and root planning with ultrasonic devices and hand instruments. Periodontal probing depth and attachment loss were recorded during clinical measurements. Periodontal surgery was considered for sites with periodontal probing depth $\geq$5 mm. CBCT scanning was performed for affected teeth before surgery.

The study protocol was approved by the Ethics Committee of Peking University Health Science Center, Beijing, China.

*Acquisition and measurements of CBCT images*

Prior to surgery, CBCT scanning was performed on the affected teeth using a 3D Accuitomo system (J. Morita MFG Corp., Kyoto, Japan) with a field of view of 4 $\times$ 4 cm, tube voltage of 75–85 kVp and tube current of 5 mA. The voxel size used was $0.125 \times 0.125 \times 0.125$ mm. CBCT images were reconstructed with 1.0-mm thickness and 1.0-mm intervals.

Distance between the cemento–enamel junction (CEJ) and the apical base of the periodontal bone defect (ABD) was measured using a six-site measuring method. The selected six sites were the mesio–buccal (MB) site, mid-buccal (B) site, disto–buccal (DB) site, mesio–lingual/palatal (ML) site, mid-lingual/palatal (L) and disto–lingual/palatal (DL) site. In the CBCT images, B and L points were chosen at the mid-buccal/lingual site in the surface. Points in proximal surfaces, *i.e.* the points of MB, DB, ML and DL, were located at the four sites close to the touch points between adjacent teeth. The schematic diagram of the six points is shown in Figure 1. Measurements of distances between CEJ and ABD were made at the six sites. The six sites were determined by observers according to the definition aforementioned with the help of a cursor on a 17-inch flat-panel monitor (L1750; Hewlett–Packard®, Palo Alto, CA). The four observers used i-Dixel-3DX software (J. Morita MFG Corp.) to view the images. Among the four observers, three observers were post-graduate students majoring in dental and maxillofacial radiology; one was a post-graduate student majoring in periodontology. Observers were trained and measuring procedure calibrated before performing the radiographic measurements.

Detailed information about the measuring procedure is shown in Figure 2. First, the image of the test tooth was opened in the i-Dixel 3DX volume viewer (Figure 2a), and then the images were rotated to make the occlusal plane parallel to the red cursor (horizontal plane) and to make the median sagittal plane perpendicular to the horizontal plane (parallel to the blue cursor) (Figure 2b). Second, the aforementioned six sites were located based on the diagram of the six points shown in Figure 1. To make sure that all the points could be viewed three-dimensionally, *i.e.* in the axial, coronal and sagittal planes, the implant button (a cylindrical object with diameter of 0.5 mm and height of 0.5 mm) was used to fix the insertion point in the multiple planes (Figure 2c). Measurements of distances between CEJ and ABD were completed in accordance with the six sites. Take the MB site for example, CEJ was defined as the point where the image of the enamel disappeared. ABD characterizes the base of periodontal bone loss in the selected plane. The following is a summary of the measuring procedure: (1) define the contour point in the displayed mesial surface as point a and the ABD point as point b; (2) connect points a and b by a straight line; (3) draw a horizontal line through the CEJ so that the two straight lines intersect each other. The intersection of the two lines was defined as point c (Figure 2d); (4) measure the distance between points c and b, which is recorded as the distance between the CEJ and ABD (Figure 2e). The observers did not know any information about the teeth before surgery. All images were reviewed by one observer 1 month later for the evaluation of intraobserver agreement. Measurements were made to the nearest 0.01 mm with a linear

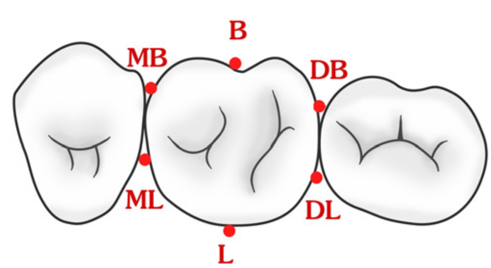


**Figure 1** The diagram of the six measurements points for one molar tooth. B, mid-buccal; DB, disto–buccal; DL, disto–lingual/palatal; L, mid-lingual/palatal; MB, mesio–buccal; ML, mesio–lingual/palatal.

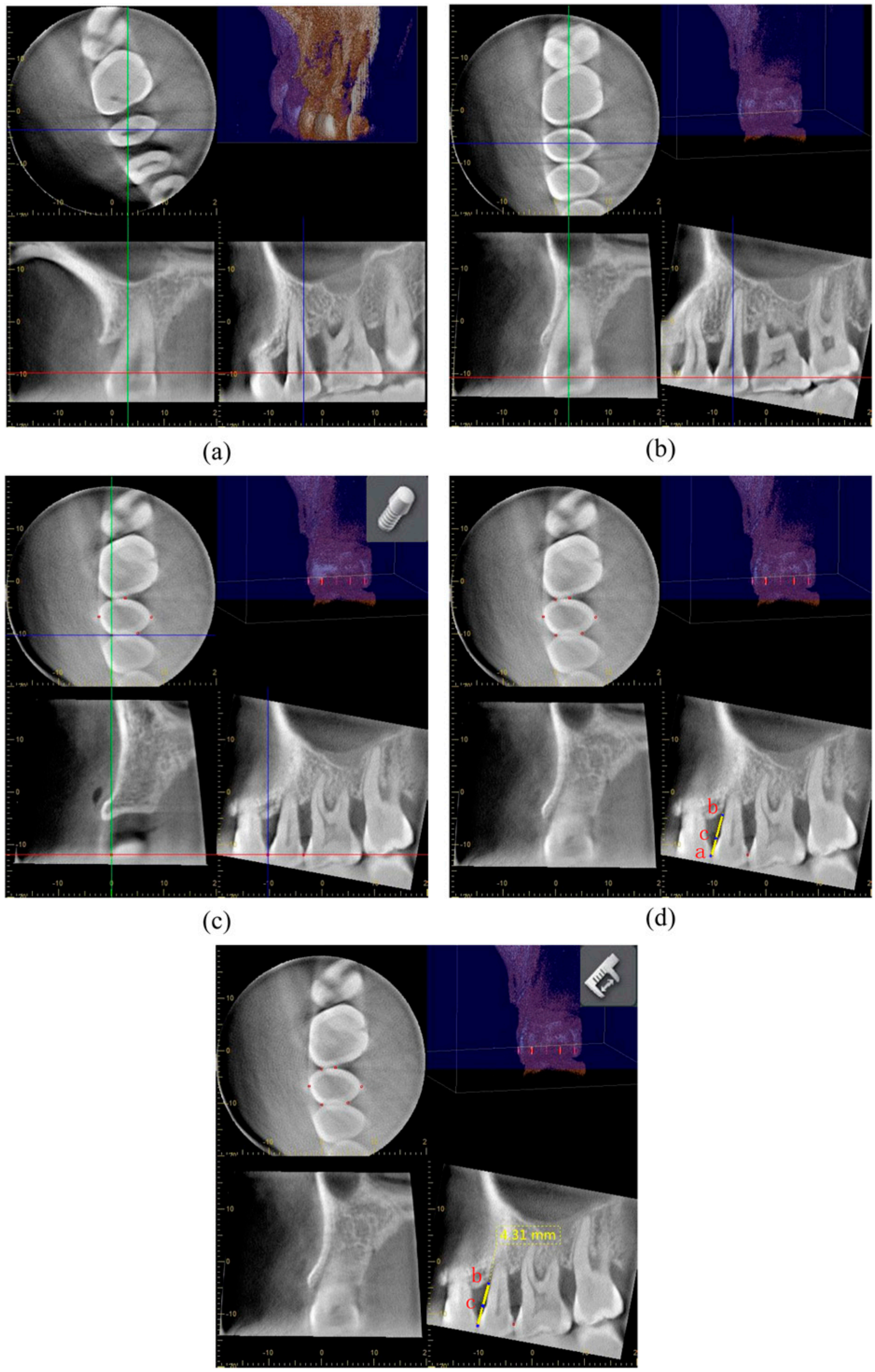


**Figure 2** (a–e) The measuring procedure of CBCT images. (a) The CBCT images of the test tooth was opened in the i-Dixel 3DX volume viewer (J. Morita MFG Corp., Kyoto, Japan). (b) The images were rotated to make the occlusal plane parallel to the red cursor (horizontal plane) and the median sagittal plane perpendicular to the horizontal plane (parallel to the blue cursor). (c) The aforementioned six sites which can be viewed three-dimensionally were located in the images, and the implant button was used. (d) Defining the contour point in the displayed mesial surface as point a, the apical base of the periodontal bone defect point as point b; connect points a and b by a straight line. Drawing a horizontal line through the cemento–enamel junction, the two straight lines intersect each other, define the intersection as point c. (e) Measuring the distance between points c and b, which is recorded as the distance from CEJ to ABD. For colour image see online.


**Figure 3** Representative images of intrasurgical measurements of the first maxillary molar in the left side. (a) measurements of mesiobuccal (MB) site; (b) measurements of mid-buccal (B) site; and (c) measurements of disto-buccal (DB) site.

measurement tool in a quiet and dark room. Test or adjacent teeth with crowns were not included because of beam-hardening artefacts.

*Intrasurgical measurements*

The patients were injected with a local anaesthesia, flaps were reflected, defects were debrided thoroughly and direct surgical measurements were made. Distances between the CEJ and ABP were measured at the six sites (Figure 3). A manual periodontal probe (UNC-15; HU-Friedy, Chicago, IL) graded in millimetres was used. Measurements were made to the nearest 1 mm. All measurements were completed by an experienced periodontist (JXH) using the probe in a line parallel to the long axis of the tooth. The intrasurgical measurements were regarded as "reference standard".

*Data analysis*

To evaluate the accuracy of site-based image assessment with clinical measurement, diagnostic coincidence rates were calculated *via* an introduced variable *D*-value.

*D*-value = intrasurgical measurement—measurement in CBCT images.

If the *D*-value ranged from −1 to 1 mm (−1 and 1 mm included), measurement in CBCT image was thought to be consistent with surgical measurement. If not, they were not consistent. Diagnostic coincidence rates were calculated.

Statistical analysis was performed with the IBM SPSS® Statistics 20 (IBM Corporation, Armonk, NY; formerly SPSS Inc., Chicago, IL). One-way analysis of variance was applied to find out whether the measurement of CBCT images differed significantly

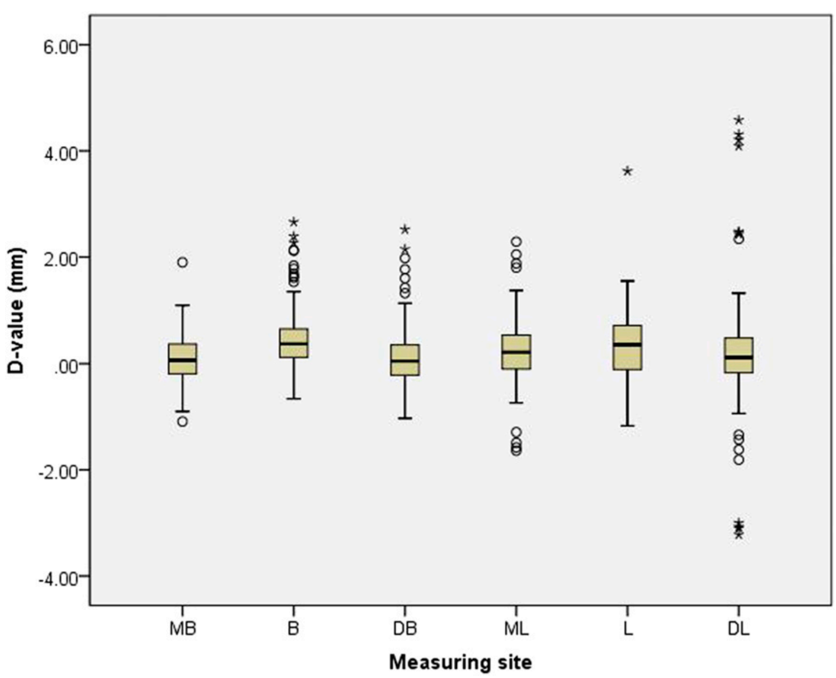


**Figure 4** The box plot of *D*-values of six measuring sites. There was no statistical significance among the measurements of all the six sites ($p > 0.5$). Symbols indicate outliers, which show the discrete degree of data. B, mid-buccal; DB, disto-buccal; DL, disto-lingual/palatal; L, mid-lingual/palatal; MB, mesio–buccal; ML, mesio–lingual/palatal.

**Table 1** The mean *D*-values and standard deviations (SDs) of the molars

| | *Molar* ($M_D \pm SD$) | | | | | |
|---|---|---|---|---|---|---|
| *Observer* | *MB* | *B* | *DB* | *ML* | *L* | *DL* |
| 1 | 0.13 ± 0.62 | 0.58 ± 0.74 | 0.29 ± 0.83 | 0.31 ± 0.88 | 0.29 ± 0.46 | −0.02 ± 1.10 |
| 2 | 0.00 ± 0.52 | 0.68 ± 0.86 | 0.17 ± 0.75 | 0.17 ± 0.73 | 0.37 ± 0.50 | −0.07 ± 1.15 |
| 3 | 0.21 ± 0.74 | 0.59 ± 0.93 | 0.13 ± 0.74 | 0.36 ± 0.78 | 0.34 ± 0.45 | −0.04 ± 1.11 |
| 4 | 0.10 ± 0.60 | 0.54 ± 0.73 | 0.54 ± 0.77 | 0.39 ± 0.69 | 0.32 ± 0.35 | −0.10 ± 1.08 |

B, mid-buccal; DB, disto-buccal; DL, disto-lingual/palatal; L, mid-lingual/palatal; $M_D$, the mean of *D*-value; MB, mesio–buccal; ML, mesio–lingual/palatal.

from the intrasurgical measurement. The *D*-values of all the observers were also tested *via* one-way analysis of variance. To test the linear correlation between the tooth category, site, observer and *D*-values, multiple linear regression analysis was applied. *D*-value was employed as the dependent variable, and tooth category (molar or premolar), site, observer were employed as independent variables. Paired-samples *t*-test was employed to test the intraobserver variances. A statistical significance was considered when $p < 0.05$.

## Results

A total of 150 measuring sites in 11 molars and 14 premolars from 6 patients (2 males and 4 females) were examined. Diagnostic coincidence rates of four observers were 86.7%, 87.3%, 88.7% and 88.0%, respectively. There was no significant difference between the measurement of CBCT images and intrasurgical measurement ($p = 0.84$), as well as no significant differences among *D*-values of all the observers ($p = 0.95$). The data distribution of the six measuring sites is shown in Figure 4. Tables 1 and 2 demonstrate the mean *D*-values and standard deviation of premolars and molars from the four observers (Table 2). Multiple linear regression analysis showed that independent variables such as tooth category, site and observer had no linear influence on *D*-values. The intraobserver variance was not significant ($p = 0.30$).

## Discussions

The results from the present study suggest that the six measuring sites provide useful alveolar bone information for premolars and molars. In the search of literature, we found that most of the studies focusing on the measurement accuracy of periodontal bone loss/defect were *in vitro* studies.[7–9,15–20] Only one *in vivo* study was performed on the measurement accuracy of bone defects on the maxillary molar.[21] Although there are a few more *in vivo* studies with regard to periodontal bone height measurement using CBCT, two of which are case reports,[22,23] others compared different methods of measuring guided tissue regeneration-treated bone defects and furcation lesions.[24–27] Thus, the present study is the first *in vivo* study for the evaluation of alveolar bone levels in premolar.[21,24,25]

CBCT can provide a 3D view of periodontal bone situation, and therefore CBCT may be a useful and practical tool for the clinical evaluation of periodontal bone changes over time.[26,28,29] However, compared with the plain two-dimensional periapical or bitewing radiographs, the big challenge for CBCT images to evaluate alveolar bone levels is how to find the same measuring site after a period of time.[1] Furthermore, the selected measuring sites should fulfil the following criteria. First, they should be feasible for clinical use, in other words, the sites are easily accessed; second, it is precise enough for a measurement; third, no interobserver or intraobserver variability is present for a measurement.[30,31] The six-site method proposed by the present study seems to be a proper choice according to the required criteria. In fact, the six sites were established on the basis of probing location clinically used for the assessment of alveolar bone level.[13,14] This makes the method practical and easy to use.

Diagnostic coincidence rate was introduced to study the accuracy of the six-site measuring method in evaluating periodontal bone levels. Since there is no gold standard or a gauge for the clinical assessment of periodontal disease,[14,31] precision to ±1 mm of a manual periodontal probe was acceptable in clinical experience.[26,32–34] Thus, when the radiographic measurements of the studied

**Table 2** The mean *D*-values and standard deviations (SDs) of premolars

| | *Premolar* ($M_D \pm SD$) | | | | | |
|---|---|---|---|---|---|---|
| *Observer* | *MB* | *B* | *DB* | *ML* | *L* | *DL* |
| 1 | 0.07 ± 0.40 | 0.48 ± 0.52 | 0.18 ± 0.53 | 0.16 ± 0.55 | 0.19 ± 0.66 | 0.52 ± 1.46 |
| 2 | 0.07 ± 0.40 | 0.42 ± 0.47 | 0.06 ± 0.67 | 0.15 ± 0.61 | 0.23 ± 0.77 | 0.42 ± 1.40 |
| 3 | 0.09 ± 0.34 | 0.41 ± 0.61 | 0.01 ± 0.55 | 0.11 ± 0.62 | 0.12 ± 0.70 | 0.31 ± 1.40 |
| 4 | 0.03 ± 0.31 | 0.34 ± 0.48 | 0.06 ± 0.64 | 0.22 ± 0.57 | 0.42 ± 1.15 | 0.38 ± 1.45 |

B, mid-buccal; DB, disto-buccal; DL, disto-lingual/palatal; L, mid-lingual/palatal; $M_D$, the mean of *D*-value; MB, mesio–buccal; ML, mesio–lingual/palatal.

alveolar bone levels were in the range of the clinical measurements ±1 mm, the radiographic measurement was considered accurate.[9] The diagnostic coincidence rates from the present study were >85% for all the measuring sites by the four observers. This implies that the six-site method provides a favourable diagnostic efficiency. Interobserver and intraobserver variability was also not found by the use of the six-site method. Since the four observers were post-graduates at different grades, the results also imply that calibration and observers' training on how to make a measurement in CBCT images before one study is more important than the observers' clinical experience. This was in accordance with the previous studies.[10,35]

To make the clinical measuring sites closely relate to the measuring sites identified in CBCT images to the maximum extent, some studies had pre-defined the measuring sites. In their *vitro* studies, gutta-percha, metal spheres or engineered notch were often used for the determination of measuring sites clinically and in CBCT images.[7,9,15] This reduces the measuring differences obtained from the different measuring method, but it is not practical in clinics. In the *in vivo* study by Feijo et al,[21] a 12-point method was suggested for the measurement of the horizontal alveolar bone defect. However, only one observer assessed the bone levels and no data on interobserver and intraobserver variability were provided in the study. Repitition test of the method was not validated.

Although the measurement accuracy of the alveolar bone levels in the studied CBCT images has been identified, Figure 4 shows a relatively large standard deviation in the measurements of DL site when compared with other sites. One possible reason may be the loss of the distal tooth, which makes it harder to identify the exact DL site in the CBCT images. The other reason may be due to the fact that the lingual side is not in a direct vision for locating a measuring site. Limited sample size may also lead to large variations among patients. Other studies also suggest that it is difficult to duplicate precisely the site and angulation of measurement from one visit to another.[7,9]

Statistical analysis indicates that no significant difference exists between the tomographic and surgical measurements of alveolar bone levels and that the overall measurement is a little bit underestimated except for the points in the distal of premolars. This is in line with the previous studies in which the measurement accuracy of alveolar bone levels in intraoral radiograph and CBCT images was compared with and confirmed by a direct surgical measurement.[9,24,26] This may imply that the severity of alveolar bone loss is heavier in a real patient than a measurement in CBCT images.

In conclusion, the six-site measuring method proposed in the present study may be a useful 3D measuring method for the evaluation of periodontal disease.

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