Original Article

Accuracy of Cone Beam Computed Tomography for Detection of Bone Loss

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Abstract

Objectives: Bone assessment is essential for diagnosis, treatment planning and prediction of prognosis of periodontal diseases. However, two-dimensional radiographic techniques have multiple limitations, mainly addressed by the introduction of three-dimensional imaging techniques such as cone beam computed tomography (CBCT). This study aimed to assess the accuracy of CBCT for detection of marginal bone loss in patients receiving dental implants.

Materials and Methods: A study of diagnostic test accuracy was designed and 38 teeth from candidates for dental implant treatment were selected. On CBCT scans, the amount of bone resorption in the buccal, lingual/palatal, mesial and distal surfaces was determined by measuring the distance from the cementoenamel junction to the alveolar crest (normal group: 0-1.5mm, mild bone loss: 1.6-3mm, moderate bone loss: 3.1-4.5mm and severe bone loss: >4.5mm). During the surgical phase, bone loss was measured at the same sites using a periodontal probe. The values were then compared by McNemar's test.

Results: In the buccal, lingual/palatal, mesial and distal surfaces, no significant difference was observed between the values obtained using CBCT and the surgical method. The correlation between CBCT and surgical method was mainly based on the estimation of the degree of bone resorption. CBCT was capable of showing various levels of resorption in all surfaces with high sensitivity, specificity, positive predictive value and negative predictive value compared to the surgical method.

Conclusion: CBCT enables accurate measurement of bone loss comparable to surgical exploration and can be used for diagnosis of bone defects in periodontal diseases in clinical settings.

Keywords: Bone Resorption; Cone Beam Computed Tomography; Periodontal Diseases

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INTRODUCTION

Periodontal disease is the most common oral disease in which the alveolar bone height decreases and morphological changes occur. In this condition, periodontal structures are destroyed due to the activity of inflammatory mediators.

As the disease advances, the gums and the alveolar crest recede, resulting in mobility and eventual tooth loss [1].

Periodontal disease is caused by an imbalance between bone formation and resorption, leading to an ultimate reduction in bone height.

Accurate assessment of the osseous structures affected by periodontal diseases could be valuable for diagnosis, treatment planning and prediction of the ultimate prognosis of treatment [2].

To achieve successful results, early diagnosis and effective treatment of the bony defects are of great importance. Numerous diagnostic approaches have been proposed for periodontal defects including surgical exploration of the area and the use of radiographic techniques, all of which have their own limitations [1,3,4].

Radiographic observations reflect the changes occurred in relation to periodontal disease and determine the pattern of bone resorption [5-9]. In the case of bone destruction, radiographs are valuable diagnostic tools as an adjunct to the clinical examination. Two-dimensional (2D) periapical and panoramic radiographs are routinely used for assessing periodontal bone levels. In 2D imaging, evaluation of bone craters, lamina dura and periodontal bone level is limited by projection geometry and superimpositions of adjacent anatomical structures. These limitations of 2D radiographs can be eliminated by three-dimensional (3D) imaging techniques such as computed tomography. Cone beam computed tomography generates 3D volumetric images and is commonly used in dentistry. All CBCT units provide axial, coronal and sagittal multi-planar reconstructed images without magnification. Also, panoramic images without distortion and magnification can be generated with curved planar reformation; CBCT displays 3D images that are necessary for the diagnosis of intra-bony defects, furcation involvements and buccal/lingual bone loss [5]. Studies comparing the use of 3D volumetric images and 2D images in detection of artificial bone defects have shown that CBCT has a sensitivity of 80–100% in the detection and classification of bone defects; while intraoral radiographs provide a sensitivity of 63–67%. When compared with periapical and panoramic images, CBCT has also shown an absence of distortion and overlapping and the dimensions it presents are compatible with the actual size [4]. Topography and clinical observation of the area under treatment via a surgical procedure are the most precise methods for diagnosing periodontal disease. Presently, radiography is used as a supplementary diagnostic tool for periodontal defects [6,10].

Surgical exploration on the other hand renders more accurate results for the diagnosis of various bone defects in periodontal diseases [11]. However, due to the invasive nature of this technique and possible post-surgical complications, the clinicians and the patients try to avoid this method. Therefore, radiographic observation along with clinical examination plays an important role in accurate diagnosis and appropriate treatment planning. Conventional 2D radiography has long been used as a common diagnostic tool. One of the major problems with diagnosing bone resorption is that the conventional radiographs only provide limited diagnostic information [1].

The amount of information gained from the analogue and digital radiographs is incomplete due to the fact that the 3D anatomy of the area being radiographed is compressed into a 2D image [4]. Interpretation of images acquired by CBCT for evaluation of alveolar bone loss and periodontal bone defects may lead to a new approach in the evaluation of patients with periodontal disease and prove to be an excellent resource when deciding on the most appropriate therapy [4].

Evidence shows that compared to conventional radiography or 2D digital techniques, CBCT enables the clinician to visualize structures in thin sections without superimposition of anatomical structures and also enables more accurate evaluation of bony changes due to periodontal diseases [12,13]. However, there are limited clinical studies in this regard.

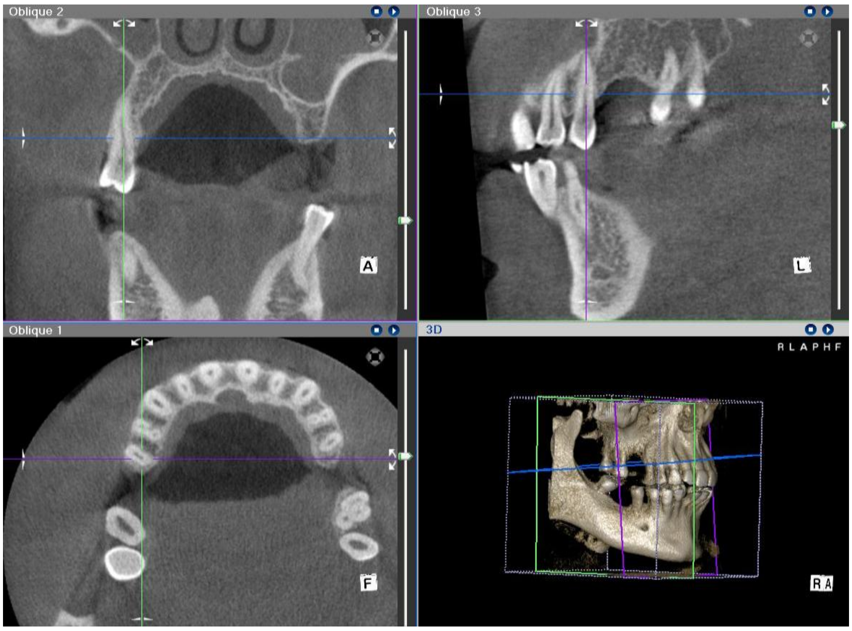

Fig. 1. Sections (2×2mm) of CBCT (3D images denoted by axial, coronal and sagittal sections)

The purpose of the present study was to evaluate the accuracy of CBCT in determining the amount of bone resorption compared to surgical method.

MATERIALS AND METHODS

This study was approved by the Ethics Committee (Code: 901128002) of School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran.

Thirty patients presenting to a private clinic in Tehran for implant treatment planning consented to participate in this study of diagnostic accuracy. According to a pilot study to identify sample size, 38 teeth with periodontal defects were selected and assessed.

Six out of 38 teeth were scheduled for immediate implant placement. Based on the surgeon's treatment plan, eight adjacent teeth with periodontal involvement were extracted before implant placement, and in 24 cases mucoperiosteal flap was extended around the abutment tooth and then the periodontal status of the abutment tooth was evaluated.

The patients who had metallic restorations on the first and second premolars and molars were excluded from the study because of CBCT imaging artifacts compromising the evaluation of the cementoenamel junction (CEJ) area. Finally, 38 teeth were selected for inclusion in the study. The CBCT scans were taken using Alphard VEGA CBCT machine (radiation time: 17s, voxel size: 0.3 × 0.3 × 0.3mm, 4.3 mA, and 80 kVp) and were evaluated for the amount of bone resorption in the buccal, lingual/palatal, mesial and distal surfaces by measuring the distance from the CEJ to the alveolar crest in millimeters (Figs. 1-5). The level of resorption was classified as normal: 0-1.5 mm, mild bone loss: 1.6-3 mm, moderate bone loss: 3.1-4.5 mm and severe bone loss: more than 4.5 mm. The measurement in coronal view was used for evaluation of the amount of bone resorption in buccal and lingual/palatal surfaces and in sagittal view for evaluation of bone loss in mesial and distal surfaces. These measurements were repeated by the surgeon using a periodontal probe during the surgery (Fig. 6).

Fig. 2. Bone levels in the buccal and lingual surfaces of a mandibular second molar (coronal view)

Statistical analysis:

Data analysis was performed using SPSS version 18.0 (Microsoft, IL, USA). The results of CBCT method were compared with the gold standard (surgery) and classified as correct or incorrect. McNemar's test was used to compare the correct and incorrect results obtained by CBCT method. In order to estimate the diagnostic parameters of CBCT according to the criteria defined by the gold standard, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy were calculated. The confidence coefficient of 95% was calculated by Wilson score interval.

RESULTS

A total of 30 patients (17 females and 13 males) and 38 teeth (five maxillary premolars, seven mandibular premolars, four maxillary first molars, eight mandibular first molars, six maxillary second molars and six mandibular second molars) were evaluated. Based on the results, there was no statistically significant difference in accuracy between the CBCT and surgical methods in all surfaces.

Tables 1-4 summarize the measurements made via the surgical technique in comparison with CBCT in all four surfaces (buccal, lingual/ palatal, mesial and distal).

Table 1. The frequency of different levels of bone resorption determined by surgery and CBCT in the buccal surface

		Classification by Surgery				
		Normal N (%)	Mild N (%)	Moderate N (%)	Severe N (%)	Total N (%)
Classification by CBCT	Normal	0	0	0	0	0
	Mild	0	11 (28.9)	0	0	11 (28.9)
	Moderate	0	0	9 (23.7)	0	9 (23.7)
	Severe	0	0	2 (5.3)	16 (42.1)	18 (47.4)
	Total	0	11 (28.9)	11 (28.9)	16 (42.1)	38 (100)

Fig. 3. Bone levels in the mesial and distal surfaces of a mandibular second molar (sagittal view)

Diagnostic parameters (sensitivity, specificity, PPV and NPV) and accuracy of methods used in this study (CBCT versus surgical method in the buccal, lingual/palatal, mesial and distal surfaces) are illustrated in Table 5.

DISCUSSION

While numerous studies have been conducted to detect the accuracy of various radiographic techniques for quantification of alveolar bone resorption, accurate diagnosis of bone resorption in periodontal diseases remains a dilemma.

Therefore, the present study aimed to compare the accuracy of CBCT and surgical techniques in the assessment of bone resorption. Some studies have compared the accuracy of 2D and 3D radiographic techniques for the diagnosis of periodontal diseases in the human skulls, using different indices.

However, few clinical trials have been performed [8,12-14]. According to the literature, the normal bone height from the CEJ ranges between 1mm and 3mm [12,15-18]. In the absence of periodontal disease, a mean height of 2 mm is expected [17].

Table 2. The frequency of different levels of bone resorption determined by surgery and CBCT in the palatal surface

		Classification by Surgery				
		Normal N (%)	**Mild N (%)**	**Moderate N (%)**	**Severe N (%)**	**Total N (%)**
Classification by CBCT	**Normal**	1 (2.6)	0	0	0	1 (2.6)
	Mild	0	10 (26.3)	0	0	10 (26.3)
	Moderate	0	2 (5.3)	13 (34.2)	1 (2.6)	16 (42.1)
	Severe	0	0	0	11 (28.9)	11 (28.9)
	Total	1 (2.6)	12 (31.6)	13 (34.2)	12 (31.6)	38 (100)

Fig. 4. Bone levels in the buccal and palatal surfaces of a maxillary second premolar (coronal view)

The same value was adopted by Grimard et al, in 2009 to compare the results of intraoral radiographs with CBCT in the assessment of bone formation after regenerative periodontal therapy [16]. In young adults, the mean alveolar bone height relative to the CEJ is 1.4 ± 0.7mm and in people over 45 years this average is reported to be 3 ± 1.5mm [4]. In a study conducted by de Faria Vasconcelos et al, in 2012, measurements greater than 3 mm between the CEJ and the alveolar crest were considered as alveolar bone resorption [4]. In a study performed by Mol and Balasundaram evaluating the accuracy of CBCT for detecting and quantifying periodontal bone defects, bone loss equal or greater than 3 mm was defined as vertical bone defect [12].

The same value was adopted by Grimard et al, in 2009 to compare the results of intraoral radiographs with CBCT in the assessment of bone formation after regenerative periodontal therapy [16].

In the current study, based on the distance between the CEJ and the alveolar bone, four categories were identified namely the normal group: 0-1.5mm, mild bone resorption: 1.6-3mm, moderate bone resorption: 3.1-4.5mm and severe bone resorption: more than 4.5 mm. This classification provided an efficient method of comparison in the current study.

Table 3. The frequency of different levels of bone resorption determined by surgery and CBCT in the mesial surface

		Classification by Surgery				
		Normal N (%)	**Mild N (%)**	**Moderate N (%)**	**Severe N (%)**	**Total N (%)**
Classification by CBCT	**Normal**	1 (2.6)	0	0	0	1 (2.6)
	Mild	0	24 (63.2)	0	0	24 (63.2)
	Moderate	0	2 (5/3)	6 (15.8)	0	8 (21.1)
	Severe	0	0	0	5 (13.2)	5 (13.2)
	Total	1 (2.6)	26 (48.4)	6 (15.8)	5 (13.2)	38 (100)

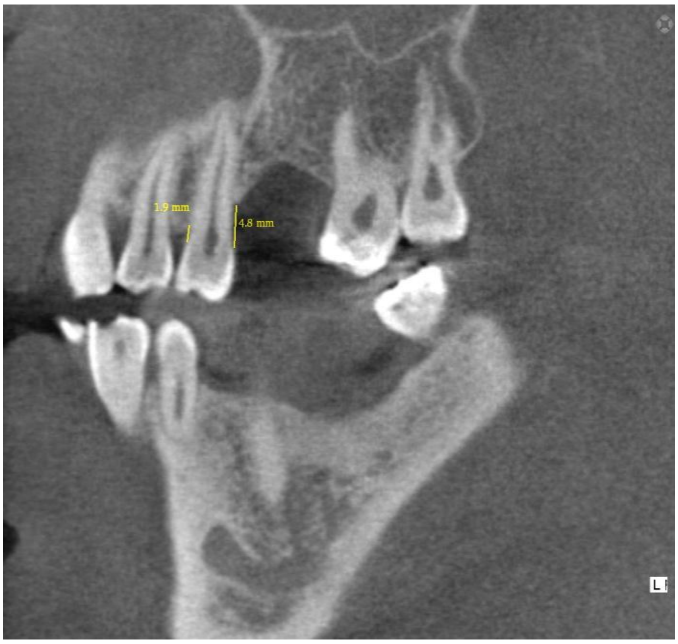

Fig. 5. Bone levels in the mesial and distal surfaces of a maxillary second premolar (sagittal view)

It was impossible to use a quantitative approach because of the limitation of the periodontal probe measurement tool used in the surgical method, which measures values as small as 0.5mm while CBCT is capable of measuring values as small as 0.01mm.

In order to balance the scale in the two methods, we used qualitative analyses. The radiation dose of the patient is significantly less in CBCT compared to multi-slice CT, making CBCT the imaging modality of choice when 3D imaging is indicated [17-20].

Moreover, the diagnostic accuracy of CBCT imaging has been documented in depicting dental [21] and periodontal [12,14] structures.

The effective radiation dose of CBCT technique varies according to the type of CBCT machine and the exposure parameters (field of view, exposure time, kilovoltage and milliampere). Compared to conventional radiography, CBCT radiation dose is equivalent to a full-mouth series and is 3-7 times higher than the dose of panoramic radiography [16].

The CBCT technique has shown greater potential in providing information compared to conventional radiography. The choices of technical parameters for imaging are important to achieve the best resolution of scan with minimum radiation dose.

Table 4. The frequency of different levels of bone resorption determined by surgery and CBCT in the distal surface

Classification by CBCT		Classification by Surgery				
		Normal N (%)	**Mild N (%)**	**Moderate N (%)**	**Severe N (%)**	**Total N (%)**
	Normal	0	0	0	0	0
	Mild	0	15 (39.5)	0	0	15 (39.5)
	Moderate	0	3 (7.9)	14 (36.8)	0	17 (44.7)
	Severe	0	0	0	6 (15.8)	6 (15.8)
	Total	0	18 (47.4)	14 (36.8)	6 (15.8)	38 (100)

Fig. 6. Measurement of bone resorption during surgery using a periodontal probe

In order to view periodontal structures such as the periodontal ligament space, cortical bone, alveolar crest and alveolar cortical plate, higher image quality and smaller voxel size are required in CBCT technique [22,23]. Additionally, factors such as slice thickness and voxel size can affect the quality of the scan and the reading of the measurements. In the current study, voxel size of 0.3mm × 0.3mm × 0.3mm was used to obtain images with Alphard VEGA CBCT unit. Therefore, it is necessary to repeat and compare the recent studies with standard methods such as clinical observations and surgery to make precise comparisons among various radiographic methods. Voxel size of 0.2 mm was used to obtain images in the study conducted by de Faria vasconcelos et al, in 2012 [4] and Grimard et al, in 2009 [16].

Misch et al, in 2006 [14] and Vandenberghe et al, in 2008 [1] used voxel size of 0.4 mm in their study. No significant difference was observed among measurements made with a digital caliper, CBCT and periapical images in artificial bone defects [14].

Another factor that affects the quality of CBCT images is the artifacts caused by metallic restorations. Metallic artifacts can make the scan difficult to interpret. Teeth with metallic restorations were excluded from the study and the observer had no difficulty in making linear measurements. In our study, there was no significant difference in the measurements made on CBCT and via the surgical method in the buccal, palatal/lingual, distal and mesial surfaces of teeth and there was a great agreement between the CBCT technique and the surgical procedure in showing the degree of bone resorption, indicating the optimal accuracy of CBCT for assessment of bone resorption in periodontal disease. Vandenberghe et al, in 2008 reported that the cross-sectional slices had the best potential for measurements (magnification of 0.29) compared to digital periapical radiography (magnification of 0.56) [1]. In a study conducted by de Faria Vasconcelos et al, in 2012, no significant difference was observed in the pattern of bone loss between the intraoral radiography and CBCT. However, CBCT was the only method that allowed for analysis of the buccal, lingual and palatal surfaces and improved visualization of the morphology of defects [4]. These findings were consistent with the results of our study. Likewise, another clinical study found no significant difference between clinical measurements and the CBCT technique in determining periodontal bone defects, and CBCT was shown to have the potential of depicting horizontal periodontal defects [24]. The results of the current study and the findings of the previous studies indicate that CBCT technique has an acceptable accuracy in detecting bone resorption compared to the measurements made via the surgical method. The CBCT yielded high sensitivity, specificity, PPV, NPV and accuracy in the buccal, lingual/palatal, mesial and distal surfaces.

Table 5. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of CBCT compared to surgery in determining alveolar bone loss in the four surfaces of teeth (buccal, lingual/palatal, mesial and distal)

CBCT		Sensitivity (95% CI) N (%)	Specificity (95% CI) N (%)	PPV (95% CI) N (%)	NPV (95% CI) N (%)
Buccal	**Normal**	74.1–100 (100.00)	87.5–100 (100.00)	74.1–100 (100.00)	87.5–100 (100.00)
	Mild	52.3-94.8 (81.82)	87.5–100 (100.00)	70.0–100 (100.00)	78.0–98.0 (93.10)
	Moderate	80.6–100 (100.00)	72.1–97.4 (90.91)	67.2–96.9 (88.89)	83.8–100 (100.00)
	Severe	90.8–100 (100.00)	72.1–97.4 (90.91)	67.2–96.9 (88.89)	90.8–100 (100.00)
Palatal/lingual	**Normal**	55.2–95.3 (83.33)	87.1–100 (100.00)	72.2–100 (100.00)	77.3–98.0 (92.86)
	Mild	77.1–100 (100.00)	75.0–97.7 (92.00)	62.1–96.2 (86.67)	85.69–100 (100.00)
	Moderate	75.75–100 (100.00)	87.13–100 (100.00)	75.7–100 (100.00)	87.1–100 (100.00)
	Severe	20.6 –100 (100.00)	90.5 –100 (100.00)	20.6–100 (100.00)	90.5–100 (100.00)
Mesial	**Normal**	71.0–96 (88.46)	75.7–100 (100.00)	85.6–100 (100.00)	54.8– 92.9 (80.00)
	Mild	43.6–96.9 (83.33)	75.78–96.76 (90.63)	30.7–86.32 (62.50)	83.3–99.4 (96.67)
	Moderate	56.5–100 (100.00)	84.68–99.46 (96.97)	43.6–96.99 (83.33)	89.2–100 (100.00)
	Severe	20.6–100 (100.00)	90.59–100 (100.00)	20.6–100 (100.00)	90.5–100 (100.00)
Distal	**Normal**	60.7–94.1 (83.33)	83.8–100 (100.00)	79.6–100 (100.00)	67.8–95.4 (86.96)
	Mild	78.4–100 (100.00)	69–95.6 (87.50)	58.9–93.8 (82.35)	84.5–100 (100.00)
	Moderate	60.9–100 (100.00)	89.2–100 (100.00)	60.9–100 (100.00)	89.2–100 (100.00)
	Severe	90.8–100 (100.00)	90.8–100 (100)	90.8–100 (100.00)	90.8–100 (100.00)

Based on our results, CBCT is a reliable diagnostic tool for the detection and quantification of bone resorption in periodontal diseases. Thus, the CBCT technique can be applied in complex periodontal procedures such as mucogingival surgery or regenerative therapy in cases where conventional 2D imaging is unable to render accurate information.

The information obtained via clinical trials plays a pivotal role in the selection of an appropriate radiographic technique for the diagnosis of periodontal diseases. Evidence supports the accuracy of CBCT compared to conventional radiographic techniques in detecting periodontal defects, measuring the length of root canals and diagnosing occlusal and interproximal caries [25,26]. Therefore, it seems that this method can be used as a complementary technique to increase the accuracy of detection of bone defects in periodontal diseases and improve the quality of treatments.

CONCLUSION

There was a significant agreement between CBCT and surgical method in determining the amount of bone resorption, and the diagnostic accuracy of CBCT was high in determining the amount of alveolar bone loss in periodontal diseases.

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