Original article

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Diagnostic Value of Panoramic Radiography, Cone Beam Computed Tomography (CBCT) and Clinical Measurement in Determining Bone Dimensions

Amirreza Babaloo[1], Seyyed Ata Eslambulchilar[2], Shima Ghasemi[3*], Masumeh Johari[4]

1. Department of Periodontics, Faculty of Dentistry, Tabriz University of Medical Sciences, Tabriz, Iran
2. Dentist, Private practice, Tabriz, Iran
3. Department of Prosthodontics, Faculty of Dentistry, Tabriz University of Medical Sciences, Tabriz, Iran
4. Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Tabriz University of Medical Sciences, Tabriz, Iran

Abstract

Introduction: Calculation of the bone dimensions is of great importance for implant treatment. Several radiographic modalities have been used for this purpose. This study compared the accuracy of mesiodistal measurements of bone using panoramic radiography, cone beam computed tomography (CBCT), and the clinical methods.
Methods: In this descriptive cross-sectional study, panoramic and CBCT images were obtained from 100 implant patients. Mesiodistal bone dimensions (distance between tooth CEJ in the mesial of edentulous region and CEJ of the tooth in distal of edentulous region) were calculated using a scaled ruler on the orthopantomograms and the system software in the CBCT images. During the implant insertions, a mucoperiosteal flap was raised and clinical dimensions of the bone were measured by a periodontal probe and bone gauge. The differences of bone height and thickness measurements between gold standard and CBCT or panoramic modalities were analyzed using Student's t- test.
Results: The mean bone height was 10.64±1.55, 11.44±1.51, and 10.68±1.6 mm in the clinical, panoramic and CBCT modalities, respectively. Statistically significant difference was noted between the clinical and panoramic techniques (P<0.0001); however, no significant difference was observed between the clinical and CBCT measurements (P>0.05). During the bone height calculations, 79%, 62% and 78% of the images were ranked in the normal range using CBCT, panoramic and gold standard measurements, respectively. The mean areas under the ROC curve were 0.92 and 0.83 in CBCT and panoramic techniques, respectively.
Conclusion: Accuracy of the CBCT images was higher than panoramic technique in measuring the bone dimensions and this technique can be confidently used to calculate the bone dimensions for the implant surgeries.

Keywords: Partially edentulous jaw; panoramic radiography; cone-beam computed tomography; bone dimensions

Corresponding author:
Shima Ghasemi
Department of Prosthodontics, Faculty of Dentistry, Tabriz University of Medical Sciences, Tabriz, Iran
Tel: +989143180309 E-mail: dr_shimaghasemi@yahoo.com

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Introduction

Selecting a proper site for implant placement is an important step in implant treatment because inappropriate implant location may compromise the treatment outcome. Different techniques are available for selection of the appropriate implant site, among which imaging is the most suitable and commonly used technique. Radiographic images can clearly show bone dimensions and exact location of the adjacent anatomic landmarks. Information about the exact height and width of residual bone at the respective site is critical for selecting the type, height and diameter of the implant and consequent success of implant treatment (1, 2). Various radiographic techniques (plain X-ray, computed tomography, etc) have been suggested prior to the implant treatment. Although ideal techniques such as CT scan are available for determining the exact bone dimensions before the implant placement, researchers are still searching for a cheaper, widely accessible technique with a reasonably low radiation dose.

Patients are usually required to obtain panoramic radiography at the beginning of implant treatment because a panoramic radiograph (OPG) provides a general view of the skull, face and the jaws and aids the dentists in selection of the appropriate site for the implant placement. However, clarity and resolution of the panoramic images are less than those of intraoral radiographs though OPG radiographs show a wider view of the jaws and adjacent structures.

Cone beam computed tomography (CBCT) is a relatively new technology with the highest application in the implant treatment; because it is specifically designed for the head and neck region. By providing different sections in various planes, it provides accurate images of the area. Therefore the dentist can accurately determine the thickness and height of the region bone to select the most suitable site for the implant placement. This is especially important in the posterior mandible. In many cases requiring the implant treatment, the patients have severe bone loss in the posterior mandibular region as long time has passed since they lost their posterior mandibular teeth. On the other hand, due to the location of the mandibular canal, the implant placement in this region is not as simple as in other areas and requires complementary evaluations regarding the height and thickness of the bone on the mandibular canal (3-5).

Mesiodistal dimension of the implant site is of great importance as well because this space can determine the number of implants that can be inserted. Therefore, the clinician should accurately measure this distance before treatment. The aim of the present study was to assess the mesiodistal dimension of bone using panoramic radiography and CBCT and to compare it with the clinical values. Moreover, diagnostic value of these two imaging techniques for the purpose of pre-implant assessment was evaluated.

Materials and methods

This descriptive cross-sectional study was carried out on 100 patients presenting to the Tabriz University School of Dentistry for the implant treatment. A panoramic radiography and a CBCT were obtained from patients under standard conditions. The inclusion criteria were: (1) single tooth loss with the teeth mesial and distal to the edentulous site present, (2) having a panoramic radiograph at the first visit; a panoramic radiograph was obtained from patients who did not have a recent one, and (3) patients who were candidates for CBCT of the respective site before implant surgery. Patients were excluded if they had a systemic or metabolic disease affecting bone quality or

quantity, a screw or plate used for fracture fixation at the site, more than 15° tilt of the teeth at mesial and distal of the edentulous site, and restorations extending to the proximal area next to the edentulous site. At the beginning of the study, a written informed consent was obtained from all patients.

Mesiodistal dimensions of bone at the respective site were marked on the panoramic radiograph using a scaled ruler and CBCT software program and measured. Calculations were done by a periodontist (university faculty member). Mesiodistal dimension was measured from the cementoenamel junction (CEJ) of the tooth at the mesial of the edentulous site to the CEJ of the tooth at the distal of the respective site. During the placement of implant a mucoperiosteal flap was elevated and mesiodistal clinical dimensions of the bone were measured by a periodontal probe and then a bone gauge. The distance between the external cortex of the buccal and lingual bone was also measured by a bone gauge. The values for the height and thickness of the bone in the two imaging modalities and clinical measurement method were calculated and recorded.

Data were presented as mean ± standard deviation (SD). All statistical analyses were performed with Statistical Package of Social Science (SPSS Inc., Chicago, IL) for Windows version 16. The difference in mean height and thickness of the bone on the OPG and CBCT images were compared with the gold standard using the Student's t-test. Moreover, sensitivity, specificity, positive and negative predictive values, and area under the curve in receiver operating characteristic (ROC) curve were calculated and recorded for the imaging modalities for determination of the mesiodistal dimensions. A P value less than 0.05 was considered statistically significant.

Results

Mesiodistal dimensions of bone

The mean bone height in the clinical measurement method (gold standard) and on panoramic radiograph was 10.64±1.55 and 11.44±1.51 mm, respectively (P<0.0001, Student's t-test). Furthermore, the mean bone height was 10.68±1.6 mm on CBCT images and 10.64±1.55 mm in the clinical measurement (P=0.87, Student's t-test).

Buccolingual bone dimensions

The mean bone thickness was 6.46±0.98 mm in CBCT and 6.59±0.99 mm in the clinical measurement (P=0.36, Student's t-test).

Diagnostic value of imaging modalities in determining the mesiodistal bone dimensions compared to the gold standard

In determination of bone height using CBCT, 79%, 11%, and 20% of patients were within the normal, under and over the normal range, respectively. Based on the panoramic radiographs, 62% of patients were estimated to be within the normal range, 3% were under and 35% were over the normal limit. Clinical measurements showed that 78% were within the normal range, 12% were under and 10% were over the normal limit (Table 1).

With regard to the determination of bone height dimensions, area under the curve was 0.92 (95% CI: 0.86-0.97) in the CBCT method (P=0.001). With cutoff point of 12mm, sensitivity and specificity values were 96.1 and 81.8, respectively. Moreover, the positive and predictive values were 94.9% and 85.7%, respectively (Table 2). These high values for CBCT indicate the high diagnostic value of this method. In the panoramic radiography method, area under the curve was 0.83 (95% CI: 0.73-0.93; P=0.007). The sensitivity, specificity, positive and negative predictive values in this technique were 67.9, 59, 85.4, and 34.2%, respectively (Table 2). These values indicate the

	Gold standard	CBCT	Panoramic	Total
Normal (9-12 mm)	78 (78%)	79 (79%)	62 (62%)	219 (73%)
Under (<9mm)	12 (12%)	11 (11%)	3 (3%)	26 (8.7%)
Over (>12mm)	10 (10%)	10 (10%)	35 (35%)	55 (18.3%)
Total	100 (100%)	100 (100%)	100 (100%)	300 (100%)

Table 1: Frequency of different diagnoses in determination of mesiodistal bone dimensions using panoramic and CBCT radiographs and clinical measurements

moderate diagnostic value of panoramic radiography.

Diagnostic value of CBCT in determining the buccolingual dimensions of bone compared to the gold standard

In determination of the bone thickness using CBCT, 81%, 1%, and 18% were within, under, and over the normal range. In the gold standard measurement, 76% were within the normal limit, 2% were under and 22% were over the normal range (Table 3).

The area under the ROC curve was 0.97 in CBCT (95% CI: 0.94-1.00). This showed that the diagnostic power of CBCT for determination of bone thickness was high. With cutoff point of 7mm, the sensitivity and specificity values were 100% and 79.1%, respectively. Furthermore, the positive and negative predictive values of CBCT were 93.8% and 100%, respectively. High sensitivity, specificity, positive and negative predictive values were indicative of the high diagnostic value of CBCT.

Method	Area under the curve	P value	95% CI	
			Min	Max
CBCT	0.92	0.001	0.86	0.97
Panoramic	0.83	0.007	0.73	0.93

Table 2: Area under the ROC curve in CBCT and panoramic radiography for bone height determination

Discussion

This study failed to find a significant difference in bone height and thickness determination between the clinical measurement (gold standard) and CBCT. However, bone height estimates using panoramic radiography were significantly higher than those measured clinically. Therefore, CBCT was more accurate than panoramic radiography in bone height determination. In addition, high LRP ratio of CBCT indicated that this method was suitable for accurate determination of the bone thickness dimensions.

An error in bone height determination less than 1mm using radiography is acceptable. Based on our results, this error in both

panoramic radiography and CBCT was less than 1mm (0.79 and 0.03 mm, respectively). Similar

	Gold standard	CBCT	Total
Normal (5-7 mm)	76 (76%)	81 (81%)	157 (78.5%)
Under (<4.9 mm)	2 (2%)	1 (1%)	3 (1.5%)
Over (>7.1 mm)	22 (22%)	18 (18%)	40 (20%)
Total	100 (100%)	100 (100%)	200 (100%)

Table 3: Frequency of different diagnoses in determination of mesiodistal bone dimensions using clinical measurements and CBCT

to our finding, Timock et al found that the mean absolute difference between direct measurement and CBCT calculations for bone height and thickness was less than 0.1 mm.6 In some cases, artifacts or bone marrow spaces on the radiographs may be misinterpreted as canal cross-section resulting in overestimation of the bone height.7 In a study by Mischkowski et al., the difference between CBCT and clinical measurement for estimation of the distance between maxillary and mandibular landmarks was found to be 0.26 mm.8 Moreover, Stratemann and colleagues reported that the absolute error values at various craniofacial distances were 0.07 and 0.00 in two CBCT devices.9 Loubele et al. demonstrated that using CBCT images caused underestimation of buccolingual thickness of the mandible by approximately 0.23 mm. No similar finding has been reported in the literature.2 It should be noted that all these studies were conducted on dry skulls and a radiopaque marker was used to help in recognition of the landmarks. Small error values have been reported for CBCT images in presence of soft tissue although the variability of results is higher in such cases. On the other hand, an error in measurement of teeth and root lengths in porcine skulls was estimated to be 0.15 and 0.3 mm, respectively.10 In measurement of the human periodontal lesions on CBCT images compared to direct measurement after flap elevation, the error of measurements was less than 0.1 mm.11 In the present study, the difference in bone thickness and height between CBCT and clinical measurement was 0.12 and 0.03 mm; which is comparable with the aforementioned values.

In the panoramic radiographs, linear measurements have less accuracy than the CBCT technique due to a superimposition of the anatomic landmarks and geometric distortion. In a study measuring the distance between the superior border of the inferior alveolar canal and the mandibular alveolar crest and also the distance between the maxillary sinus floor and maxillary alveolar crest and comparing the results with direct measurements on the skulls, Doran and coworkers found no significant difference between CBCT and physical measurements.12 However, significant differences were found between the panoramic and physical measurements;12 which are in accordance with those of our study indicating high accuracy of CBCT calculations. In contrast to the CBCT images, the panoramic images suffer magnification and distortion. However, if magnification can be calculated, it will not be problematic but distortion is unequal because magnification at different parts of an image is different. Panoramic images due to distortion are not very reliable for accurate linear measurements.13 Nonetheless, some authors believe that biologic risks of ionizing radiation

have the first priority. Therefore, conventional radiographic methods such as panoramic and intraoral radiography should be used for bone height and thickness calculations prior to the implant treatment since they have adequate accuracy, yet less than the accuracy of CBCT or CT, to prevent high exposure dose and the related high costs. Nevertheless, the importance of CBCT or CT in special cases of implant treatment has always been emphasized.14,15

Radiographic assessment of the patients prior to the implant surgery requires accuracy and efficacy of the technique used for precise estimation of the quality and quantity of the jaw bone. Additionally, patient's received dose following the respective imaging technique and its advantages and disadvantages should be evaluated. On the other hand, it is believed that tomographic images such as CBCT, due to their 3D nature, can effectively enhance the surgeon's spatial visualization of the jaw. These images allow the assessment of jaw bone thickness and can be used in association with the conventional intraoral imaging techniques.16

Conclusion

The CBCT technique was more accurate than the panoramic technique in determination of the bone dimensions. As no significant difference was found between CBCT and gold standard measurements, CBCT can be reliably used in calculation of the bone dimensions for the implant surgery.

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