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Assessment of the Accuracy of Panoramic Radiography (PR), Cone Beam Computed Tomography (CBCT) and Clinical Methods in Measuring Alveolar Bone Dimension: A Comparative Study

Running Title: CBCT and panorama in bone dimensions

[1] Kuldip Singh Sangha [2] Prateek Khetrapal [3] Shikha Gupta [4] Abhilasha Singh, [5]Jitendra Kumar [6] Priyal Billaiya

[1] Assistant Professor, Department of Periodontics, Government Dental College, Raipur, Chhattisgarh, Email: dentico29@gmail.com

[2] Assistant Professor, Department of Oral and maxillofacial surgery, New Horizon Dental College and Hospital, Bilaspur, Chhattisgarh Email: prateekkhetrapal21@gmail.com

[3] Assistant Professor, Department of Prosthodontics, Ahmedabad Dental college and Hospital Email: guptashikhad@gmail.com

[4] Assistant Professor, Department of Periodontics, New Horizon Dental College and Hospital, Bilaspur, Chhattisgarh, Email: abhilashasingh05@gmail.com

[5] Resident Doctor, Department of Dentistry, All India Institute of Medical Sciences, Bhopal Email: jsinha53@gmail.com

[6] Private Practitioner, Bhilai, Chhattisgarh. Email: priyal.bill@gmail.com

Abstract

Objective: To assess and compare the accuracy of panoramic radiography, cone beam computed tomography (CBCT) and clinical methods in measuring dimensions of alveolar bone.

Methods: One hundred and four panoramic radiographs (PR) and CBCT images were obtained from patients attending for implant therapy. Alveolar bone dimensions were determined using a accompanying system software on the PRs and the CBCT images. Mucoperiosteal flap was raised and clinical dimensions of the bone were measured by a periodontal probe and bone gauge while placing the implants. The differences of bone height and thickness measurements between clinical measurements and CBCT or PR were calculated using Student's t- test.

Results: The mean bone height was 11.98±1.23 mm clinically, 11.04±1.42 and 11.01±1.47 mm when measured on PR and CBCT respectively. A significant difference was observed between the clinical and PR($P<0.0001$) but clinical and CBCT measurements revealed no significant difference ($P>0.05$). When the bone height was calculated, 61.5%, 53.8% and 59.61% of the images were in the normal range using CBCT, PR and clinical measurements, respectively. The mean areas under the ROC curve were 0.89 in CBCT and 0.84. The mean bone thickness was 7.09±0.54 mm when measured clinically and was 6.86±0.16 mm in CBCT ($P=0.346$, Student's t-test).

Conclusion: Precision of the images by CBCT was higher than PR in analyzing the bone measurements and this system can be unquestionably used to compute the bone measurements during implant therapy.

Keywords: Dental implants; panoramic radiography; cone beam computed tomography

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Introduction

Cone-beam computed tomography (CBCT) imaging has expanded open doors for analyzing morphologic parts of the head and neck structures, including alveolar bone, however confinements of the innovation have yet to be characterized.[1],[2] Selecting a legitimate site for placing an implant is an imperative stride in treatment planning on the grounds that improper implant location may trade off the treatment result.[3] Distinctive systems are accessible for choice of the appropriate implant site, among which imaging is the most reasonable and regularly utilized procedure. Radiographic pictures can unmistakably indicate bone measurements and correct area of the nearby anatomic points of interest. Data about the precise height and width of lingering bone at the individual site is basic for selecting the type, stature and measurement of the implant and ensuing achievement of implant therapy.[4] Different radiographic methods (plain X-ray, computed tomography, etc) have been recommended preceding the implant therapy. Albeit perfect skill, for example, CT scan are accessible for deciding the correct bone measurements before the placement of implant, specialists are yet exploring down a less expensive, generally available procedure with a sensibly low rate of patient exposure to radiation. [5]

Patients are typically required to get panoramic radiograph (PR) toward the start of implant therapy on the grounds that a PR gives a general perspective of the jaws and face and helps the dental practitioners in determination of the suitable site for the implant placement. In any case, clarity and determination of the panoramic images are not exactly those of intraoral radiographs however they demonstrate a more extensive perspective of the jaws and related anatomy.[6]

Cone beam computed tomography (CBCT) is a new innovation with the most extensive application in the implant therapy; since it is particularly intended for imaging the head and neck structures. CBCT exhibits exact pictures of the desired zone by displaying diverse areas in different planes. In this manner the dental specialist can precisely decide the thickness and stature of the locale bone that remains to be worked out the most reasonable site for the placement of implants particularly in posterior segment of mandible. Majority of patients requiring implant treatment report with greater bone loss in the mandibular posterior region because of delay in replacement of their teeth. On the other hand, due to the existence mandibular canal, the implant placement in this site is not as straightforward as in other location and needs corresponding assessments with respect to the stature and thickness of the bone on the mandibular canal.[7,8]

The measurement of the height of alveolar bone at the implant location is of compelling significance also in light of the fact that this site can decide the sum of implants to be placed. Along these lines, the dental practitioners ought to precisely quantify this dimension while planning the implant treatment. [9] With this background the present study was aimed to determine the dimensions of alveolar bone using PR and CBCT and to correlate it with the clinical measurements.

Material and methods

This study was carried out among 104 patients presenting for the implant treatment. Ethical clearance was taken from the Institutional Ethical Committee before the commencement of the study. A digital panoramic radiograph was obtained using Cranex (SOREDEX, Tuusula,

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Finland), tube current, 6 mA; tube voltage of 65kV; exposure time for 20 seconds at 50 Hz; inherent filtration, 1.8mm Al; and total filtration of 2.7mm Al. CBCT was obtained using Scanora 3D; Soredex, Tuusula, Finland with 6 mA and 89 kVp and the evaluation of the scans were carried out with the dedicated software (NewTom 3G: NNT, QR SRL; Scanora 3D: OnDemand®, Cypermed Inc., Irvine, CA). Written consent was obtained from all the participants of the study. Patients with loss of only one tooth with the presence of teeth, mesial and distal to the missing teeth and who were suitable for obtaining CBCT of the respective location before implant surgery were included in this study. Individuals with any disease which affects the bone quality or quantity and restorations extending to the proximal area next to the edentulous site were excluded from the study.

Measurement of alveolar bone height at the implant location was carried out on PR and CBCT with the aid of accompanying software program. The alveolar bone height was measured from the cementoenamel junction (CEJ) of the tooth to the alveolar crest. The clinical measurements of the bone were estimated clinically using a Williams periodontal probe. The span from the external cortex of the buccal and lingual bone was also evaluated using a bone gauge. Thus the amount of height and thickness of the bone in the PR and CBCT and clinical measurement were ascertained and registered.

All the dimensions were measured twice by two experienced professionals independently and the mean values were considered for analysis. The reliability of measurements was evaluated by kappa statistics.

The collected data was recorded and analyzed using SPSS 21.0 (Chicago, USA). The difference in mean height and thickness of the alveolar bone on the PR and CBCT images were compared with the clinical measurements by applying Student’s t-test. The sensitivity, specificity, positive and negative predictive values, and area under the curve in receiver operating characteristic (ROC) curve were estimated and documented for PR and CBCT for assessing the measurements of the height of alveolar bone. The statistical significance was set at 5% level of significance ($p<0.05$).

Results

The reliability was very good, with Kappa values of 0.92 for intraoperator agreement and of 0.83 for interoperator agreement.

Mean bone height (Table 1)

The mean bone height when measured clinically was 11.04±1.42 mm, on PR it was 11.98±1.23 mm ($P<0.0001$, Student’s t-test) and it was 11.01±1.47 mm when measured on CBCT images ($P=0.72$, Student’s t-test).

Buccolingual bone thickness

The mean bone thickness was 7.09±0.54 mm when measured clinically and was 6.86±0.16 mm in CBCT ($P=0.346$, Student’s t-test).

Determination of bone height from clinical, CBCT and PR measurements (Table 2)

In determination of bone height using CBCT, 61.5%, 21.1%, and 17.3% of patients were within the normal, under and over the normal range, respectively. Based on the panoramic radiographs, 53.8% of patients were estimated to be within the normal range, 10.5% were under and 35.5% were over the normal limit. Clinical measurements showed that 59.61%

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were within the normal range, 22.11% were under and 18.26% were over the normal limit (Table 2).

With regard to the determination of bone height dimensions, area under the curve was 0.89 (95% CI: 0.83-0.94) in the CBCT modality (P=0.001). With cutoff point of 12 mm, sensitivity and specificity values were 94.4 and 78.6 respectively. Moreover, the positive and predictive values were 92.1% and 81.3%, respectively. These high values for CBCT indicate the high diagnostic value of this method. In the panoramic radiography method, area under the curve was 0.84 (95% CI: 0.76- 0.96; P=0.008) (Table 3).

The sensitivity, specificity, positive and negative predictive values with regards to PR were 65.7, 54.6, 81.9%, and 31.6%, respectively. These values indicate the moderate diagnostic value of panoramic radiography.

Determination of the bone thickness using clinical measurements and CBCT (Table 4).

In determination of the bone thickness using CBCT, 75.9%, 2.88%, and 21.15% were within, under, and over the normal range. In the clinical measurements, 70.19% were within the normal limit, 3.8% were under and 25.9% were over the normal range.

The area under the ROC curve was 0.94 in CBCT (95% CI: 0.91-1.00). 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 89.1%, respectively. Furthermore, the positive and negative predictive values of CBCT were 91.6% and 100% respectively. High sensitivity, specificity, positive and negative predictive values were indicative of the high diagnostic value of CBCT.

Tables

Table 1: Comparison of mean bone height (Student's t-test)

<table>
<tr><td rowspan="2">Measurements</td><td rowspan="2">(Clinical)
11.04±1.42 mm</td><td>(PR)
11.98±1.23 mm</td><td>(P<0.0001)</td></tr>
<tr><td>(CBCT)
11.01±1.47 mm</td><td>(P=0.72)</td></tr>
</table>

Table 2: Determination of bone height from clinical, CBCT and PR measurements

Criteria	Clinical Measurements	CBCT	PR	Total
Normal (9-12 mm)	62 (59.6%)	64 (61.5%)	56 (53.8%)	182 (60.66%)
Under (<9mm)	23 (22.1%)	22 (21.1%)	11 (10.5%)	56 (18.6%)

Over (>12mm)	19 (18.2%)	18 (17.3%)	37 (35.5%)	74 (24.6%)
Total	104 (100%)	104 (100%)	104 (100%)	312 (100%)

Table 3: Area under the ROC curve in CBCT and panoramic radiography for bone height determination

Imaging Modality	Area under the curve	P value	95% CI	
			Min	Max
CBCT	0.89	0.001	0.83	0.94
PR	0.84	0.008	0.76	0.96

Table 4: Determination of the bone thickness using clinical measurements and CBCT

Criteria	Clinical Measurements	CBCT	Total
Normal (5-7 mm)	73 (70.1%)	79 (75.9%)	152 (73.0%)
Under (<4.9 mm)	4 (3.8%)	3 (2.8%)	7 (3.3%)
Over (>7.1 mm)	27 (25.9%)	22 (21.15%)	49 (23.5%)
Total	104 (100%)	104 (100%)	208 (100%)

Discussion

No significant difference in bone height and thickness determination between the clinical measurement and CBCT was observed in this study. The bone height measurements on the PR were significantly higher than the clinical measurements. These observations, CBCT proved to be more authentic than PR in bone height determination and the high LRP ratio of confirmed that CBCT is a preferred imaging modality for to determine the bone thickness dimensions precisely.

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 (0.82 and 0.06 mm, respectively), this observation was in accordance with the findings of Timock et al., who noted t the mean absolute difference between direct measurement and CBCT calculations for bone height and thickness was not exceeding 1mm.[10]

The artifacts or bone marrow spaces on the X rays may be misinterpreted as canal cross-section which may result in overestimation of the bone height.[11] Mischkowski et al., noted that the difference of 0.26 mm for CBCT and clinical measurement for estimation of the distance between maxillary and mandibular landmarks.[12] CBCT images lead to underestimation of buccolingual dimension of the mandible by approximately 0.23 mm in a study by Loubele et al.[13] Presence of soft tissue in CBCT can cause minimal error values although the variability of results may be higher in similiar cases. An error in estimating the dimension of teeth and root height in porcine skulls was approximated to be 0.15 and 0.3 mm, respectively.[9]

When the dimensions periodontal lesions of the human on CBCT images were correlated to direct measurement after flap elevation, the error of measurements was lower than 0.1 mm.[14] The results of this study revealed that the difference in bone thickness and height between CBCT and clinical measurement was 0.14 and 0.06 mm; which is comparable with the aforementioned values.

When measured on the PR, linear measurements demonstrate less precise values in comparison with CBCT because of Superimposition of the anatomic landmarks and geometric distortion. Doran et al., observed no significant difference between CBCT and physical measurements when they measured various maxillofacial dimensions but a significant differences were found between the PR and physical measurements; which were similar with the observations of the present study which suggested steep precision of CBCT arithmetics.[15] A significant amount of magnification can be observed on PR images when compare to the CBCT images and also the PR images are not very reliable for accurate linear measurements because of distortion.[16] Considering the biologic risks of ionizing radiation, conventional imaging modalities like Intraoral and PR were supported to be used for estimating bone height and thickness while planning implant therapy calculations prior to the implant treatment since they have adequate accuracy even though less than the that of CBCT. Nevertheless, the significance of CBCT in extraordinary instances of implant therapy has dependably been stressed.[17]

Radiographic appraisal of the patients before the implant therapy requires precision and viability of the system utilized for exact estimation of the quality and amount of the jaw bone. Also, patient's radiation dose after the different imaging modalities and its preferences and drawbacks ought to be assessed. It is trusted that the 3D images obtained from CBCT can adequately improve the specialist's spatial perception of the jaw when compared to 2D images of conventional imaging modalities. These images permit the evaluation of jaw bone thickness and can be utilized as a part of relationship with the customary intraoral imaging procedures.[18,19]

Conclusion

From the observations of the present study, we conclude that CBCT technique was more precise than the PR in estimation the bone dimensions. No significant difference was observed between CBCT and clinical measurements confirm that CBCT can be decisively used in computation of the bone dimensions during implant placement.

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