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Research Paper: Accuracy of Panoramic Radiography in Determining the Distance to Anatomical Landmarks Compared to Cone-Beam Computed Tomography

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ABSTRACT

Introduction: The aim of this study was to determine the accuracy of digital panoramic radiography in estimating the height of bone between alveolar crest and anatomical landmarks of both jaws(maxillary sinus and inferior alveolar nerve canal) in molar and premolar areas in comparison with CBCT.

Materials and Methods: A total of 217 samples from patients who had both digital panoramic radiographs and CBCT before implant insertion were selected. Shortest distance between alveolar crest and IANC (of mandible), and between the alveolar crest and maxillary sinus (of maxilla) in molar and premolar area has been measured. The differences of these measurements have been analyzed using paired t-test, the Bland-Altman plot and ICC.

Results: Measurements of panoramic radiography were significantly greater than CBCT in mandibular premolar and molar area plus maxillary premolar area ($p<0.001$, $p<0.001$, $p=0.008$ respectively), but the results were insignificant in maxillary molar area ($p=0.147$). By using ICC, the measurements were closely and positively correlated in all areas, with correlation coefficient ranging from 0.916 to 0.947. The Bland-Altman plots showed significant difference between two modalities except maxillary molar area ($p<0.05$).

Conclusion: Panoramic radiographs contain valuable information of both jaws, however they could not be reliable for meticulous measuring such as distance to anatomical regions- except posterior maxillary one - in surgeries. So that, it is essential to use precise 3D systems such as CBCT for implant measurements.

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Introduction

Nowadays, dental implants have shown remarkable results in treatment of missing teeth, full mouth rehabilitation; to maintain facial aesthetic and functions (1,2). They have become an ideal option in treatment plans of edentulous mouths due to stable outcomes and high success rate (3). However, the success can be affected by many complications, such as too much proximity to anatomic landmarks like inferior alveolar nerve canal (IANC) and the floor of maxillary sinus. Invasion to these areas may lead in pain, swelling, hemorrhage, infection and area-specific symptoms such as mucosa perforation and epistaxis, and sensory disturbance and limitation of mouth opening due to soft and hard tissue damage (4-6).

Thorough clinical and radiological examinations play an important role in avoiding complications and improving treatment success (7). It is a prerequisite to estimate the distance between alveolar crest and these anatomical structures by different radiographic modalities pre-operatively.

One of these modalities, digital panoramic radiography has been widely used, since they are cost-effective, readily available and offering a noticeable amount of information about jaws and dentition albeit its reduced radiation dose (8-9). However, image distortion and unequal magnification is its inherent feature due to its two-dimensional (2D) view. Additionally, the blurred view of structures outside the focal trough as well as other ghosts an artifacts would deteriorate the quality of the radiographs (7). These disadvantages could cause errors in distance estimation and lead in damage to critical anatomic sites.

Newer advanced imaging systems have been invented using three-dimensional (3D) reconstruction methods. Cone-Beam Computed Tomography (CBCT) is the one becoming widely utilized in oral and maxillofacial practice (10). CBCT obtains a large amount of data in a relatively short period of X-ray exposure and provides images with higher resolution in several orthogonal planes (11).

The aim of this study was to evaluate the accuracy of digital panoramic radiography compared to CBCT in determining the distance between the alveolar crest and floor of maxillary sinus in the maxilla, and between the alveolar crest and inferior alveolar nerve canal (IANC) in the mandible.

Methods and Materials

Sample Criteria

In this cross-sectional analytic study, all panoramic and CBCT radiographs of patients, referred to a private maxillofacial radiology office from Mar 2017 to Mar 2018, were collected. All the patients were either males or females between 14 to 73 years old. Premolar or molar dentitions in their respective jaw, if being important in measuring, should have been present. The radiographs which 1.the condition of patient's dentition was different in panoramic and CBCT radiographs, 2.more than six-month period between two radiographs, 3.without high quality and resolution and 4.not in right position and desired field of view were excluded. At last, 217 samples were included. The demographic data of patients were concealed due to ethical issues. This study is approved By Resaerch Ethics Committee of Guilan University of Medical Sciences (Code No: IR.GUMS.REC.1396.275).

Data Collection

The brand of the CBCT imaging device was NewTom 3G (NewTom, Verona, Italy) and its reconstruction software was NNT viewer Version 4 (with considering the slice thickness of 1mm, the step of 1mm and the section width of 30 mm). The measurements were performed bilaterally if the other side was available. Exposure parameters were customized to each patient (Figure 1).

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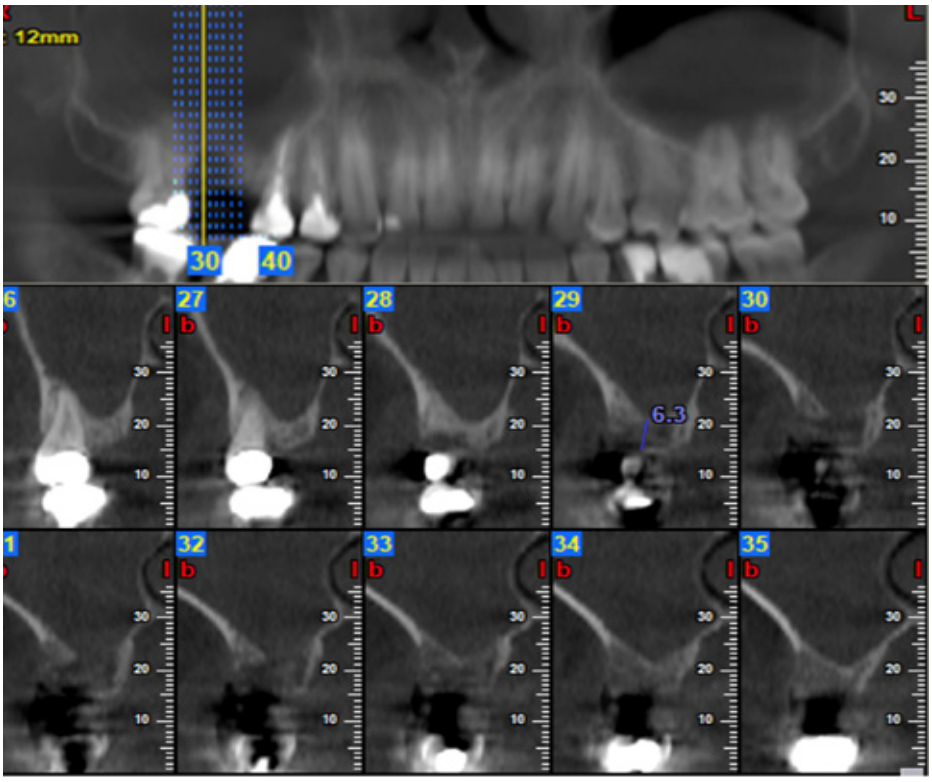

Figure 1. Cross-sectional views of a CBCT scan of one of the patients and their guide showing how the measurements had been done

In the mandible, the shortest distance between alveolar crest and superior border of IANC was measured in cross-sectional images of two regions :

1.above the opening of mental foramen (premolar area)

2. between the contact of first and second molar (molar area)

Also in the maxilla, the shortest distance between alveolar crest and floor of maxillary sinus was measured in two regions :

1.distal of second premolar (premolar area)

2.mesial of second molar (molar area)

The digital panoramic device was Planmeca Poramax Scara 3 (Helsinki, Finland) displaying on a 17-inch monitor (LA1905WG, LG, Korea; Resolution: 1280 *1024 pixels), being set in right position and standard exposure conditions. The shortest distance in respective locations of the radiographs was measured by a precise caliper tool with 100% scale (Figure 2).

Two skilled observers separately extracted the needed data from the scans and radiographs and the inter-examiner accordance was evaluated. All the measurements were repeated after 10 days by the same observer to reduce intra-examiner bias.

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Figure 2. A digital caliper showing how the measurements were done on a panoramic radiograph of one of the patients

Statistical Analysis

Descriptive values such as mean, standard deviation (SD) and 95% of confidence interval (95% CI) were gathered. Statistical analysis was performed by using Statistical Package for the Social Sciences (version 21 for Windows; SPSS, Chicago, IL, USA). To compare the measurements of two modalities, paired t-test and Bland-Altman plots were utilized. To check the validity and reliability of data between the observers and the frequency of testing for each observer , intra-class correlation (ICC) was used. The level of significance of 5% (α=0.05) was considered for all analytic tools.

Results

In this cross-sectional analytic study, 217 CBCT scans and their respective panoramic radiographs (109 of maxilla and 108 of mandible) were collected. 53.25% of radiographs belonged to females and 46.75% to males between 14 to 73 years old.

The mean values of distance measurements between the alveolar crest and anatomical regions are shown in Table 1.

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Table1. Measurements of distance to anatomical landmarks on digital panoramic radiography (PAN) and CBCT in molar and premolar region

	region	modality	Mean and SD of measurements
Maxillary Sinus	Premolar area	PAN	10.49 ±4.08
		CBCT	10.03 ±4.03
	Molar area	PAN	8.99±3.29
		CBCT	8.73±3.41
Mandibular Inferior Alveolar Nerve Canal	Premolar area	PAN	15.41±4.54
		CBCT	13.93±3.90
	Molar area	PAN	14.96±4.27
		CBCT	13.864±.54

Result of paired t-test and their significance in all groups have been shown in Table 2.

Table 2. The mean and SD of difference between panoramic and CBCT measurements and results of paired t-test

Area of jaw	Mean and SD of difference	T test	P
Maxillary premolar	0.46±1.78	4.602	0.008
Maxillary molar	0.26±1.86	2.594	0.147
Mandibular premolar	1.47±2.03	5.33	<0.001
Mandibular molar	1.09±1.97	4.08	<0.001

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In all regions there was significant difference between two modalities except in the maxillary molar area (p= 0.147). Moreover, the Bland-Altman plots have been illustrated for all regions (Figure 3).

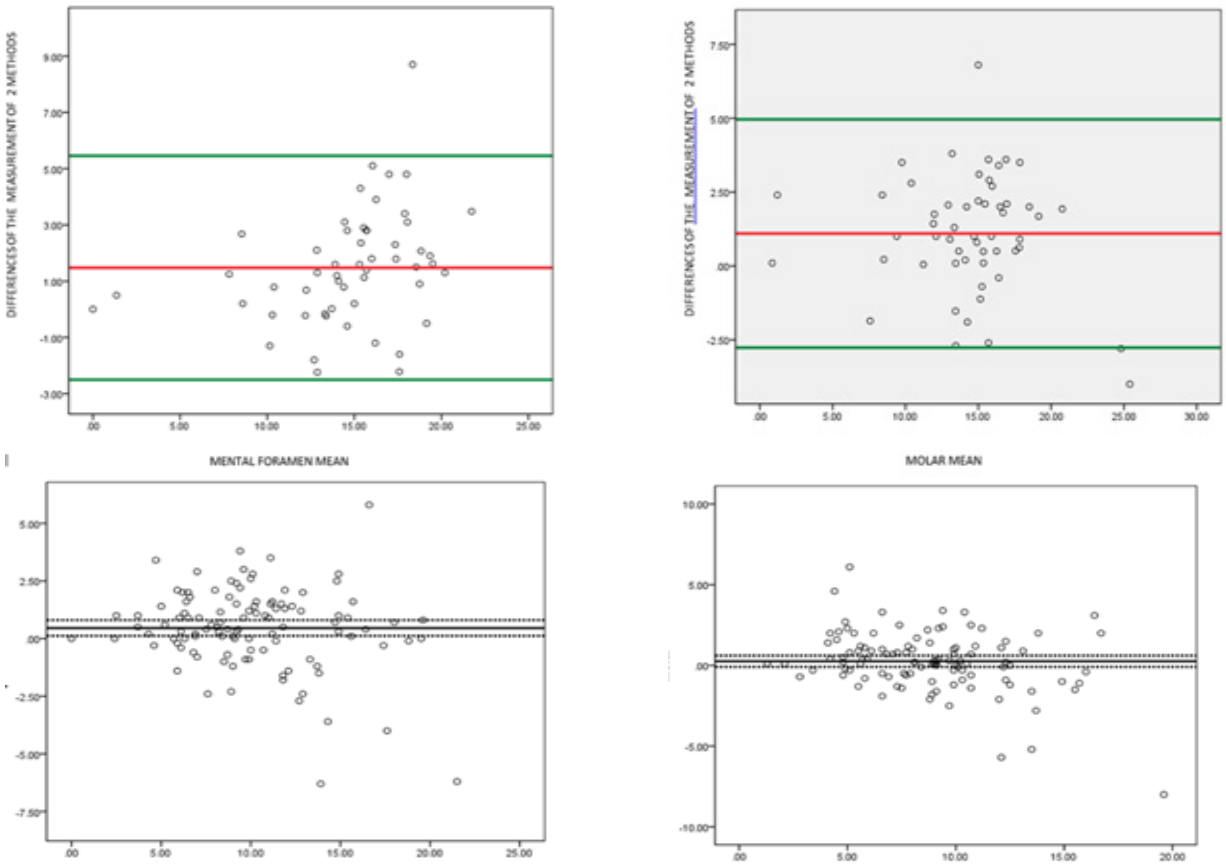

Figure 3. The Bland-Altman plots showing comparison of two modalities in different jaw areas (upper left= mandibular premolar, upper right= mandibular molar, lower left= maxillary premolar, lower right= maxillary molar)

The results of ICC of inter-observer reliability between the paired samples obtained from two modalities have been show in Table 3.

Table 3. Correlation Coefficients (r) of ICC analysis between measurements of panoramic radiography and CBCT at different regions

Region	Correlation Coefficient
Maxillary Premolar	0.949
Maxillary Molar	0.916
Mandibular Premolar	0.939
Mandibular Molar	0.947

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The level of agreement of 0.7 was considered acceptable for the correlation coefficient (r). All the measurements In addition, the rate of overestimation and underestimation of panoramic radiography compared to CBCT has been measured and shown in Table 4.

Table 4. Rate of overestimation and underestimation of panoramic measurements compared to CBCT

	Region	Overestimation(%)	Underestimation(%)
Maxilla	Premolar area	66.1	27.5
	Molar area	56.9	37.6
Mandible	Premolar area	75.9	22.5
	Molar area	81.5	18.5

In the maxilla, the measurements of premolar area on panoramic radiography was 1.78 ± 0.46 mm higher than CBCT (t=4.602, p<0.05). In addition, the results of panoramic radiography showed 27.5% underestimation and 66.1% overestimation compared to CBCT. In molar area, the measurements of panoramic radiography was 0.26 ±1.86 mm greater than CBCT (t=2.594, p=0.147), however, there was not significant difference just in this area. The results of panoramic radiography showed 37.6% underestimation and 59.6% overestimation in comparison with CBCT.

In the mandible, the measurements of premolar area on panoramic radiography was 2.03 ± 1.47 mm higher than CBCT (t=5.33, p<0.05). In addition, the results of panoramic radiography showed 22.5% underestimation and 75.9% overestimation compared to CBCT. In the molar area, the measurements of panoramic radiography was 1.09±1.97mm greater than CBCT (t=4.08, p<0.05). The results of panoramic radiography showed 18.5% underestimation and 81.5% overestimation in comparison with CBCT.

The results of ICC showed that in all regions, the measurements of panoramic and CBCT radiography were closely and positively correlated ranging from 0.916 to 0.947. (Table 3). The ICC values were more than 0.7, indicating good reliability.

In all regions, none of Bland-Altman plots included zero in 95% CI of the measurements; meaning that the two modalities were significantly different (p<0.05).

Discussion

Damaging vital anatomical structures must be avoided in every dental procedure especially implant insertion. Invasion to inferior alveolar nerve canal (IANC) or floor of maxillary sinus are one of those with high rate of complications. Thorough investigation of these areas and estimating remaining alveolar bone height via correct radiological techniques are substantial beforehand.

Digital panoramic radiography is a great tool giving a total scheme of both jaws simultaneously but it is shown that it would rather not completely rely on its measurements because of two-dimensional (2D) view of three-dimensional (3D) structures. Consequently, in CBCT reconstructed 3D images, the morphology of alveolar ridge and the height of alveolar bone can be accurately displayed12,13, showing

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buccolingual thickness, mesio-distal width, fine bony structures and their anatomical relationship with surrounding anatomical structures, especially IANC and the maxillary sinus (14).

In the present study, the accuracy of digital panoramic radiography and CBCT was evaluated in determining the alveolar bone height from crest to IANC in lower jaw and to floor of maxillary sinus in upper jaw. In the mandible it was found out there was significant difference between two modalities in both molar and premolar areas ($p<0.05$). Panoramic radiography has shown underestimation in 22.5% of samples in premolar area and 18.5% of molar ones compared to CBCT. Additionally, it had overestimation in 75.9% of samples in premolar area and 81.5% of molar ones. In the maxilla, there was significant difference between two modalities in premolar area ($p<0.05$) but in molar areas there were not ($p>0.05$). Panoramic radiography has shown 66.1% of overestimation in premolar areas and 59.6% of that in molar ones; while its rate of underestimation was 27.5% in premolar areas and 37.6% in molar ones. Moreover, findings of ICC showed that in all groups, opinions of one observer and between the observers were in accordance.

The different results in maxillary jaw between molar and premolar areas could be explained in order that the form and symmetry of dental arch, teeth arrangement, teeth shape, tilt angle of teeth and surrounding tissues also have effect on the image14. So, It is anticipated that the accuracy of panoramic radiography might be lower in premolar area and more distortion and magnification would be seen in turning point of the jaws.

Many of previous studies have exerted similar results. Malina-Altzinger et al (15) assessed the maxillary sinus in panoramic and CBCT radiographs. CBCT showed more accurate measurements. However, there was more significant difference observed in panoramic images in contrast to the present study. In some studies, the difference between CBCT and panoramic images have been investigated and compared to real measurements on jaw bone (probing during mucoperiosteal flap surgery in the study of Babaloo et al (16) and measuring dried skull dimensions with digital caliper in the study of Talayipoor et al (17). Both of them found CBCT more precise than panoramic radiography. Abdinian et al [18] compared the accuracy of linear (horizontal and vertical) and angular measurements in panoramic and CBCT images. They outlined anterior, canine, premolar and molar area by gutta-percha as opaque markers. CBCT in all three dimensions was more accurate than panoramic images. The difference was maximized in horizontal measurements and minimized in angular ones.

Tang et al (14) found that the measurements of panoramic and CBCT were highly correlated ; however, they would be significantly different in patients with periodontal problems because of decreased density of alveolar bone. In the present study, clinical examination and periodontal situation had not been recorded. This issue could have impact on measurements and it is more accurate to consider clinical situation.

In the study of Guerro et al (19), measuring the height of bone in posterior parts of mandible using panoramic radiography leaded in choosing longer implant fixtures (overestimation); but the difference in anterior parts was not significant. In the present study, both molar and premolar areas had overestimated measures via panoramic imaging; molar area showed greater amounts but was not significant ($p>0.05$).

On the other hand, some studies did not agree with the present findings. Amarnath et al (11) found no significant difference in bone height amounts by panoramic or CBCT compared to direct ridge mapping. In contrast to the current study, panoramic radiography showed more tendency to underestimation in posterior parts of mandible.

In the present study, one of the probable reasons causing overestimation in the mandibular molar area, would be the fact that the IANC had been located buccally in these jaws and the measurement had been done from the crest level to the inferior border of the mandible with

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ignoring the safe area for the IANC. (Table 4).

Hu et al (20) reported that using digital panoramic radiography was safe in surgical treatment plans in the mandible; but suggested to use CBCT in determining buccolingual dimension of maxillary alveolar bone. The difference between two studies may originate from measuring methods. They measured the distances in new cadavers using surgical guides; while, in current study, distances were measured by digital ruler and caliper to be statically compared.

Although, according to the findings of the present study, there is statistically significant difference between CBCT and digital panoramic radiography (Table 2); Panoramic radiographs could still be used in clinical practice; because, based on standard deviations (Table 1), panoramic radiography can be acceptable when the remaining bone height is more than 12 mm in panoramic radiographs (21). Additionally, it can be helpful in primary determination of fixture height in treatment planning, or in measurements of surgeries like sinus lift or bone augmentation.

After all, according to probable complications and contradictions among studies, it is reasonable to use CBCT in meticulous measurements, especially if the remaining bone height is less than 10 mm in panoramic radiography [21]. Moreover, it is suggested to consider periodontal and other clinical examinations to make the best decision about the measuring methods.

Conclusion

Panoramic radiographs contain valuable information of both jaws, however they could not be reliable for meticulous measuring such as distance to anatomical regions- except posterior maxillary molar area - in surgeries. So that, it is essential to use precise 3D systems such as CBCT for implant measurements.

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Authors' contributions

Farzaneh Ostovarrad: Conceptualization, Methodology, Writing - Review & Editing **Hadi Ranjzad:** Resources, Investigation, Visualization **Faezeh Kashi:** Methodology, Visualization **Amir Delsouz Khaki:** Writing - Original Draft, Data **Golabatoon Maleki:** Funding acquisition, Project administration, Supervision

Conflict of Interest

The authors declared no potential conflict of interest in personal, financial or other fields with respect to the research, authorship, and/or publication of this article within three years of beginning the submitted work.

Ethical declarations

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Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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