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Three-Dimensional versus two- dimensional Radiographic Analysis of Alveolar Bone Dimensions and Maxillofacial Landmarks: A Comparative Evaluation for Precision Treatment Planning

Dr. Preeti Upadhyay[1], Dr. Manpreet Kaur[2], Dr. Manika Mittel[3], Dr. S. Kumar[4], Dr. Deepanshu Panwar[5], Dr. Ashish Pandit[6]

[1]MDS Professor and Head, Department of Oral Medicine and Radiology, Inderprastha Dental College and Hospital, Sahibabad, Ghaziabad, U.P., India

[2]MDS (3rd Year Postgraduate Student)Department of Oral and Maxillofacial Radiology Inderprastha Dental College and Hospital, Sahibabad, Ghaziabad, U.P., India

[3]MDS Professor, Department of Oral and Maxillofacial Radiology, Inderprastha Dental College and Hospital, Sahibabad, Ghaziabad, U.P., India

[4]MDS Professor and Head, Department of Oral and Maxillofacial Surgery, Inderprastha Dental College and Hospital, Sahibabad, Ghaziabad, U.P., India

[5]MDS (3rd Year Postgraduate Student) Department of Periodontology, Inderprastha Dental College and Hospital, Sahibabad, Ghaziabad, U.P., India

[6]MDS Reader, Department of Prosthodontics, Inderprastha Dental College and Hospital, Sahibabad, Ghaziabad, U.P., India

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ABSTRACT

Background: Dental radiography is essential for diagnosing oral and maxillofacial conditions. Panoramic radiography (OPG) offers a cost-effective two-dimensional view suitable for routine assessments, while cone-beam computed tomography (CBCT) provides three-dimensional imaging, ideal for complex cases like implant planning and surgical precision. Although OPG is quick and low in radiation, it has spatial inaccuracies, making CBCT preferable for advanced diagnostics. Evaluating OPG's magnification factor is vital for accurate diagnoses.

Methods: Seventy-five patients at Inderprastha Dental College and Hospital with clear OPG and CBCT images of maxillary and mandibular landmarks were included. Only patients without jaw pathologies and with healthy periodontal conditions were selected. Vertical and horizontal distances from key anatomical sites were measured, with CBCT used as the reference. Statistical analyses validated the results.

Results: OPG measurements of alveolar bone dimensions were comparable to CBCT, showing a strong positive correlation ($r = 0.924$ to 0.994; $p < 0.001$). Minor accuracy discrepancies were noted in complex regions, although statistically insignificant. These variations may be relevant in high-precision cases like implant placement. CBCT's three-dimensional imaging provides superior insights into critical spatial relationships.

Conclusion: OPG is reliable for routine alveolar bone measurements, but slight variations in complex areas can affect precision. While OPG is effective for preliminary assessments, CBCT offers enhanced accuracy for intricate cases, such as surgical procedures.

1. INTRODUCTION

Dental radiography is vital in diagnosing and managing various oral and maxillofacial conditions. It aids in detecting dental caries, periodontal diseases, bone infections, and anatomical anomalies. Advances in imaging technology, such as Cone Beam Computed Tomography (CBCT), have revolutionized diagnostic accuracy and treatment planning.

Intraoral and extraoral radiographic devices are routinely used for diagnostic purposes. Intraoral radiographs, such as bitewing and occlusal radiographs, provide detailed imaging of individual teeth and adjacent structures. Extraoral radiographs, including panoramic and cephalometric radiographs, offer a broader perspective on skeletal relationships and jaw alignment. Despite the usefulness of these traditional techniques, they are limited by their two-dimensional nature and inability to visualize soft tissues or depth accurately.

CBCT, introduced in 1996, addresses these limitations by providing three-dimensional imaging of dental and maxillofacial structures, enhancing implant planning, orthodontic treatment, and surgical interventions. This study compares the diagnostic utility of OPG and CBCT in measuring alveolar bone dimensions and anatomical landmarks.

AIM OF THE STUDY

To evaluate and compare digital panoramic radiography with cone beam computed tomography (CBCT) for measuring alveolar bone and assessing important maxillary-mandibular anatomical landmarks for treatment planning.

OBJECTIVES OF THE STUDY

1. To evaluate and measure the distance between the alveolar ridges of maxillary molars (16, 26) and the sinus floor.
2. To evaluate and measure the distance between the alveolar ridges of mandibular molars (36, 46) and the mandibular nerve canal.
3. To evaluate and measure the distance between the alveolar ridge crests of maxillary incisors (11, 21) and the nasal cavity.
4. To evaluate and measure the distance between the alveolar ridges of adjacent teeth of maxillary molars (16, 26).
5. To evaluate and measure the distance between the alveolar ridges of adjacent teeth of mandibular molars (36, 46).
6. To evaluate and measure the distance between the alveolar ridges of adjacent teeth of maxillary incisors (11, 21).

2. MATERIALS AND METHODS

This study was conducted in the Department of Periodontology at Indraprastha Dental College and Hospital, Sahibabad. Seventy-five patients were included based on specific inclusion and exclusion criteria. Participants were divided into two groups:

- Group A (n=75): Patients underwent OPG.
- Group B (n=75): Patients underwent CBCT.

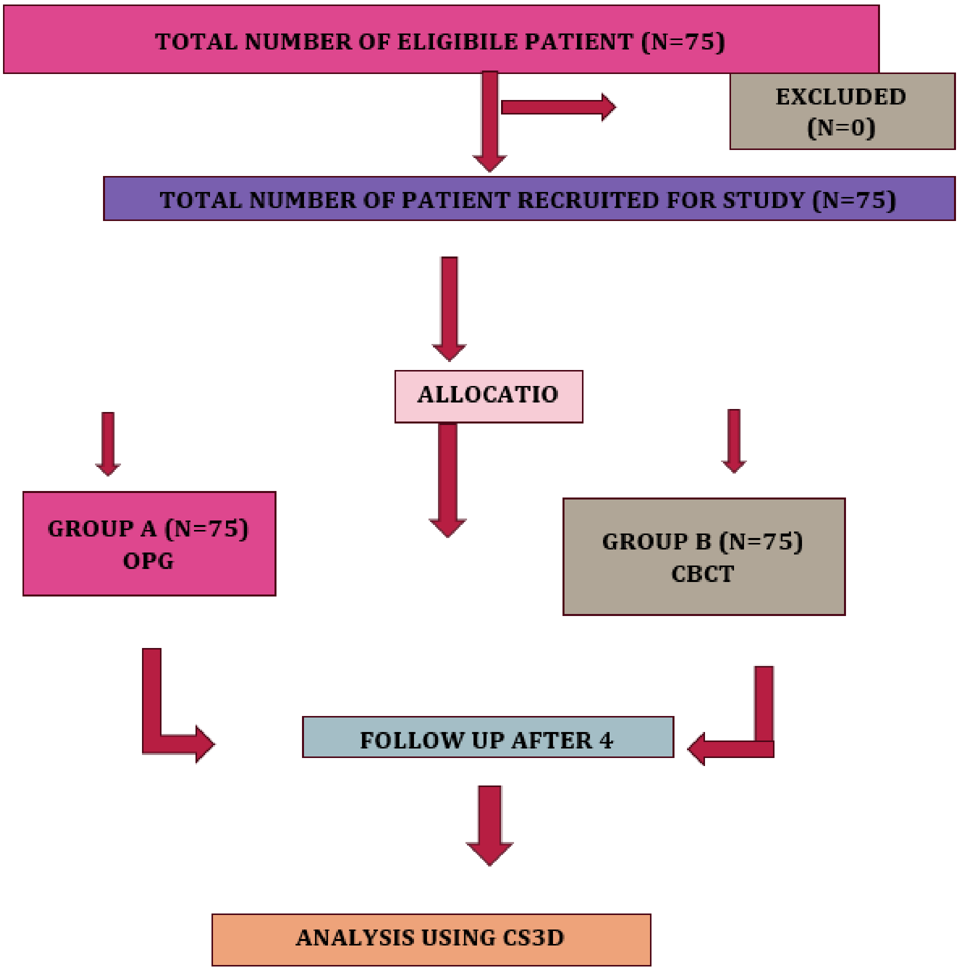
Inclusion Criteria

- Clear OPG and CBCT images showing critical anatomical landmarks.
- Patients in good periodontal health and aged 17 years or older.
- Stable systemic and mental health.

Exclusion Criteria

- History of jaw lesions, surgery, or significant deformities.
- Pregnancy, lactation, or recent radiotherapy.
- Presence of bone diseases or abnormalities.

During their first visit, patients were screened, and informed consent was obtained.



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Imaging Procedures

- OPG (Group A): Scans were taken with patients in a standing position, using a panoramic scanner set to 66 kV and 9 mA. Measurements included distances between anatomical landmarks, such as the alveolar ridge crest and sinus floor.
- CBCT (Group B): Scans were performed with patients seated upright. The CBCT scanner operated at 96 kV and 10 mA, generating 3D images reconstructed in 0.15 mm slices. Measurements were taken for similar anatomical landmarks as OPG.

Statistical Analysis

Robust statistical methods, including paired t-tests, Wilcoxon signed-rank tests, and one-way ANOVA, were employed to validate the findings. The high consistency within groups highlights the reliability of the data. However, the limited sample size (n = 75) underscores the need for larger studies to confirm the generalizability of these results.

3. RESULTS

Analysis of Clinical Parameters

Age Distribution

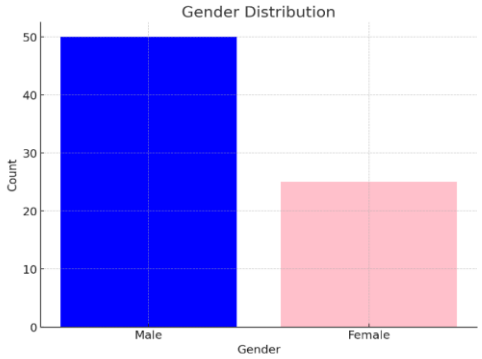
Variable	Mean	SD	Range
Age (in years)	44.81	12.44	18–69

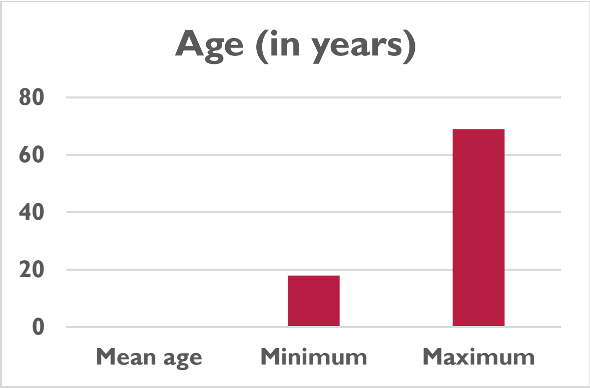
This table summarizes the age distribution of study participants. The mean age was 44.81 years, with a range of 18 to 69 years.

Gender Distribution

Variable	Male	Female
Gender	50	25

A bar graph illustrates the gender and age distribution, with 50 male and 25 female participants.





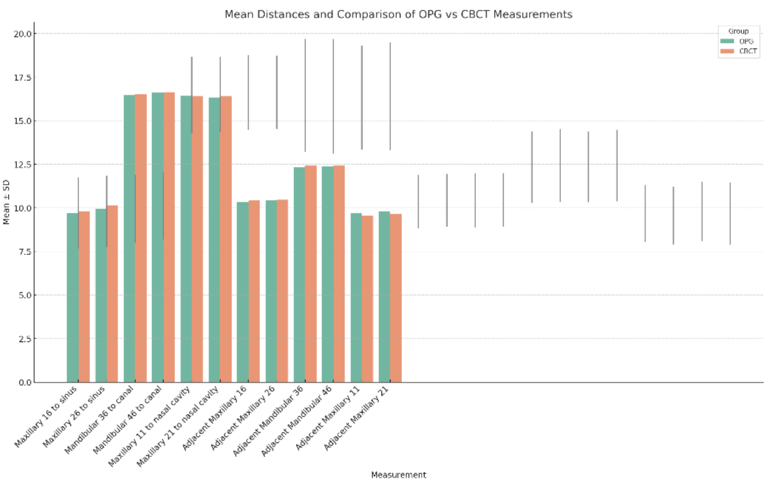
Comparison of Alveolar Bone Measurements Between OPG and CBCT

Measurement	Group	Mean	SD	Difference	p-value
The distances between the alveolar ridges of maxillary first molars (16) and the bottoms of the maxillary sinus	OPG	9.70	2.05	-0.11	0.203#
	CBCT	9.81	2.05		
The distances between the alveolar ridges of maxillary first molars (26) and the bottoms of the maxillary sinus	OPG	9.96	1.94	-0.16	0.204#
	CBCT	10.12	1.94		
The distance between the alveolar ridges of mandibular first molars (36) and the inferior alveolar nerve canal	OPG	16.47	2.19	-0.04	0.776##
	CBCT	16.51	2.17		
The distance between the alveolar ridges of mandibular first molars (46) and the inferior alveolar nerve canal	OPG	16.61	2.14	-0.03	0.711##
	CBCT	16.64	2.10		
The distance between the alveolar ridge crest of maxillary central incisors (11) and the bottoms of the nasal cavities	OPG	16.44	3.25	0.03	0.691#
	CBCT	16.41	3.28		
The distance between the alveolar ridge crest of maxillary central incisors (21) and the bottoms of the nasal cavities	OPG	16.33	2.99	-0.07	0.550#
	CBCT	16.40	3.09		
The distances between the alveolar ridges of adjacent teeth of maxillary first molars (16)	OPG	10.35	1.55	-0.07	0.227#
	CBCT	10.42	1.51		
The distances between the alveolar ridges of adjacent teeth of maxillary	OPG	10.44	1.55	-0.02	0.858#

first molars (26)					
	CBCT	10.46	1.53		
The distance between the alveolar ridges of adjacent teeth of mandibular first molars (36)	OPG	12.33	2.05	-0.10	0.279#
	CBCT	12.43	2.08		
The distance between the alveolar ridges of adjacent teeth of mandibular first molars (46)	OPG	12.36	2.02	-0.06	0.412#
	CBCT	12.42	2.06		
The distance between the alveolar ridges of adjacent teeth of maxillary central incisors (11)	OPG	9.68	1.64	0.12	0.931##
	CBCT	9.56	1.67		
The distance between the alveolar ridges of adjacent teeth of maxillary central incisors (21)	OPG	9.79	1.70	0.12	0.958##
	CBCT	9.67	1.80		

#Paired t-test; ##Wilcoxon signed-rank test

Measurements of alveolar ridge distances using OPG and CBCT show negligible differences across various anatomical landmarks, with no statistically significant results (p > 0.05) according to paired t-tests and Wilcoxon signed-rank tests.



A bar graph presents the mean measurements for OPG and CBCT across various anatomical landmarks, including error bars for standard deviations. These findings indicate no significant differences between the two imaging modalities, supporting their interchangeable use in clinical practice for these measurements.

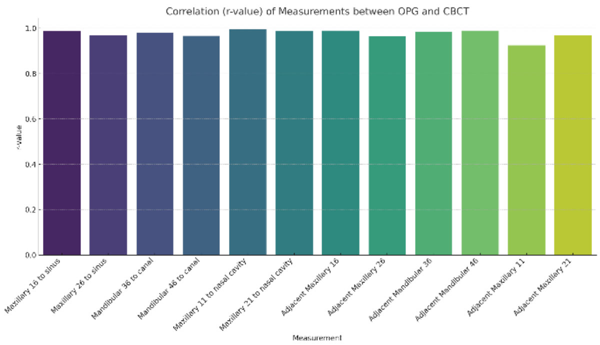
Correlation Between OPG and CBCT Measurements

Correlation Between OPG and CBCT Measurements		
Measurement	r-value	p-value
The distances between the alveolar ridges of maxillary first molars (16) and the bottoms of the maxillary sinus	0.988	<0.001*
The distances between the alveolar ridges of maxillary first molars (26) and the bottoms of the	0.968	<0.001*

maxillary sinus		
The distance between the alveolar ridges of mandibular first molars (36) and the inferior alveolar nerve canal	0.979	<0.001*
The distance between the alveolar ridges of mandibular first molars (46) and the inferior alveolar nerve canal	0.967	<0.001*
The distance between the alveolar ridge crest of maxillary central incisors (11) and the bottoms of the nasal cavities	0.994	<0.001*
The distance between the alveolar ridge crest of maxillary central incisors (21) and the bottoms of the nasal cavities	0.988	<0.001*
The distances between the alveolar ridges of the adjacent teeth of maxillary first molars (16)	0.990	<0.001*
The distances between the alveolar ridges of the adjacent teeth of maxillary first molars (26)	0.964	<0.001*
The distance between the alveolar ridges of adjacent teeth of mandibular first molars (36)	0.985	<0.001*
The distance between the alveolar ridges of adjacent teeth of mandibular first molars (46)	0.990	<0.001*
The distance between the alveolar ridges of adjacent teeth of maxillary central incisors (11)	0.924	<0.001*
The distance between the alveolar ridges of adjacent teeth of maxillary central incisors (21)	0.968	<0.001*

Measurements of alveolar ridge distances using OPG and CBCT show negligible differences across various anatomical landmarks, with no statistically significant results ($p > 0.05$) according to paired t-tests and Wilcoxon signed-rank tests.

The test used is Pearson's correlation coefficient (r-value), showing a strong positive correlation ($r = 0.924–0.994$) between OPG and CBCT measurements, with p-values <0.001 indicating high statistical significance.



A bar graph illustrates the correlation (r-value) of measurements between OPG and CBCT across various anatomical landmarks. All p-values are less than 0.001, indicating significant correlations.

The analysis demonstrates a consistently strong positive correlation between measurements obtained using OPG and CBCT for various anatomical landmarks in both the maxilla and mandible. These findings highlight the reliability and compatibility of OPG and CBCT in assessing critical dental and anatomical relationships, supporting their use in diagnostic and treatment planning.

4. LIMITATIONS AND FUTURE DIRECTIONS

Limitations

1. Sample Size

The study's small sample size (n=8) limits the statistical power and generalizability of the findings. Future studies should include larger and more diverse cohorts, considering factors like age, gender, and dental conditions, to enhance applicability.

Future Directions:

- Conduct larger, diverse studies.

- Include participants with varying dental conditions.
- Perform longitudinal studies assessing treatment stages.

2. Technological Variability

Variations in CBCT and OPG machines, settings, and operator expertise can affect accuracy. Standardizing protocols and adopting AI tools may reduce discrepancies.

Future Directions:

- Standardize imaging protocols.
- Develop automated measurement systems.
- Provide clinician training.

3. Cost and Accessibility

The high cost and limited availability of CBCT restrict its adoption. Strategies to reduce costs and promote hybrid imaging methods could improve accessibility.

Future Directions:

- Explore cost-reduction strategies.
- Optimize OPG for routine use and reserve CBCT for complex cases.
- Advocate for subsidized imaging technologies in underserved areas.

Discussion

Dental radiography plays a crucial role in the diagnosis, treatment planning, and management of oral and maxillofacial conditions. The advent of advanced imaging techniques, such as Cone Beam Computed Tomography (CBCT), has significantly enhanced the precision of radiographic evaluations, particularly in the assessment of alveolar bone dimensions and anatomical landmarks. This study compares the diagnostic accuracy of digital panoramic radiography (OPG) and CBCT in evaluating alveolar ridge measurements and their correlation with critical maxillary-mandibular structures.

The present study analyzed the ability of OPG and CBCT to measure distances between the alveolar ridges and adjacent anatomical landmarks. The results indicate that while both imaging modalities yield comparable mean values for various anatomical distances, CBCT offers a more precise three-dimensional representation. However, the differences between OPG and CBCT measurements were not statistically significant ($p > 0.05$), suggesting that OPG remains a viable diagnostic tool in routine clinical settings.

One of the key findings of this study was the high correlation between OPG and CBCT measurements, as indicated by Pearson's correlation coefficient ($r = 0.924$–0.994, $p < 0.001$). This strong positive correlation suggests that OPG can reliably approximate CBCT measurements for certain clinical applications. Nevertheless, CBCT remains the superior modality in cases requiring enhanced spatial resolution and volumetric assessment.

The ability to accurately measure the distances between the alveolar ridges and adjacent anatomical landmarks is critical in several dental procedures, including implant placement, periodontal surgeries, and orthodontic treatments. CBCT's three-dimensional imaging provides enhanced visualization of alveolar bone topography, allowing clinicians to make more informed treatment decisions, particularly in complex cases involving sinus proximity, nerve canal assessments, and bone grafting.

For implant planning, CBCT's precise measurement capabilities are essential in determining optimal implant positioning, avoiding iatrogenic damage to the inferior alveolar nerve, and ensuring adequate bone volume for osseointegration. Similarly, in orthodontics, CBCT allows for more detailed evaluations of jaw relationships, enabling precise treatment planning. In contrast, OPG, while effective in providing an overall view of dental and skeletal structures, lacks depth perception and may be limited in detecting subtle bone deficiencies.

Conclusion

This study highlights the comparative efficacy of OPG and CBCT in evaluating alveolar bone dimensions and their correlation with anatomical landmarks. While OPG provides a reliable and cost-effective method for routine clinical assessments, CBCT's superior three-dimensional accuracy makes it indispensable for complex cases requiring enhanced spatial visualization.

The high correlation between OPG and CBCT measurements ($r = 0.924$–0.994, $p < 0.001$) reinforces the validity of OPG as an alternative to CBCT in standard diagnostic applications. However, CBCT remains the preferred modality when precise bone volume assessments, implant planning, or surgical interventions are required.

The findings of this study support the selective use of CBCT, advocating for its application in scenarios where conventional radiography falls short. Future research should focus on optimizing CBCT technology to reduce radiation exposure, improving cost-efficiency, and integrating artificial intelligence for automated analysis to further enhance diagnostic precision. Moreover, large-scale studies with diverse populations should be conducted to validate these findings and establish standardized radiographic protocols for periodontal and implant treatment planning.

In conclusion, while OPG continues to serve as a fundamental imaging tool in dentistry, CBCT offers unparalleled diagnostic accuracy for complex maxillofacial evaluations. A judicious approach to imaging selection, balancing diagnostic necessity with patient safety, will ensure optimal treatment outcomes in modern dental practice.

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