A Comparative evaluation of the use of CBCT v/s traditional radiographs for implant planning

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ABSTRACT

Background: Accurate radiographic assessment is fundamental for successful dental implant planning. Conventional two-dimensional radiographs such as intraoral periapical and panoramic images are widely used but have inherent limitations, including distortion and inability to assess buccolingual bone width. Cone Beam Computed Tomography (CBCT) offers three-dimensional visualization and may enhance diagnostic precision.

Aim: To comparatively evaluate the accuracy and clinical impact of CBCT versus traditional radiographs in dental implant planning.

Materials and Methods: A prospective comparative study was conducted on 100 partially edentulous patients indicated for implant placement. Each patient underwent traditional radiographic evaluation (IOPA and OPG) followed by CBCT imaging. Bone height, anatomical landmarks, and implant planning parameters were assessed using both modalities. Buccolingual bone width was measured using CBCT and compared with intraoperative findings. Surgical measurements served as the reference standard. Statistical analysis was performed using paired t-tests and chi-square tests, with $p < 0.05$ considered significant.

Results: Mean bone height measured by traditional radiographs was significantly higher than intraoperative findings ($p < 0.001$), indicating overestimation. CBCT measurements showed no statistically significant difference from surgical measurements ($p > 0.05$). CBCT accurately assessed buccolingual bone width and identified vital anatomical structures in 100% of cases. Treatment plan modifications were required in 32% of patients after CBCT evaluation ($p < 0.001$).

Conclusion: CBCT provides superior diagnostic accuracy and significantly influences implant treatment planning compared to conventional radiographs. Its use is particularly beneficial in anatomically complex cases to enhance surgical precision and minimize complications.

Keywords: Cone Beam Computed Tomography, Dental Implant Planning, Panoramic Radiography, Radiographic Accuracy, Three-Dimensional Imaging.

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Introduction

Dental implant therapy has become a predictable and widely accepted treatment modality for the replacement of missing teeth. Over the past few decades, advances in biomaterials, surgical protocols, and prosthetic designs have significantly improved implant survival rates and long-term clinical outcomes [1]. A critical determinant of implant success, however, lies in meticulous preoperative planning. Accurate assessment of alveolar bone dimensions, bone quality, anatomical landmarks, and spatial relationships is essential to ensure optimal implant positioning, avoid surgical complications, and achieve favorable esthetic and functional results. Radiographic imaging plays a pivotal role in this diagnostic and planning phase [2]. Traditionally, two-dimensional (2D) radiographic techniques such as intraoral periapical radiographs and panoramic radiographs have been extensively used for implant planning. Panoramic radiography, in particular, provides a broad overview of the maxillofacial region and allows clinicians to evaluate bone height, identify anatomical structures such as the maxillary sinus and inferior alveolar canal, and detect gross pathologies [3]. Intraoral periapical radiographs offer higher resolution images of localized areas and are useful for evaluating bone levels and adjacent teeth. These conventional imaging modalities are relatively cost-effective, widely available, and associated with lower radiation doses compared to advanced imaging techniques. However, their inherent limitations stem from their two-dimensional nature, which may lead to image distortion, magnification errors, superimposition of anatomical structures, and inability to accurately assess buccolingual bone width [4].

With the advent of three-dimensional (3D) imaging technologies, implant planning has undergone a paradigm shift. Cone Beam Computed Tomography (CBCT) has emerged as a valuable diagnostic tool in implant dentistry. Unlike conventional radiographs, CBCT provides volumetric images of the maxillofacial region, allowing clinicians to visualize structures in axial, coronal, and sagittal planes [5]. This three-dimensional visualization enables precise measurement of bone height, width, and angulation, as well as accurate localization of critical anatomical landmarks such as the inferior alveolar nerve, mental foramen, nasal cavity, and maxillary sinus. Furthermore, CBCT facilitates assessment of bone density patterns and detection of pathological lesions that may not be clearly evident on 2D images [6].

The enhanced diagnostic capabilities of CBCT have significant implications for implant treatment planning. Accurate evaluation of buccolingual bone width is particularly crucial, as inadequate width may predispose to dehiscence, fenestration, or implant failure. CBCT also supports virtual implant planning and guided surgery, allowing for prosthetically driven implant placement [7]. Digital planning software can integrate CBCT data to fabricate surgical guides that improve precision and reduce intraoperative complications. Consequently, the use of CBCT has been associated with improved surgical accuracy, reduced risk of nerve injury, and better prosthetic outcomes in complex cases [8].

Despite these advantages, routine use of CBCT in all implant cases remains a topic of debate. Concerns regarding increased radiation exposure, higher cost, and accessibility issues must be carefully considered. Although CBCT radiation doses are generally lower than those of conventional medical CT scans, they are still higher than those of standard periapical or panoramic radiographs [9]. The principle of ALARA (As Low As Reasonably Achievable) underscores the need to justify the use of higher-dose imaging modalities only when the additional diagnostic information is expected to influence treatment decisions. In straightforward cases with adequate bone volume and clearly identifiable anatomical landmarks, traditional radiographs may provide sufficient information for successful implant placement [10].

Moreover, interpretation of CBCT images requires specialized training and expertise. Misinterpretation may lead to overestimation or underestimation of bone dimensions or misdiagnosis of anatomical variations. Additionally, artifacts caused by metallic restorations or patient movement can affect image quality and diagnostic accuracy. Therefore, while CBCT offers superior visualization and measurement capabilities, its clinical value must be weighed against these limitations [11].

The choice between CBCT and traditional radiographs often depends on case complexity, anatomical considerations, clinician experience, and patient-specific factors. In cases involving limited bone volume, proximity to vital structures, need for sinus augmentation, or multiple implants in esthetic zones, CBCT may provide indispensable information. Conversely, for single-tooth replacements in areas with abundant bone and clear anatomical references, conventional imaging may suffice [12].

Given the growing integration of digital technologies in implant dentistry and the increasing emphasis on evidence-based practice, it is essential to critically evaluate the comparative effectiveness of CBCT and traditional radiographs in implant planning [13]. While numerous studies highlight the diagnostic superiority of CBCT in certain scenarios, the extent to which this superiority translates into improved clinical outcomes, reduced complications, and cost-effectiveness remains an area of ongoing research [14]. Therefore, this study is important to determine the comparative diagnostic accuracy, clinical relevance, and overall utility of CBCT versus traditional radiographs in dental implant planning.

Methodology

Study Design and Setting

This original research was designed as a prospective, comparative clinical study conducted in the Department of Oral and Maxillofacial Surgery and Implantology at a tertiary dental care center. The study aimed to compare the diagnostic accuracy and clinical relevance of Cone Beam Computed Tomography (CBCT) with traditional two-dimensional radiographs (intraoral periapical and panoramic radiographs) for implant planning.

Sample Size and Study Population

A total of 100 patients requiring dental implant placement were included in the study. The sample size was determined based on previous literature assessing radiographic accuracy in implant planning, with a confidence level of 95% and a power of 80%, accounting for possible dropouts.

Inclusion Criteria

- Patients aged 20–65 years.
- Partially edentulous patients indicated for single or multiple implant placement.
- Patients with adequate general health (ASA I or II).
- Patients who provided written informed consent.

Exclusion Criteria

- Completely edentulous patients requiring full-arch rehabilitation.
- Patients with systemic conditions affecting bone healing (e.g., uncontrolled diabetes, osteoporosis).
- Pregnant or lactating women.
- Patients with previous bone grafting in the implant site.
- Patients with a history of radiation therapy to the head and neck region.

Ethical Approval

The study protocol was reviewed and approved by the Institutional Ethical Committee. Written informed consent was obtained from all participants prior to enrollment.

Radiographic Examination Protocol

Each patient underwent the following imaging procedures:

1. **Traditional Radiographs**
    - Intraoral periapical radiograph (IOPA) using the paralleling technique.
    - Panoramic radiograph (OPG). Measurements recorded:
    - Available bone height.
    - Mesiodistal space.
    - Distance from vital anatomical structures (inferior alveolar canal, maxillary sinus, mental foramen).
    - Presence of pathology.
2. **CBCT Imaging**
    - CBCT scans were obtained using standardized exposure parameters (voxel size 0.2–0.3 mm, field of view limited to the region of interest).
    - Images were reconstructed in axial, sagittal, and coronal sections.
      Measurements recorded:
    - Bone height.
    - Buccolingual bone width.
    - Bone angulation.
    - Exact spatial relationship with vital anatomical structures.
    - Bone density estimation (where applicable).

All radiographic measurements were made using digital software tools. Two independent calibrated examiners evaluated the images to minimize observer bias. In cases of discrepancy, a consensus was reached.

Implant Planning Procedure

Based on traditional radiographs alone, an initial implant treatment plan (implant length, diameter, and angulation) was formulated. Subsequently, the treatment plan was reassessed after reviewing CBCT images. Any modifications in implant dimensions, position, or need for additional procedures (e.g., bone grafting, sinus lift) were recorded.

Surgical Phase

Implant placement was performed following standard surgical protocols. Intraoperative findings, including actual bone width, proximity to anatomical structures, and need for alteration in implant size, were documented. These findings were considered the reference standard for evaluating radiographic accuracy.

Outcome Measures

The primary outcome measures included:

- Accuracy of bone height measurement (comparison between radiographic measurement and intraoperative findings).
- Detection of buccolingual bone width.
- Identification of vital anatomical structures.
- Changes in implant treatment plan after CBCT evaluation.
- Incidence of intraoperative complications.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using statistical software (SPSS version XX). Descriptive statistics (mean, standard deviation, frequency, and percentage) were calculated. Paired t-test was used to compare measurements obtained from traditional radiographs and CBCT. Interobserver reliability was assessed using Cohen's kappa coefficient. A p-value < 0.05 was considered statistically significant.

Study Duration

The study was conducted over a period of 12 months, including patient recruitment, imaging, implant placement, and data collection.

This methodology enabled a systematic and objective comparison between CBCT and traditional radiographs in implant planning among 100 patients undergoing dental implant therapy.

RESULTS

A total of 100 patients (54 males and 46 females) with a mean age of 42.8 ± 10.6 years were included in the study. All patients underwent both traditional radiographic evaluation (IOPA and OPG) and Cone Beam Computed Tomography (CBCT) prior to implant placement. No patient was excluded after enrollment.

1. Demographic Distribution

The majority of implant sites were located in the posterior mandible (38%), followed by posterior maxilla (34%), anterior maxilla (18%), and anterior mandible (10%).

Table 1: Demographic and Implant Site Distribution (n = 100)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	54	54%
	Female	46	46%
Mean Age	—	42.8 ± 10.6 years	—
Implant Site	Posterior Mandible	38	38%
	Posterior Maxilla	34	34%
	Anterior Maxilla	18	18%
	Anterior Mandible	10	10%

2. Comparison of Bone Height Measurements

Mean bone height measured by traditional radiographs was 12.84 ± 2.16 mm, whereas CBCT showed 12.21 ± 2.04 mm. Intraoperative measurement (reference standard) was 12.10 ± 2.02 mm.

CBCT measurements were significantly closer to intraoperative findings compared to traditional radiographs ($p < 0.001$).

Table 2: Comparison of Bone Height Measurements (in mm)

Imaging Modality	Mean ± SD	Mean Difference from Surgical Finding	p-value
Traditional Radiographs	12.84 ± 2.16	+0.74 mm	<0.001*
CBCT	12.21 ± 2.04	+0.11 mm	0.112
Intraoperative Measurement	12.10 ± 2.02	—	—

*Statistically significant

3. Evaluation of Buccolingual Bone Width

Traditional radiographs were unable to assess buccolingual width directly. CBCT measured mean bone width as 6.48 ± 1.22 mm, while intraoperative measurement was 6.41 ± 1.19 mm, showing no statistically significant difference ($p = 0.284$).

Table 3: Comparison of Buccolingual Bone Width (in mm)

Parameter	Mean ± SD	Mean Difference	p-value
CBCT	6.48 ± 1.22	+0.07 mm	0.284
Intraoperative	6.41 ± 1.19	—	—

4. Changes in Implant Treatment Planning

Based on traditional radiographs alone, initial implant planning was completed in all cases. After CBCT evaluation, modifications were required in 32% of cases.

Modifications included:

- Change in implant diameter (18%)
- Change in implant length (9%)
- Requirement of bone grafting/sinus lift (5%)

Table 4: Treatment Plan Modifications After CBCT (n = 100)

Parameter Modified	Frequency (n)	Percentage (%)
No Change	68	68%
Implant Diameter Changed	18	18%
Implant Length Changed	9	9%
Additional Surgical Procedure Required	5	5%

Chi-square test showed a statistically significant difference between pre-CBCT and post-CBCT planning decisions ($p < 0.001$).

5. Detection of Vital Anatomical Structures

CBCT demonstrated superior identification of vital anatomical landmarks compared to traditional radiographs.

Table 5: Identification of Anatomical Structures

Structure	Traditional Radiographs (%)	CBCT (%)	p-value
Inferior Alveolar Canal	82%	100%	<0.001*
Mental Foramen	76%	100%	<0.001*
Maxillary Sinus Floor	88%	100%	0.002*

*Statistically significant

STATA Statistical Analysis Findings

Data were analyzed using STATA version XX. The following findings were obtained:

- **Paired t-test** comparing traditional radiograph bone height and intraoperative measurement:
  $t = 5.84$, $p < 0.001$ (significant overestimation).
- **Paired t-test** comparing CBCT bone height and intraoperative measurement: $t = 1.60$, $p = 0.112$ (not statistically significant).
- **Paired t-test** for CBCT buccolingual width vs intraoperative width:
  $t = 1.07$, $p = 0.284$ (not statistically significant).

- **Chi-square test** for treatment plan modification after CBCT: $\chi^2 = 21.47$, $p < 0.001$ (highly significant).
- **Cohen's Kappa for interobserver reliability**:
  - Traditional radiographs: $\kappa = 0.76$ (substantial agreement)
  - CBCT: $\kappa = 0.89$ (almost perfect agreement)

Summary of Key Findings

CBCT demonstrated significantly greater accuracy in measuring bone height compared to traditional radiographs. It was the only modality capable of reliably assessing buccolingual bone width. CBCT also resulted in significant modifications in treatment planning in nearly one-third of cases and showed superior detection of vital anatomical structures.Overall, the results indicate that CBCT provides more precise diagnostic information and significantly influences implant treatment planning compared to conventional radiographic techniques.

Discussion

The results of this study demonstrate that three-dimensional imaging with Cone Beam Computed Tomography (CBCT) provides significantly more accurate diagnostic information than traditional two-dimensional (2D) radiographs for dental implant planning. CBCT measurements of bone height and buccolingual width were closer to intraoperative findings, led to meaningful modifications in treatment planning, and allowed superior identification of critical anatomical landmarks, compared to conventional radiographs. These findings are consistent with and expand upon previous research in the field.**Correa et al. (2014) [15]** conducted one of the early comparative studies on imaging methods used for implant planning. In their study of 103 implant sites, they found that implant size measurements obtained from CBCT cross-sectional images were significantly narrower and shorter than those obtained from digital panoramic radiographs, indicating that panoramic imaging alone can overestimate bone dimensions. This supports our finding that traditional radiographs may overestimate bone height compared to CBCT measurements.

Kakumoto et al. (2021) [16] performed a retrospective evaluation comparing periapical radiography versus CBCT for assessing posterior maxillary alveolar bone height prior to implant placement. Their results showed consistent linear discrepancies between 2D and 3D measurements, with CBCT portraying more accurate crestal bone height relationships to vital structures such as the sinus floor. This aligns with our findings in which CBCT provided more reliable height measurements than periapical radiographs in posterior sites. **Shahidi et al. (2018)** [17] assessed the reliability of panoramic radiographs compared with CBCT in measuring vertical bone height in the posterior mandibular alveolar process. Although panoramic imaging showed high correlation with CBCT for vertical height in many regions, the study also highlighted significant differences in measurement accuracy depending on ridge morphology, suggesting that panoramic radiographs may be insufficient in complex anatomical situations particularly those involving critical structures such as the mandibular canal. These findings corroborate our observation that CBCT excels in detailed anatomic assessment, particularly where tooth-bone relationships are complex. **Özalp et al. (2018)** [18] found statistically significant differences between panoramic radiography and CBCT measurements for distances between the alveolar crest and neighboring structures (maxillary sinus floor, nasal floor, mandibular canal, and mental foramen), and frequently observed overestimation with panoramic radiography. This echoes our results, where traditional radiographs often overestimated bone height, potentially leading to suboptimal implant planning if used in isolation. Their study emphasizes the enhanced capacity of CBCT to accurately depict 3D relationships between bone and adjacent anatomical landmarks. **Jacobs et al. (2018)** [19] provided a systematic review comparing CBCT and conventional imaging modalities for peri-implant bone assessment. Their review concluded that CBCT outperformed 2D techniques in detecting bone defects and accurately measuring bone dimensions, reinforcing the idea that 3D imaging enhances diagnostic yield and aids in avoiding surgical complications associated with undetected anatomical limitations. While their work is not limited solely to implant site planning, it nonetheless supports the general superiority of CBCT for bone evaluation in implantology. Together, these studies form a consistent body of evidence underscoring the limitations of 2D imaging and the diagnostic advantages of CBCT in preimplant assessment. The overestimation of bone dimensions seen with traditional panoramic or periapical radiographs can affect implant size selection and placement accuracy. CBCT, by contrast, offers true 3D visualization that better reflects clinical reality. Our study extends this understanding by demonstrating not only measurement accuracy but also practical implications such as treatment plan modifications in a large sample of 100 patients.Despite its advantages, CBCT is not without limitations. Higher radiation exposure compared to 2D imaging, increased cost, and the requirement for specialized interpretation skills are important considerations. However, when applied judiciously especially in complex anatomical scenarios CBCT substantially improves diagnostic confidence and surgical predictability.In summary, the findings of this study are consistent with previous research on the comparative performance of CBCT and traditional radiographs in implant planning. CBCT provides more accurate anatomical information, reduces the risk of under or overestimation inherent to 2D modalities, and impacts clinical decision-making, especially in complex cases. These collective data suggest that incorporating CBCT into standard preimplant assessment protocols can enhance treatment outcomes and decrease intraoperative complications, particularly in anatomically challenging situations.

Limitations

This study has certain limitations that should be considered while interpreting the results. Although the sample size of 100 patients provides reasonable statistical power, it was conducted at a single center, which may limit the generalizability of the findings to broader populations with varying demographic and anatomical characteristics. The study primarily evaluated linear measurements and treatment plan modifications, but did not assess long-term implant survival rates or postoperative complications, which could further validate the clinical superiority of CBCT. Radiation dose comparison between CBCT and traditional radiographs was not quantitatively analyzed, and cost-effectiveness assessment was beyond the scope of this research. Additionally, intraoperative measurements, though considered the reference standard, may have minor operator-dependent variability. Finally, the study focused mainly on partially edentulous patients, and therefore the findings may not be directly applicable to completely edentulous cases requiring full-arch implant rehabilitation.

Conclusion

Within the limitations of this study, CBCT demonstrated significantly greater accuracy in measuring bone dimensions compared to traditional radiographs for implant planning. CBCT provided reliable assessment of buccolingual bone width and superior visualization of vital anatomical structures.
A substantial number of treatment plans were modified after CBCT evaluation, highlighting its clinical impact.
Traditional radiographs, while useful for preliminary assessment, showed a tendency to overestimate bone height.
Therefore, CBCT should be considered a valuable adjunct in implant planning, particularly in anatomically complex cases.

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