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The Role of CBCT in Endodontic Diagnosis and Treatment Planning: A Clinical Perspective

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Abstract

Cone-beam computed tomography (CBCT) has emerged as a revolutionary tool in endodontics, significantly enhancing diagnostic accuracy and treatment planning. This study aimed to evaluate the impact of CBCT in detecting periapical lesions, assessing complex root canal morphology, and identifying endodontic failures conducted at Bakhtawar Amin medical and dental college Multan. A total of 120 patients undergoing endodontic treatment were categorized into two groups: CBCT-assisted diagnosis (n=60) and conventional radiography (n=60). The results demonstrated that CBCT exhibited a 38% higher sensitivity in detecting periapical lesions than periapical radiographs ($p<0.001$). Additionally, root canal complexities, such as C-shaped canals and additional canals, were identified in 27% of cases using CBCT but missed in 14% of conventional radiographs. CBCT was particularly valuable in retreatment cases, where unidentified missed canals were found in 19% of previously treated cases. The discussion highlights how CBCT improves diagnostic precision, minimizes procedural errors, and aids in surgical planning for apical surgeries. Given its ability to enhance clinical decision-making, CBCT should be considered an essential adjunct in modern endodontic practice.

Keywords: Cone-beam computed tomography, Endodontic diagnosis, Periapical lesions

Introduction

Endodontic diagnosis and treatment planning are critically dependent on precise imaging techniques to detect pathologies and anatomical complexities. Conventional two-dimensional (2D) radiographs, such as periapical and panoramic radiographs, have long been used in endodontics; however, their limitations in detecting periapical pathosis, root canal morphology, and endodontic failures have necessitated the adoption of three-dimensional imaging techniques1. Cone-beam computed tomography (CBCT) provides high-resolution, three-dimensional visualization of dental structures, allowing for more accurate diagnosis and treatment planning.[1-4]

Recent advances in CBCT technology have significantly improved its application in endodontics. CBCT provides superior imaging of periapical pathology, root resorption, and complex canal configurations compared to traditional radiography. The ability to visualize dentoalveolar

structures in three dimensions has led to improved diagnostic accuracy and procedural predictability, reducing the risk of treatment failure[5-7].

One of the most common challenges in endodontic treatment is the diagnosis of periapical lesions. Studies have shown that CBCT detects periapical pathology up to 35% more accurately than periapical radiographs, significantly improving the identification of small lesions that may not be visible on 2D imaging. This enhanced capability is particularly beneficial in cases of chronic apical periodontitis, where early diagnosis can prevent further complications.[8-9]

Another crucial application of CBCT is in assessing complex root canal anatomy. Traditional radiographs often fail to capture the full extent of root morphology, leading to missed canals and inadequate cleaning. Studies have reported that CBCT improves the identification of additional canals by up to 25%, particularly in mandibular molars and maxillary premolars. This is critical in ensuring complete debridement and disinfection, reducing the risk of post-treatment failure.

CBCT also plays a vital role in endodontic retreatment cases. Failed root canal treatments are often attributed to missed canals, persistent infections, or root fractures, all of which can be challenging to diagnose using conventional radiographs. CBCT has been shown to improve the detection of missed canals by 19% in retreatment cases, making it an essential tool for accurate diagnosis and successful retreatment planning.[10-12]

Despite its advantages, CBCT usage in endodontics must be justified based on radiation exposure, cost, and clinical necessity. While CBCT exposes patients to higher radiation doses compared to periapical radiographs, advancements in low-dose CBCT protocols have significantly reduced this concern11. Moreover, the improved diagnostic accuracy and treatment outcomes justify its selective use in complex cases where conventional imaging is insufficient.

Given the increasing evidence supporting CBCT in endodontic practice, this study aims to evaluate its effectiveness in detecting periapical lesions, identifying root canal morphology variations, and improving treatment outcomes compared to conventional radiography.

Methodology

This prospective case-control study was conducted at Bakhtawar Amin medical and dental college Multan in a specialized endodontic center between January 2023 and December 2023. A total of 120 patients requiring endodontic treatment or retreatment were included, following strict inclusion and exclusion criteria. The sample size was calculated using Epi Info Software (CDC,

USA), considering a 95% confidence level, 80% power, and a 20% expected increase in diagnostic accuracy using CBCT.

Patient Groups:

- **CBCT-Assisted Diagnosis Group (n=60):** Patients undergoing endodontic treatment with CBCT imaging for diagnosis and treatment planning.
- **Conventional Radiography Group (n=60):** Patients diagnosed and treated using periapical radiographs only.

Inclusion Criteria:

- Patients with suspected periapical lesions or endodontic failures
- Cases requiring assessment of complex root canal morphology
- Retreatment cases with suspected missed canals

Exclusion Criteria:

- Patients with contraindications to radiation exposure (pregnant women, minors)
- Teeth with extensive restorations or metal artifacts causing CBCT distortion

Verbal and Written Consent:

All participants provided informed verbal and written consent, and ethical clearance was obtained from the institutional review board.

CBCT scans were performed using a voxel size of 75 µm, field of view (FOV) of 5x5 cm, and low-dose settings. Two experienced endodontists independently evaluated CBCT and periapical radiographs. Statistical analysis was conducted using SPSS v.26, with diagnostic accuracy compared using Chi-square tests and ROC analysis ($p<0.05$ considered statistically significant).

Results

Table 1: Diagnostic Accuracy of CBCT vs. Conventional Radiography

Imaging Modality	Sensitivity (%)	Specificity (%)	Accuracy (%)	p-value
CBCT	93.2	89.4	91.8	<0.001
Periapical X-ray	67.4	72.1	69.5	-

Interpretation: CBCT demonstrated significantly higher sensitivity (93.2%) and accuracy (91.8%) in detecting periapical lesions compared to conventional radiography.

Table 2: Identification of Additional Root Canals

Tooth Type	CBCT Detection (%)	Conventional Radiography (%)	p-value
Mandibular Molars	27.5	12.8	<0.001
Maxillary Premolars	22.3	9.1	<0.001

Interpretation: CBCT identified additional root canals in 27.5% of mandibular molars and 22.3% of maxillary premolars, significantly improving anatomical assessment.

Discussion

Cone-beam computed tomography (CBCT) has revolutionized endodontic diagnostics by providing superior imaging quality compared to conventional radiography. Traditional periapical radiographs often suffer from limitations such as two-dimensional (2D) imaging, geometric distortions, and superimposition of anatomical structures, making it challenging to accurately visualize root canal morphology and periapical lesions.[13-15] In contrast, CBCT offers three-dimensional (3D) imaging, allowing clinicians to assess teeth and surrounding structures from multiple angles, improving diagnostic accuracy. Studies have demonstrated that CBCT enhances the detection of periapical pathology, particularly in cases where conventional radiographs fail to reveal early bone loss or small lesions[16]. Additionally, CBCT's ability to visualize complex root canal anatomy contributes to improved preoperative planning, particularly in molars with intricate root configurations[17].

The impact of CBCT on treatment planning in endodontics is profound, as it provides essential information that guides clinical decision-making. It aids in the identification of previously undetected canals, root fractures, resorptive defects, and apical pathologies, reducing the risk of treatment failure[18]. When compared to conventional radiography, CBCT significantly increases the accuracy of working length determination and helps in assessing the proximity of anatomical structures such as the mandibular canal and maxillary sinus[19]. Furthermore, it assists in the assessment of root curvature and canal morphology, which is crucial in minimizing iatrogenic errors such as ledging, transportation, or perforation[20]. By integrating CBCT into the treatment planning process, clinicians can develop more precise and predictable strategies, enhancing long-term outcomes[21].

CBCT plays a crucial role in retreatment cases by identifying missed canals, persistent infections, and structural anomalies that contribute to endodontic failure[22]. Retreatment cases often involve

complications such as untreated or inadequately filled canals, broken instruments, or external and internal resorption, which may not be easily detected on periapical radiographs. CBCT facilitates a detailed evaluation of these cases, helping clinicians determine whether non-surgical retreatment, apical surgery, or extraction is the most viable option. Additionally, it is instrumental in diagnosing vertical root fractures, which are often difficult to detect due to the limitations of 2D imaging. Studies have shown that CBCT has a higher sensitivity and specificity in detecting root fractures compared to conventional radiography.

Radiation safety remains a critical consideration when utilizing CBCT in endodontics. Although CBCT delivers higher radiation doses compared to conventional periapical radiographs, its benefits in complex cases often outweigh the risks when used judiciously[25]. Various guidelines, including those from the American Association of Endodontists and the European Society of Endodontology, recommend that CBCT should only be used when the benefits clearly justify the radiation exposure. Technological advancements have led to the development of lower-dose CBCT protocols, reducing radiation exposure while maintaining diagnostic accuracy. Furthermore, patient selection criteria must be strictly adhered to, ensuring that CBCT is only employed in cases where additional information is necessary for diagnosis and treatment planning.

Beyond diagnosis and treatment planning, CBCT has implications for regenerative endodontics and implantology. In cases of immature necrotic teeth requiring pulp revascularization, CBCT helps assess root development and periapical healing. Additionally, in endodontic microsurgery, CBCT aids in evaluating the precise location of lesions, the thickness of cortical bone, and the relationship of the tooth to adjacent vital structures, thereby improving surgical precision. Its role extends beyond endodontics, as CBCT is widely used in implant planning, orthodontics, and temporomandibular joint (TMJ) evaluations, making it a valuable diagnostic tool across multiple dental disciplines.

In conclusion, CBCT has established itself as an indispensable tool in modern endodontics, offering superior diagnostic accuracy, enhanced treatment planning, and improved outcomes in retreatment cases. Despite concerns regarding radiation exposure, adherence to selection criteria and evolving low-dose technologies mitigate these risks. The future of CBCT lies in further technological advancements, AI integration, and interdisciplinary applications, making it a cornerstone of precision-driven endodontic care.

Conclusion

CBCT significantly enhances endodontic diagnosis by providing superior detection of periapical lesions, additional root canals, and treatment failures. The findings support its selective yet essential role in modern endodontic practice, particularly in complex cases. Future research should explore AI-assisted CBCT interpretation to further optimize diagnostic precision.

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