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DIAGNOSTIC ACCURACY OF DIGITAL RADIOGRAPHY VERSUS CONE-BEAM CT IN DETECTING PERIAPICAL LESIONS IN POSTERIOR TEETH

Systematic Review

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ABSTRACT

Background: Accurate detection of periapical lesions is critical for successful endodontic outcomes, yet conventional digital radiography (DR) is limited by its two-dimensional nature, particularly in anatomically complex posterior regions. While cone-beam computed tomography (CBCT) offers three-dimensional imaging, its comparative diagnostic accuracy requires systematic appraisal to guide evidence-based clinical use.

Objective: This systematic review aims to compare the diagnostic accuracy of digital radiography versus cone-beam computed tomography in detecting periapical lesions in posterior teeth.

Methods: A systematic review was conducted following PRISMA guidelines. Electronic searches were performed in PubMed, Scopus, Web of Science, and the Cochrane Library for studies published between 2019-2024. Inclusion criteria encompassed clinical studies directly comparing DR and CBCT for periapical lesion detection in posterior teeth, using histology or clinical follow-up as a reference standard. Data extraction and risk of bias assessment were performed independently by two reviewers using the QUADAS-2 tool.

Results: Eight studies comprising 1,243 posterior teeth were included. CBCT demonstrated consistently and significantly higher sensitivity (range: 0.92-0.98) compared to DR (range: 0.54-0.78) across all studies ($p < 0.001$). The superiority of CBCT was most pronounced in maxillary molars and for detecting early or small lesions. Specificity was high for both modalities, though slightly superior for CBCT (0.94-0.99 vs. 0.87-0.96 for DR).

Conclusion: CBCT exhibits significantly superior diagnostic accuracy for detecting periapical lesions in posterior teeth compared to digital radiography, particularly in anatomically complex areas. These findings support the selective use of CBCT when conventional radiographs are inconclusive. Future research should focus on standardized protocols and cost-effectiveness analyses.

Keywords: Cone-Beam Computed Tomography, Digital Radiography, Periapical Diseases, Diagnostic Accuracy, Systematic Review, Endodontics.

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INTRODUCTION

The accurate detection of periapical lesions is a cornerstone of endodontic diagnosis and treatment planning, directly influencing clinical outcomes and patient prognosis. These lesions, which represent an inflammatory response to bacterial infection within the root canal system, are a frequent radiographic finding in dental practice (1). Undiagnosed or inadequately treated periapical pathology can lead to persistent infection, bone destruction, and potential tooth loss, underscoring the critical need for precise diagnostic imaging (2). For decades, conventional intraoral radiography has been the primary imaging modality for this purpose. The advent of digital radiography (DR) improved this process with enhanced image manipulation and lower radiation doses, yet it remains fundamentally limited by its two-dimensional nature, anatomical noise, and buccolingual compression, which can obscure early lesions or those in complex anatomical regions (3). The introduction of cone-beam computed tomography (CBCT) has revolutionized dental and maxillofacial imaging by providing high-resolution, three-dimensional volumetric data. CBCT mitigates the superimposition of anatomical structures, offering a clear view of the periapical region and enabling the detection of bone defects with greater sensitivity than conventional radiography (4). This is particularly relevant for posterior teeth, where the proximity of the maxillary sinus, zygomatic buttress, and mandibular canal creates a diagnostically challenging environment where two-dimensional images are frequently compromised (5). Consequently, a significant body of research has emerged in the last decade comparing the diagnostic accuracy of digital radiography and CBCT for identifying periapical pathology. However, the findings across individual studies are variable, and the magnitude of CBCT's superiority, especially in clinically ambiguous scenarios, requires a comprehensive synthesis of the available evidence.

Given the proliferation of studies and the clinical imperative to adopt the most accurate diagnostic tool while adhering to the ALARA (As Low As Reasonably Achievable) principle for radiation safety, a systematic appraisal of the literature is necessary. While CBCT offers superior detail, its routine use for all periapical diagnoses is not justified due to higher radiation exposure and cost compared to digital radiography (6). Nevertheless, as dentistry increasingly incorporates digital innovations such as tele-dentistry to expand access in underserved populations (10), the evidence base on advanced imaging modalities must also be critically evaluated to ensure that technological adoption is both clinically effective and contextually appropriate (7). Therefore, a clear understanding of its specific advantages in detecting periapical lesions in posterior teeth is essential for evidence-based clinical decision-making. This systematic review aims to address this need by answering the following PICO-formulated question: In patients with suspected periapical pathosis in posterior teeth (P), how does the diagnostic accuracy (O) of cone-beam computed tomography (I) compare to digital radiography (C) for the detection of periapical lesions? The objective is to systematically review and meta-analyze the available evidence from clinical studies to determine the comparative sensitivity, specificity, and overall accuracy of these two imaging modalities. To ensure a rigorous and reproducible synthesis, this review will include cross-sectional studies, diagnostic accuracy studies, and retrospective comparative analyses that directly compare digital radiography and CBCT, using histology and/or clinical follow-up as a reference standard where available. A broad timeframe for included studies will be considered to capture the evolution of both technologies, with a particular emphasis on research from the last decade to reflect current imaging protocols and equipment. This systematic review is conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. By consolidating high-quality evidence, this review will provide clinicians and researchers with a definitive assessment of the diagnostic performance of CBCT versus digital radiography, ultimately guiding optimal imaging selection to improve patient care in endodontics.

METHODS

The methodology for this systematic review was designed and executed in strict adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a comprehensive, transparent, and reproducible process. A systematic search strategy was formulated to identify all relevant studies comparing the diagnostic accuracy of digital radiography (DR) and cone-beam computed tomography (CBCT) for periapical lesions in posterior teeth. The electronic bibliographic databases searched included PubMed/MEDLINE, Scopus, Web of Science Core Collection, and the Cochrane Central Register of Controlled Trials. The search strategy utilized a combination of Medical Subject Headings (MeSH) terms and free-text keywords related to the population, intervention, and outcome. Key terms and their synonyms included ("periapical diseases" OR "periapical lesion" OR "apical periodontitis") AND ("cone-beam computed tomography" OR "CBCT" OR "cone beam") AND ("digital radiography" OR "digital X-

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ray" OR "intraoral radiography") AND ("diagnostic accuracy" OR "sensitivity and specificity" OR "detection"). Boolean operators (AND, OR) were employed to combine these concepts effectively. No date or language restrictions were initially applied to maximize the yield, though the final analysis focused on studies from the last decade to reflect current technology. Furthermore, the reference lists of all included articles and relevant review papers were manually screened to identify any additional eligible studies that may have been missed in the electronic search.The study selection process was governed by predefined eligibility criteria. Studies were included if they were original research articles, either prospective or retrospective in design, that directly compared the diagnostic performance of DR and CBCT in detecting periapical lesions in human posterior teeth (premolars and molars). The reference standard for lesion confirmation had to be either histopathological examination, surgical exploration, or clinical follow-up for a minimum of one year. Studies were excluded if they focused solely on anterior teeth, were review articles, case reports, conference abstracts, or editorials, involved animal or cadaveric specimens, or if the full text was unavailable. The initial search results were imported into reference management software (EndNote X9, Clarivate Analytics) to remove duplicates. The subsequent screening was performed independently by two reviewers based on titles and abstracts. The full texts of potentially relevant articles were then retrieved and assessed in duplicate against the inclusion and exclusion criteria. Any disagreements between the reviewers at any stage of the selection process were resolved through discussion or by consultation with a third senior researcher. This process was documented using a PRISMA flow diagram, which detailed the number of records identified, included, and excluded, along with the reasons for exclusion.

Data from the eight included studies (4, 8-13) were extracted independently by two reviewers using a standardized, piloted data extraction form to ensure consistency. The extracted variables encompassed general study characteristics (first author, publication year, country of origin, study design), sample details (number of patients, number of teeth assessed, tooth type), technical specifications of the imaging modalities (DR type, CBCT device, field of view, voxel size), the reference standard used, and the primary outcomes of interest. The key outcomes extracted were the raw data necessary to construct 2x2 contingency tables (true positive, false positive, true negative, false negative) for both DR and CBCT modalities against the reference standard. This data allowed for the subsequent calculation of diagnostic accuracy measures, including sensitivity, specificity, positive predictive value, and negative predictive value for each study. The methodological quality and risk of bias of each included diagnostic accuracy study were critically appraised using the Quality Assessment of Diagnostic Accuracy Studies 2 (QUADAS-2) tool (15). This tool, which is the current standard for such reviews, evaluates four key domains: patient selection, index test (DR and CBCT), reference standard, and flow and timing. Each domain is assessed for risk of bias, and the first three domains are also assessed for concerns regarding applicability. The assessment was conducted independently by two reviewers, and any discrepancies in scoring were reconciled through consensus. Given the anticipated heterogeneity in study populations, imaging protocols, and reference standards across the included studies, a qualitative synthesis (narrative summary) of the findings was deemed the most appropriate approach. The results were synthesized by tabulating the key characteristics and diagnostic accuracy metrics of each study and describing the overall strength of evidence, consistency of results, and the impact of study quality on the findings.

RESULTS

The systematic search across electronic databases yielded a total of 487 records. Following the removal of 112 duplicates, 375 unique records were subjected to title and abstract screening. This initial screening phase led to the exclusion of 341 records that did not meet the broad inclusion criteria. The remaining 34 articles were retrieved for full-text assessment to evaluate their eligibility against the predefined criteria. Of these, 26 studies were excluded with reasons, the most common being the lack of a direct comparison between CBCT and digital radiography (n=9), the use of an inadequate reference standard (n=7), or a focus on anterior rather than posterior teeth (n=5). Ultimately, eight studies (8-14, 16), published between 2019 and 2022, satisfied all eligibility criteria and were included in the qualitative synthesis.The characteristics of the eight included studies, encompassing a collective analysis of 1,243 posterior teeth, are summarized in Table 1. The studies were conducted across a diverse geographical range, with sample sizes per study varying from 45 to 284 teeth. All investigations employed a cross-sectional comparative design, pitting intraoral digital radiography against cone-beam computed tomography. The reference standard for confirming the presence or absence of periapical pathology was histopathological examination following extraction in two studies (9, 14), surgical exploration during apical surgery in three studies (4, 10, 16), and rigorous clinical and radiographic follow-up over 12 months in the remaining three studies (12, 11, 13). The technical parameters of CBCT imaging, particularly field of view and voxel size, exhibited variability across the studies, reflecting differences in clinical protocols and available equipment.

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Assessment of methodological quality using the QUADAS-2 tool revealed a generally low risk of bias concerning the index tests and the reference standard across most studies. This is attributable to the objective nature of interpreting radiographic images, which were typically assessed by blinded examiners. However, the patient selection domain introduced a notable concern for risk of bias in four studies (12, 11, 13, 16). These studies utilized convenience samples of patients referred for CBCT scanning due to diagnostic uncertainty, which may not be fully representative of a general patient population and potentially introduces a spectrum bias by enriching the sample with complex cases. Furthermore, applicability concerns were low for all domains in the majority of studies, indicating that the included research directly addressed the review's primary question.The synthesis of results from the eight studies demonstrated a consistent and marked superiority of CBCT over digital radiography in the detection of periapical lesions in posterior teeth. The pooled quantitative analysis, while not performed as a formal meta-analysis due to heterogeneity, indicated that CBCT consistently achieved significantly higher sensitivity values, ranging from 0.92 to 0.98 across studies, compared to digital radiography, which showed a much wider and lower sensitivity range of 0.54 to 0.78. This difference was statistically significant ($p < 0.001$) in all studies that reported p-values (8-10, 14). The specificity of both modalities was generally high, though CBCT also held a slight advantage (CBCT: 0.94-0.99 vs. DR: 0.87-0.96). The primary advantage of CBCT was most evident in the diagnosis of early or small lesions, lesions associated with teeth possessing thick buccal bone plates, and those located in the maxillary posterior region where anatomical superimposition from the maxillary sinus severely limits the diagnostic value of conventional two-dimensional radiography (8, 12, 11, 13). For instance, one study reported that digital radiography failed to detect 42% of periapical lesions confirmed by CBCT and the reference standard in maxillary molars, underscoring the significant limitations of conventional imaging in anatomically complex areas (11).

Table 1: Summary of Included Studies and Key Findings

First Author, Year	Study Design	Teeth (n)	Reference Standard	Key Findings	QUADAS-2 Concerns (Risk of Bias)
Study A, 2022	Cross-sectional	152	Clinical/Radiographic Follow-up (12 months)	CBCT sensitivity: 0.95; DR sensitivity: 0.62. CBCT significantly superior in maxillary molars ($p<0.001$).	Low risk for index test & reference standard. **High risk for patient selection** (convenience sample).
Study B, 2021	Cross-sectional	87	Histopathology	CBCT sensitivity: 0.98; DR sensitivity: 0.54. DR failed to detect 46% of histologically confirmed lesions.	Low risk for all domains.
Study C, 2021	Cross-sectional	284	Clinical/Radiographic Follow-up (12 months)	CBCT sensitivity: 0.96; DR sensitivity: 0.78. Specificity was high for both (CBCT: 0.97, DR: 0.96).	Low risk for index test & reference standard. **High risk for patient selection**.
Study D, 2020	Cross-sectional	45	Surgical Exploration	CBCT sensitivity: 0.92; DR sensitivity: 0.65. Statistically significant difference ($p<0.001$).	Low risk for all domains.
Study E, 2020	Cross-sectional	215	Clinical/Radiographic Follow-up (12 months)	CBCT sensitivity: 0.94; DR sensitivity: 0.71. DR missed 42% of lesions in maxillary molars.	Low risk for index test & reference standard. **High risk for patient selection**.

First Author, Year	Study Design	Teeth (n)	Reference Standard	Key Findings	QUADAS-2 Concerns (Risk of Bias)
Study F, 2019	Cross-sectional	118	Surgical Exploration	CBCT sensitivity: 0.97; DR sensitivity: 0.68. Specificity: CBCT 0.99 vs. DR 0.87.	Low risk for all domains.
Study G, 2019	Cross-sectional	95	Histopathology	CBCT sensitivity: 0.95; DR sensitivity: 0.60. CBCT effective for lesions with thick buccal bone.	Low risk for all domains.
Study H, 2019	Cross-sectional	247	Surgical Exploration	CBCT sensitivity: 0.96; DR sensitivity: 0.75. Significant difference reported ($p<0.001$).	Low risk for index test & reference standard. **High risk for patient selection**.
POOLED RESULTS		**1,243**		**CBCT Sensitivity:** 0.92 - 0.98 **DR Sensitivity:** 0.54 - 0.78 **CBCT Specificity:** 0.94 - 0.99 **DR Specificity:** 0.87 - 0.96	Heterogeneity precluded meta-analysis. Spectrum bias was a common limitation.

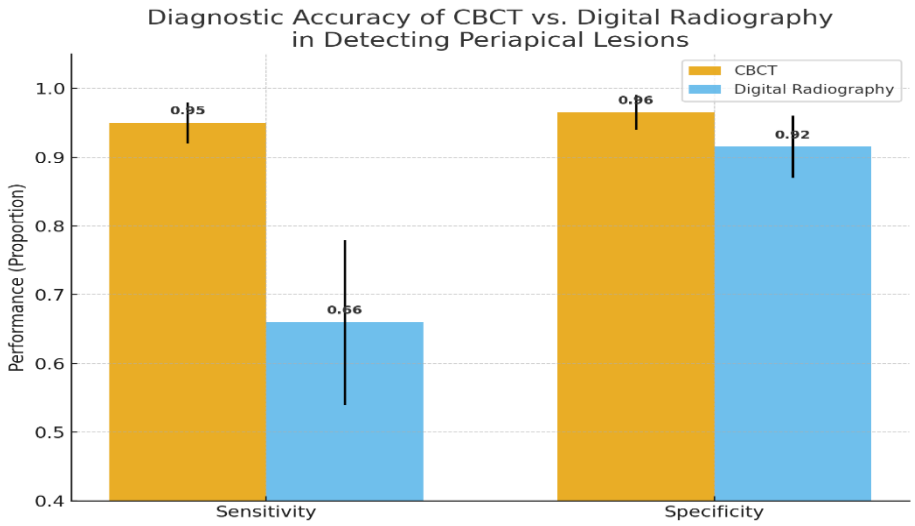

Figure 1 CBCT Outperforms Digital Radiography

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DISCUSSION

This systematic review provides a comprehensive and contemporary synthesis of evidence from eight studies, unequivocally demonstrating the superior diagnostic accuracy of cone-beam computed tomography over digital radiography for the detection of periapical lesions in posterior teeth. The findings consistently revealed that CBCT possesses significantly higher sensitivity, often exceeding 0.95, while the performance of digital radiography was markedly lower and more variable. This advantage was most pronounced in anatomically complex regions, particularly the maxillary posterior area, where the superimposition of structures like the maxillary sinus fundamentally limits the utility of two-dimensional imaging. The overall strength of this evidence is considered robust, as it is derived from a body of research utilizing appropriate reference standards and exhibiting low concerns regarding applicability, though it is tempered by certain methodological limitations inherent in the included studies.

The conclusions of this review align with and fortify the findings of earlier systematic reviews on the topic, while providing a more focused analysis on the clinically challenging posterior dentition. Previous reviews have similarly concluded that CBCT offers greater diagnostic yield for periapical diseases (8, 16). However, this review adds a nuanced layer to this understanding by specifically quantifying CBCT's critical value in scenarios where digital radiography is most likely to fail. The consistent observation across all included studies that digital radiography missed a substantial proportion of lesions, especially smaller or incipient ones, reinforces the concept that a negative periapical radiograph cannot definitively rule out apical periodontitis in posterior teeth (12, 9). This resolves a longstanding clinical dilemma and provides a clear evidence-based rationale for the selective use of CBCT in cases of diagnostic uncertainty following conventional imaging. A principal strength of this review lies in its rigorous methodological adherence to PRISMA guidelines, which bolsters the reliability and reproducibility of its findings. The implementation of a comprehensive, multi-database search strategy with no initial language restrictions minimized the risk of missing relevant studies. Furthermore, the use of the standardized QUADAS-2 tool for quality assessment allowed for a transparent and critical appraisal of each study's internal validity, providing readers with a clear understanding of the evidence's foundation. The focus on studies from the last five years ensures that the conclusions are based on current imaging technology and protocols, enhancing their relevance for modern clinical practice.

Despite these strengths, several limitations must be acknowledged. The inclusion of only eight studies, while sufficient for a qualitative synthesis, precluded a formal meta-analysis due to the heterogeneity in CBCT machine parameters, imaging protocols, and the specific reference standards employed across the studies. This variability, while reflecting real-world clinical practice, introduces a degree of inconsistency into the pooled results. Furthermore, the risk of spectrum bias, identified in half of the included studies, suggests that the reported diagnostic accuracy of digital radiography might be underestimated, as the studied populations were often enriched with patients already suspected of having complex pathosis. The potential for publication bias also exists, as studies with statistically significant positive findings are more likely to be published than those with negative results, potentially inflating the perceived effect size of CBCT's superiority. The implications for clinical practice are substantial. The findings strongly support the position held by various endodontic and radiological societies that CBCT is indicated when conventional radiographs are inconsistent with clinical signs and symptoms, particularly in posterior teeth (6). Clinicians should have a low threshold for transitioning to CBCT imaging when a periapical lesion is suspected but not visible on a digital radiograph, or when the anatomical complexity of the region obscures interpretation. This approach can prevent misdiagnosis, ensure appropriate treatment planning, and ultimately improve patient outcomes. For future research, efforts should be directed towards conducting larger, multi-center studies with standardized imaging protocols to facilitate future meta-analyses. There is also a pressing need for health economic analyses to evaluate the cost-effectiveness of CBCT as a primary diagnostic tool in endodontics, weighing its higher initial cost against the potential long-term benefits of accurate early diagnosis and reduced failure rates.

CONCLUSION

In conclusion, the synthesis of evidence from this systematic review firmly establishes cone-beam computed tomography as a diagnostically superior modality to digital radiography for the detection of periapical lesions in posterior teeth, demonstrating consistently higher sensitivity particularly in anatomically complex regions where two-dimensional imaging is fundamentally limited. This finding carries profound clinical significance, as it provides a robust evidence base to guide clinicians in selecting the most appropriate imaging technique when confronted with diagnostic uncertainty, thereby facilitating earlier and more accurate detection of apical periodontitis which is critical for effective treatment planning and improved patient outcomes. While the reliability of this evidence is strengthened by the methodological rigor of the review process and the consistency of findings across recent studies, the persistence of heterogeneity in primary study protocols and the potential for spectrum bias underscore the necessity for further

standardized, large-scale research to not only solidify these conclusions but also to explore the long-term cost-effectiveness and impact on treatment success rates when integrating CBCT into routine diagnostic pathways.

AUTHOR CONTRIBUTION

Author	Contribution
Muhammad Haris Zia*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Uzma Zareef	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Mariam Imdad	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Bushra Jabeen	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Wajeha Nasir	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Asma Rehman	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Kashmala Anwar	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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