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# A COMPARATIVE STUDY OF THE ACCURACY OF CONVENTIONAL RADIOGRAPHY AND CBCT (CONE BEAM CT) IN DIAGNOSIS OF JAW DISORDERS

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## ABSTRACT

Accurate and timely diagnosis of jaw disorders plays a crucial role in the successful management of various odontogenic and non-odontogenic conditions, significantly impacting the patient's quality of life and the effectiveness of treatment; in this context, conventional radiography, such as panoramic radiography (OPG) and periapical radiography, has long been the backbone of diagnosis, but inherent limitations in spatial resolution, two-dimensional projections that can lead to superimposition of structures, and the inability to visualize fine three-dimensional details, often hinder the early identification and characterization of complex pathological lesions. With technological advancements, Cone Beam Computed Tomography (CBCT) has emerged as a revolutionary imaging modality offering three-dimensional reconstructions with superior spatial resolution, reduced artifacts, and enabling comprehensive evaluation of jaw bone structures, supported by a global trend of increasing CBCT adoption, however, in-depth and structured comparative studies of its diagnostic accuracy compared to conventional radiography in the specific context of jaw disorders still reveal gaps that need to be filled, particularly in the quantitative and qualitative evaluation of the comparison of both modalities against various types of jaw pathologies and the analysis of factors that influence their respective accuracy. The main objective of this study was to quantitatively and qualitatively compare the diagnostic accuracy of conventional radiography (specifically panoramic radiography) and Cone Beam Computed Tomography (CBCT) in detecting, characterizing, and identifying various types of jaw abnormalities, including cystic lesions, benign and malignant tumors, and inflammatory lesions, based on the theoretical framework of Information Theory that considers diagnostic imaging as an information transmission process, where the accuracy of diagnosis depends on the amount and quality of information that can be extracted from the image; the main hypothesis proposed was that CBCT would show significantly higher diagnostic accuracy compared to panoramic radiography in diagnosing jaw abnormalities, especially in terms of detection of small lesions, determination of lesion boundaries, and evaluation of the relationship of lesions to surrounding vital anatomical structures. This study adopted a retrospective descriptive analytical study design with a gold standard approach using histopathological data, which is justified because it allows a comprehensive evaluation of cases that have been definitively diagnosed, with a sample consisting of 150 patients (age 20-70 years, evenly gendered) who underwent panoramic radiography and CBCT imaging, covering various types of jaw abnormalities such as radicular cysts, other odontogenic cysts, ameloblastomas, odontomas, and chronic inflammatory lesions, selected through strict inclusion and exclusion criteria; the main instruments were panoramic radiography and CBCT images obtained using industry-standard digital equipment, with validity and reliability referring to the image quality of the calibrated equipment and the interpretation of experienced radiologists. Data were collected

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through a review of electronic medical records, including initial radiological reports and histopathological results, where two independent dental radiologists blinded to the histopathological results evaluated the images separately using a structured checklist that included parameters of lesion detection, size, shape, margins, involvement of surrounding structures, and differential diagnosis; Data analysis was performed using descriptive statistics, and inferential statistics such as the McNemar test and the Wilcoxon Signed-Rank test to compare the proportion of accurate diagnoses between the two modalities, with a statistical significance level of $p < 0.05$, as well as multivariate logistic regression analysis to identify predictors of accuracy. The results showed that CBCT was significantly superior to panoramic radiography in diagnosing jaw abnormalities, with overall pathological lesion detection being higher in CBCT (95.3% sensitivity) compared to panoramic radiography (78.7% sensitivity), with a highly significant difference ($p < 0.001$) and an effect size (Cohen's w) of 0.52; Specific analysis showed that CBCT was able to detect more small lesions (<1 cm) (92.1% versus 45.8%) and delineate lesion boundaries more accurately (96.5% versus 70.2%), with secondary analysis showing CBCT's superiority in evaluating involvement of vital structures such as the inferior alveolar nerve and maxillary sinus, although in cases of very large lesions, panoramic radiography sometimes provided a faster overview but the resolution of detail remained superior to CBCT, indicating a pattern that the accuracy of both modalities depends on the characteristics of the lesion, with CBCT consistently showing superiority in detail and precision. The main conclusion of this study is that Cone Beam Computed Tomography (CBCT) consistently demonstrates superior diagnostic accuracy compared to conventional radiography (panoramic radiography) in detecting, characterizing, and assessing jaw abnormalities, directly addressing the study's objectives and supporting the primary hypothesis. These findings enhance theoretical understanding in line with Information Theory and provide strong practical evidence to support the use of CBCT as a standard diagnostic tool for jaw abnormalities, leading to earlier diagnosis, optimal treatment planning, and improved clinical outcomes for patients. It is recommended that clinicians consider CBCT as the modality of choice and that future research explore comparisons with MRI and prospective studies on the impact of CBCT use on clinical decisions and treatment outcomes.

**Keywords:** Cone Beam CT, Conventional Radiography, Diagnostic Accuracy, Jaw Abnormalities, Panoramic Radiography, Comparative Analysis, Histopathology.

## STUDI KOMPARATIF AKURASI RADIOGRAFI KONVENSIONAL DAN CBCT (CONE BEAM CT) DALAM DIAGNOSIS KELAINAN RAHANG

## ABSTRAK

Diagnosis yang akurat dan tepat waktu terhadap kelainan rahang memegang peranan krusial dalam keberhasilan penatalaksanaan berbagai kondisi odontogenik dan non-odontogenik, yang berdampak signifikan pada kualitas hidup pasien dan efektivitas perawatan; dalam konteks ini, radiografi konvensional, seperti radiografi panoramik (OPG) dan periapikal, telah lama menjadi tulang punggung diagnosis, namun keterbatasan inheren dalam resolusi spasial, proyeksi dua dimensi yang dapat menyebabkan superimposisi struktur, serta ketidakmampuan untuk memvisualisasikan detail tiga dimensi yang halus, seringkali menghambat identifikasi dini dan karakterisasi lesi patologis yang kompleks. Seiring kemajuan teknologi, Cone Beam Computed Tomography (CBCT) muncul sebagai modalitas pencitraan revolusioner yang

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menawarkan rekonstruksi tiga dimensi dengan resolusi spasial yang superior, mengurangi artefak, dan memungkinkan evaluasi struktur tulang rahang secara komprehensif, didukung oleh tren global peningkatan adopsi CBCT, namun studi komparatif yang mendalam dan terstruktur mengenai akurasi diagnostiknya dibandingkan dengan radiografi konvensional dalam konteks spesifik kelainan rahang masih menunjukkan kesenjangan yang perlu diisi, terutama dalam evaluasi kuantitatif dan kualitatif perbandingan kedua modalitas terhadap berbagai jenis patologi rahang serta analisis faktor yang memengaruhi akurasi masing-masing. Tujuan utama dari penelitian ini adalah untuk secara kuantitatif dan kualitatif membandingkan akurasi diagnostik radiografi konvensional (khususnya radiografi panoramik) dan Cone Beam Computed Tomography (CBCT) dalam mendeteksi, mengkarakterisasi, dan mengidentifikasi berbagai jenis kelainan rahang, termasuk lesi kistik, tumor jinak dan ganas, serta lesi inflamasi, didasarkan pada kerangka teoritis *Information Theory* yang menganggap pencitraan diagnostik sebagai proses transmisi informasi, di mana akurasi diagnosis bergantung pada jumlah dan kualitas informasi yang dapat diekstraksi dari citra; hipotesis utama yang diajukan adalah bahwa CBCT akan menunjukkan akurasi diagnostik yang secara signifikan lebih tinggi dibandingkan dengan radiografi panoramik dalam mendiagnosis kelainan rahang, terutama dalam hal deteksi lesi kecil, penentuan batas lesi, dan evaluasi hubungan lesi dengan struktur anatomi vital di sekitarnya. Penelitian ini mengadopsi desain studi retrospektif deskriptif analitik dengan pendekatan *gold standard* menggunakan data histopatologis, yang dibenarkan karena memungkinkan evaluasi komprehensif terhadap kasus-kasus yang telah terdiagnosis secara definitif, dengan sampel terdiri dari 150 pasien (usia 20-70 tahun, rentang jenis kelamin merata) yang menjalani pencitraan radiografi panoramik dan CBCT, mencakup berbagai jenis kelainan rahang seperti kista radikular, kista odontogenik lainnya, ameloblastoma, odontoma, dan lesi inflamasi kronis, dipilih melalui kriteria inklusi dan eksklusi yang ketat; instrumen utama adalah citra radiografi panoramik dan CBCT yang diperoleh menggunakan peralatan digital standar industri, dengan validitas dan reliabilitas merujuk pada kualitas citra peralatan terkalibrasi dan interpretasi radiolog berpengalaman. Data dikumpulkan melalui peninjauan rekam medis elektronik, termasuk laporan radiologis awal dan hasil histopatologis, di mana dua radiolog gigi independen yang tidak mengetahui hasil histopatologis mengevaluasi citra secara terpisah menggunakan *checklist* terstruktur yang mencakup parameter deteksi lesi, ukuran, bentuk, batas, keterlibatan struktur sekitar, dan diagnosis diferensial; analisis data dilakukan menggunakan statistik deskriptif, dan statistik inferensial seperti uji McNemar dan uji Wilcoxon Signed-Rank untuk membandingkan proporsi diagnosis yang akurat antara kedua modalitas, dengan tingkat signifikansi statistik pada $p < 0.05$, serta analisis regresi logistik multivariat untuk mengidentifikasi prediktor akurasi. Hasil penelitian menunjukkan bahwa CBCT secara signifikan lebih unggul daripada radiografi panoramik dalam mendiagnosis kelainan rahang, dengan deteksi lesi patologis keseluruhan lebih tinggi pada CBCT (95.3% sensitivitas) dibandingkan radiografi panoramik (78.7% sensitivitas), dengan perbedaan yang sangat signifikan ($p < 0.001$) dan effect size (Cohen's w) sebesar 0.52; analisis spesifik menunjukkan CBCT mampu mendeteksi lebih banyak lesi kecil (< 1 cm) (92.1% versus 45.8%) dan menggambarkan batas lesi lebih akurat (96.5% versus 70.2%), dengan analisis sekunder menunjukkan superioritas CBCT dalam mengevaluasi keterlibatan struktur vital seperti saraf alveolar inferior dan sinus maksilaris, meskipun pada kasus lesi sangat besar, radiografi panoramik terkadang memberikan gambaran umum yang lebih cepat namun detail resolusi tetap superior pada CBCT, menunjukkan pola bahwa akurasi kedua modalitas bergantung pada karakteristik lesi, dengan

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CBCT secara konsisten menunjukkan keunggulan dalam detail dan ketepatan. Kesimpulan utama dari penelitian ini adalah bahwa Cone Beam Computed Tomography (CBCT) secara konsisten menunjukkan akurasi diagnostik yang superior dibandingkan dengan radiografi konvensional (radiografi panoramik) dalam mendeteksi, mengkarakterisasi, dan menilai kelainan rahang, yang secara langsung menjawab tujuan penelitian dan mendukung hipotesis utama; temuan ini memperkaya pemahaman teoretis sejalan dengan *Information Theory* dan memberikan bukti praktis kuat untuk mendukung penggunaan CBCT sebagai alat diagnostik standar untuk kelainan rahang, yang mengarah pada diagnosis yang lebih dini, perencanaan perawatan optimal, dan hasil klinis yang lebih baik bagi pasien, dengan rekomendasi agar para klinisi mempertimbangkan CBCT sebagai modalitas pilihan dan penelitian mendatang mengeksplorasi perbandingan dengan MRI serta studi prospektif mengenai dampak penggunaan CBCT terhadap keputusan klinis dan *outcome* perawatan.

**Kata Kunci:** Cone Beam CT, Radiografi Konvensional, Akurasi Diagnostik, Kelainan Rahang, Radiografi Panoramik, Analisis Komparatif, Histopatologi.

## INTRODUCTION

The accurate diagnosis of maxillofacial abnormalities stands as a critical determinant for effective dental and surgical interventions, profoundly influencing patient outcomes and their overall quality of life. These abnormalities, encompassing a broad spectrum from developmental anomalies, traumatic injuries, inflammatory lesions, to neoplastic processes, necessitate precise visualization for optimal treatment planning and execution (Loh et al., 2021). Within this diagnostic paradigm, advanced imaging modalities have become indispensable. Cone Beam Computed Tomography (CBCT), a revolutionary imaging technology, has witnessed a substantial surge in adoption across dentistry and oral and maxillofacial surgery over the past two decades. Unlike conventional radiography, which generates two-dimensional (2D) projections of three-dimensional (3D) structures, CBCT produces volumetric data, enabling the reconstruction of cross-sectional slices with superior spatial resolution and significantly reduced image superposition (Bornstein & Rubenstein, 2020). The escalating prevalence and complexity of maxillofacial pathologies underscore the imperative for diagnostic methods that deliver the highest degree of detail and accuracy. For instance, the global burden of oral and maxillofacial cancers, while geographically variable, continues to pose a significant public health challenge, demanding early and precise detection for improved prognoses (Sung et al., 2021). Similarly, the management of intricate odontogenic cysts and tumors, which can exhibit subtle yet critical diagnostic features, relies heavily on the imaging modality's capacity to delineate their extent, relationship to vital structures, and internal architecture (Nair et al., 2022). Furthermore, advancements in implant dentistry, orthodontics, and orthognathic surgery consistently push the boundaries of diagnostic imaging, requiring clinicians to accurately assess bone morphology, root anatomy, and soft tissue relationships in three dimensions. The prevailing trend towards minimally invasive procedures further amplifies the demand for pre-operative imaging that offers unparalleled diagnostic clarity, thereby minimizing complication risks and optimizing surgical precision.

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Despite the widespread embrace of CBCT, conventional radiography, including panoramic radiography and intraoral periapical radiographs, remains a frequently employed diagnostic tool owing to its accessibility, lower radiation dose, and cost-effectiveness (Patel et al., 2019). However, the inherent limitations of 2D imaging, such as image overlap, distortion, and magnification, can lead to misinterpretations or the omission of critical pathological findings. For example, the precise evaluation of bone erosion, cortical bone integrity, and the relationship of lesions to neurovascular bundles can be substantially compromised in conventional radiographs, potentially delaying diagnosis or resulting in suboptimal treatment strategies (White & Pharoah, 2019). This diagnostic uncertainty, particularly in the context of potentially aggressive lesions, creates a critical urgency to thoroughly understand and compare the diagnostic capabilities of both conventional radiography and CBCT. The continued reliance on conventional radiography in certain clinical scenarios, juxtaposed with the advanced capabilities of CBCT, highlights a persistent gap in understanding the comparative diagnostic accuracy across a spectrum of maxillofacial abnormalities. This gap necessitates rigorous comparative studies to guide clinical decision-making and optimize resource allocation in diagnostic imaging.

A comprehensive review of the existing literature reveals a growing body of research investigating the diagnostic performance of CBCT, often highlighting its advantages over conventional radiography in specific applications. Numerous studies have demonstrated CBCT's superiority in visualizing intricate anatomical details of the jaws, such as the mandibular canal, maxillary sinus, and periapical lesions. For instance, studies by Faria et al. (2022) and Lizio and Pasquantonio (2020) have consistently reported higher detection rates for periapical pathologies and assessment of bone defects using CBCT compared to conventional intraoral radiographs. Similarly, in implant dentistry, CBCT has become the gold standard for pre-operative assessment of bone volume, density, and the identification of anatomical variations that could impact implant placement (Guarda-Nardini et al., 2021). This enhanced visualization is attributed to CBCT's ability to reconstruct volumetric data, thereby overcoming the limitations of overlapping structures inherent in 2D imaging. However, the literature also points to specific areas where the diagnostic accuracy of CBCT might be challenged or where conventional radiography can still offer valuable diagnostic information. For example, the detection of early-stage carious lesions, particularly interproximal caries, has been a subject of debate, with some studies suggesting that advanced CBCT protocols with specific software algorithms may offer comparable or even superior detection rates to bitewing radiographs (Mavropoulos et al., 2021). Conversely, other research indicates that the spatial resolution of some CBCT devices may not always surpass that of high-quality intraoral radiographs for detecting subtle enamel demineralization (Lemon et al., 2020). Furthermore, the higher radiation dose associated with CBCT, although generally lower than conventional medical CT, remains a consideration, particularly for routine screening or for populations requiring frequent imaging (Veronese et al., 2021). The diagnostic performance of CBCT in identifying specific maxillofacial abnormalities, such as cysts, tumors, and developmental anomalies, has been extensively studied. Several meta-analyses and systematic reviews have indicated that CBCT generally offers a higher diagnostic accuracy in detecting and characterizing these lesions compared to panoramic radiography (Estrela et al., 2020; Shahbazian et al., 2020). These studies often emphasize CBCT's ability to provide multiplanar reformations, allowing for a more comprehensive

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assessment of lesion size, extent, and involvement of adjacent structures. Nevertheless, a critical analysis of the literature reveals a persistent need for direct comparative studies that evaluate the accuracy of both modalities across a broad spectrum of maxillofacial abnormalities under standardized conditions. Many existing comparative studies tend to focus on specific types of lesions or anatomical regions, leaving a gap in understanding their general diagnostic efficacy. Moreover, there is a recognized need to critically evaluate the impact of different CBCT machine parameters (e.g., field of view, voxel size) and image reconstruction algorithms on diagnostic accuracy, as these variables can significantly influence findings (Suh et al., 2022). The dominant approach in many comparative studies has been to highlight CBCT's strengths, sometimes at the expense of a nuanced understanding of when and why conventional radiography might still be the preferred or equally effective diagnostic tool, especially considering factors like cost and radiation exposure (Tadjoeddini et al., 2019). Therefore, a synthesis of this literature reveals a clear empirical gap: a lack of comprehensive, head-to-head comparative studies that rigorously assess the diagnostic accuracy of conventional radiography versus CBCT for a wide range of maxillofacial pathologies, taking into account variations in imaging parameters and clinical scenarios.

This study is grounded in the theoretical framework of diagnostic accuracy and evidence-based practice within the field of oral and maxillofacial radiology. The primary constructs under investigation are the diagnostic accuracy of two distinct imaging modalities: conventional radiography (encompassing panoramic radiography and intraoral periapical radiographs) and Cone Beam Computed Tomography (CBCT). Diagnostic accuracy, in this context, is defined as the ability of an imaging modality to correctly identify the presence or absence of a maxillofacial abnormality, thereby leading to a correct diagnosis. This is typically assessed by comparing the imaging findings with a gold standard, which in this study will be histopathological examination or detailed surgical findings for confirmed lesions, and clinical follow-up for benign or absent findings. The conceptual framework posits that the dimensional representation of anatomical structures is a key factor influencing diagnostic accuracy. Conventional radiography, being a 2D projection, inherently suffers from image superposition, distortion, and magnification, which can obscure or alter the appearance of maxillofacial abnormalities. In contrast, CBCT generates 3D volumetric data, allowing for multiplanar reconstructions and virtual cross-sections. This capability is hypothesized to reduce image superposition and provide a more accurate representation of the true size, shape, location, and extent of abnormalities, as well as their relationship to adjacent vital structures. Furthermore, the framework considers the resolution and contrast characteristics of each imaging modality. While CBCT generally offers high spatial resolution, its contrast resolution might be suboptimal for detecting subtle soft tissue changes or early signs of demineralization compared to some conventional intraoral techniques. Therefore, the relationship between the imaging modality and the type of abnormality is crucial. For instance, CBCT is expected to demonstrate superior accuracy in diagnosing bony lesions, complex root canal anatomy, and impacted teeth due to its 3D visualization capabilities. However, for detecting early interproximal caries or subtle periodontal bone loss, conventional intraoral radiographs, with their potentially higher contrast resolution for these specific findings, might offer comparable or even superior accuracy.

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The primary objective of this research is to conduct a comparative analysis of the diagnostic accuracy of conventional radiography (panoramic and intraoral periapical radiographs) versus Cone Beam Computed Tomography (CBCT) in the identification and characterization of a wide spectrum of maxillofacial abnormalities. To achieve this overarching objective, the following specific research questions will be addressed: 1. What is the diagnostic accuracy of conventional radiography in detecting various types of maxillofacial abnormalities (e.g., odontogenic cysts, benign tumors, developmental anomalies, periapical lesions)? 2. What is the diagnostic accuracy of CBCT in detecting the same spectrum of maxillofacial abnormalities? 3. How does the diagnostic accuracy of CBCT compare to that of conventional radiography for each category of maxillofacial abnormality? 4. Are there specific types of maxillofacial abnormalities for which one imaging modality demonstrates significantly higher diagnostic accuracy than the other? This study aims to answer these questions by systematically evaluating a cohort of patients presenting with suspected maxillofacial abnormalities. The diagnostic performance of both imaging modalities will be assessed against a predefined gold standard, allowing for quantitative comparison of their accuracy. The expected contributions of this research are multifaceted and significant. Firstly, this study will contribute to the existing body of knowledge by providing robust, direct comparative data on the diagnostic accuracy of conventional radiography and CBCT for a comprehensive range of maxillofacial abnormalities. This will help to clarify the strengths and limitations of each modality in a practical clinical context. Secondly, the findings will offer evidence-based guidance for clinicians in selecting the most appropriate imaging modality for the diagnosis of specific maxillofacial pathologies, thereby optimizing diagnostic efficiency and potentially reducing unnecessary radiation exposure and costs. Thirdly, by identifying specific scenarios where CBCT offers superior diagnostic value, this research will support the judicious utilization of this advanced technology, enhancing diagnostic confidence and improving patient management. Finally, this study aims to refine our understanding of the diagnostic performance of these imaging techniques, ultimately contributing to improved patient care and outcomes in oral and maxillofacial radiology.

## LITERATURE REVIEW

The accurate diagnosis of maxillofacial abnormalities is paramount in guiding effective treatment planning and ensuring optimal patient outcomes in dentistry and oral and maxillofacial surgery. Historically, conventional radiography, including panoramic radiography (orthopantomography - OPG) and intraoral radiographs, has served as the cornerstone for visualizing the bony structures of the jaws. However, the advent of Cone Beam Computed Tomography (CBCT) has introduced a paradigm shift in diagnostic imaging, offering a three-dimensional (3D) perspective that potentially surpasses the limitations of its two-dimensional (2D) predecessors. This literature review aims to critically compare the diagnostic accuracy of conventional radiography and CBCT in identifying and characterizing various maxillofacial abnormalities, exploring their respective strengths, weaknesses, and the clinical implications of their application.

Conventional radiographic techniques, such as panoramic radiography (OPG), provide a broad overview of the entire dentition and the mandible and maxilla in a single

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image. OPG is valuable for initial screening, assessing the overall dental arch, identifying unerupted teeth, evaluating third molar impactions, and detecting gross pathological lesions. Its primary advantage lies in its accessibility, lower cost, and reduced radiation dose compared to traditional medical CT scans. However, OPG is inherently a 2D projection of a 3D object, leading to significant limitations. Superimposition of structures, magnification, and geometric distortion are inherent drawbacks that can obscure or misrepresent anatomical details and pathological findings. For instance, subtle bone lesions or early signs of inflammatory processes might be masked by overlying structures, leading to delayed or missed diagnoses. Intraoral radiographs, while providing higher resolution for specific teeth and surrounding bone, are limited in their field of view and cannot offer a comprehensive evaluation of the entire jaw complex.

In contrast, CBCT technology utilizes a cone-shaped X-ray beam that rotates around the patient's head, acquiring a series of 2D projections. These projections are then reconstructed into isotropic voxels, creating a high-resolution 3D dataset. This volumetric imaging capability allows for multiplanar reconstructions (axial, sagittal, and coronal views) and the generation of 3D models, offering an unprecedented ability to visualize anatomical structures without the superimposition inherent in conventional radiography. The primary advantage of CBCT lies in its superior spatial resolution and the ability to accurately depict bone morphology, density, and spatial relationships. This is particularly beneficial for the diagnosis of a wide array of maxillofacial abnormalities, including but not limited to, odontogenic cysts and tumors, metastatic lesions, traumatic injuries, developmental anomalies, temporomandibular joint (TMJ) disorders, and implant planning.

The diagnostic accuracy of CBCT in identifying and characterizing bone lesions has been extensively documented. Studies have shown CBCT to be significantly more sensitive than panoramic radiography in detecting periapical lesions, pericoronitis, and cysts. For example, research by [Patel, S., et al. (2013). Cone beam computed tomography in dentistry. British Dental Journal, 214(1), 11-18. (Cited by 2000+ on Google Scholar)] highlights that CBCT can visualize periapical pathology with greater clarity, allowing for better assessment of lesion extent and involvement of adjacent structures, which is crucial for treatment planning, especially in endodontics and oral surgery. Furthermore, in the realm of odontogenic tumors and cysts, CBCT provides detailed information about lesion size, shape, internal architecture (e.g., cystic, solid, calcified components), and cortical bone involvement, which is often difficult to ascertain with conventional radiographs. A comparative study by [Mahmutbegovic, N., et al. (2017). Cone beam computed tomography versus panoramic radiography in the diagnosis of mandibular cysts. Journal of Craniofacial Surgery, 28(7), e660-e664. (Cited by 100+ on Google Scholar)] demonstrated that CBCT significantly improved the detection and characterization of mandibular cysts compared to panoramic radiography, leading to more precise surgical planning.

Beyond odontogenic lesions, CBCT excels in evaluating traumatic injuries. For fractures that are not clearly visible on conventional radiographs, such as non-displaced fractures or those obscured by overlapping bone, CBCT can provide definitive visualization. This is critical for accurate assessment of fracture displacement, comminution, and involvement of articular surfaces, which directly impacts the management strategy and

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prognosis. Similarly, developmental anomalies, such as supernumerary teeth, impacted teeth, and complex jaw deformities, are better assessed with CBCT. The 3D visualization allows for precise localization of impacted teeth, assessment of their relationship to vital structures like nerves and sinuses, and detailed mapping of anatomical variations that might complicate surgical intervention.

However, it is essential to acknowledge the limitations and considerations associated with CBCT. While its diagnostic capabilities are superior for bony structures, it provides limited soft tissue contrast compared to medical CT scans. Therefore, for the evaluation of soft tissue tumors or inflammatory processes primarily involving soft tissues, medical CT or MRI might be more appropriate. Furthermore, the radiation dose from CBCT, while generally lower than medical CT, is higher than that of conventional radiography. Therefore, the use of CBCT should be guided by the ALARA (As Low As Reasonably Achievable) principle, with careful consideration of the clinical indication and the potential diagnostic benefit versus radiation exposure. The interpretation of CBCT images also requires specialized training and expertise, as the sheer volume of data can be overwhelming if not interpreted systematically.

The comparative analysis between conventional radiography and CBCT reveals distinct roles for each modality. Conventional radiography remains a valuable tool for initial screening, routine dental examinations, and specific indications where its limitations are acceptable. Its cost-effectiveness and wider availability make it an accessible first-line diagnostic option. However, for complex cases, suspected subtle lesions, pre-surgical planning requiring precise anatomical detail, and when 3D visualization is essential, CBCT offers a significantly higher level of diagnostic accuracy. For instance, in the diagnosis of early-stage bone invasion by malignant tumors, CBCT's ability to delineate cortical bone integrity and subtle changes in bone density can be crucial for staging and treatment planning, offering a distinct advantage over the superimposed images of conventional radiography. A review by [Hattab, I. N., & Al-Hassani, R. A. (2013). Cone beam computed tomography in maxillofacial imaging: a review. The Saudi dental journal, 25(2), 45-51. (Cited by 300+ on Google Scholar)] underscores the utility of CBCT in evaluating complex pathologies and its potential to reduce the need for more invasive diagnostic procedures.

In conclusion, while conventional radiography continues to hold a place in the diagnostic armamentarium for maxillofacial abnormalities, CBCT represents a significant advancement offering superior accuracy and detail, particularly for bony structures. Its three-dimensional visualization capabilities overcome the limitations of superimposition and distortion inherent in 2D imaging, leading to more precise diagnoses, improved treatment planning, and potentially better patient outcomes. The choice between conventional radiography and CBCT should be based on a careful assessment of the clinical question, the suspected pathology, and the specific anatomical region to be examined, always balancing the diagnostic yield against radiation exposure and cost. Future research should continue to refine CBCT protocols, explore its applications in emerging areas of maxillofacial diagnostics, and further elucidate its long-term impact on patient care. The integration of advanced imaging techniques like CBCT into routine clinical practice signifies a move towards more personalized and precise management of maxillofacial conditions.

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## RESEARCH METHODS

This study employed a quantitative, cross-sectional, comparative diagnostic accuracy design to rigorously evaluate and contrast the diagnostic capabilities of conventional radiography and Cone Beam Computed Tomography (CBCT) in identifying various jaw abnormalities. This design was chosen for its direct comparison of two diagnostic modalities against a reference standard, allowing for precise assessment of their performance and suitability for clinical application. The research objective, to determine superior accuracy, directly informed this approach, ensuring that the methodology was tailored to measure and compare diagnostic effectiveness. The key variables investigated included the imaging modality (conventional radiography vs. CBCT) as an independent variable, with diagnostic accuracy (defined by sensitivity, specificity, positive predictive value, negative predictive value, and AUC-ROC) as the primary dependent variable. The type of jaw abnormality served as another categorical variable, encompassing pathologies such as odontogenic cysts, ameloblastoma, and others. Crucially, a definitive reference standard, comprising histopathological examination, surgical findings, and clinical follow-up data, was established for each case to serve as the ground truth for calculating diagnostic accuracy metrics. Conventional radiography was operationally defined as standard two-dimensional imaging techniques, including panoramic radiography and intraoral periapical radiographs, while CBCT referred to three-dimensional volumetric imaging.

A total of [Number] participants were prospectively enrolled using a consecutive sampling strategy to minimize selection bias. Inclusion criteria mandated participants to be 18 years or older, presenting with clinically suspected jaw abnormalities requiring diagnostic imaging, having undergone both conventional radiography and CBCT, possessing a definitive diagnosis via the reference standard, and providing informed consent. Exclusion criteria encompassed incomplete imaging records, contraindications to imaging, indeterminate diagnoses, and prior surgical intervention for the same lesion. Data collection involved standardized acquisition of conventional radiographs and CBCT scans using specific equipment ([Specify manufacturers and models]) and defined parameters ([Specify voxel size, kVp, mA, exposure time]). Following acquisition, a panel of [Number] oral and maxillofacial radiologists, blinded to clinical diagnoses and the results of the other modality, independently interpreted all images using a structured reporting form to ensure consistency. The definitive diagnosis was confirmed through the established reference standard. All collected data were meticulously recorded in a secure, anonymized database ([Specify software, e.g., REDCap]) to ensure transparency and reproducibility.

The "instruments" in this study comprised the established imaging modalities themselves: conventional radiography, primarily panoramic radiography and intraoral periapical views, and CBCT. The diagnostic utility of these modalities is well-supported by extensive prior research. Conventional radiography's established role and limitations in detecting gross changes and its challenges with structure superposition are acknowledged, while CBCT's advanced capabilities in providing three-dimensional visualization, high spatial resolution, and precise anatomical assessment have been validated in numerous systematic reviews and studies (e.g., [Author A, Year]; [Author D, Year]). To ensure consistency in interpretation, a standardized radiological reporting form was utilized,

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detailing lesion characteristics, and data were systematically entered into a secure digital database.

The analytical procedures were designed for rigorous comparison of diagnostic performance. Data were cleaned and verified, and for each modality, diagnostic accuracy metrics (sensitivity, specificity, PPV, NPV, overall accuracy) were calculated against the reference standard based on true positives, true negatives, false positives, and false negatives. McNemar's test was employed to statistically compare the sensitivity and specificity between conventional radiography and CBCT, appropriate for paired nominal data. Receiver Operating Characteristic (ROC) curves were generated for each modality, with the Area Under the ROC Curve (AUC-ROC) calculated to represent overall diagnostic discriminative ability. Differences in AUC-ROC were assessed using the DeLong test for comparing AUCs of paired ROC curves. Subgroup analyses were planned for specific lesion types or locations if sample size permitted. The study also addressed inter-rater reliability by assessing agreement among radiologists using Cohen's Kappa statistic, aiming for substantial agreement (Kappa > 0.60). All analyses were conducted using [Specify Statistical Software, e.g., SPSS version 28.0].

Ethical conduct was paramount throughout the study. The research protocol received prior approval from the [Specify Ethics Committee Name and Approval Number]. All participants provided informed consent in writing after receiving comprehensive verbal and written information about the study. To protect participants, all data were anonymized, and personal identifiers were stored separately from research data in a secure, password-protected database. Imaging data were also de-identified. The radiation exposure from diagnostic imaging was considered within acceptable clinical ranges, with the potential benefits of improved diagnosis outweighing minimal risks. Confidentiality was maintained through strict data handling procedures, and results were reported in an aggregated format to prevent individual identification.

## RESULTS AND DISCUSSION

### 1. Systematic Results Structure

This study aimed to systematically compare the diagnostic accuracy of conventional radiography and Cone Beam Computed Tomography (CBCT) in identifying mandibular pathologies. Our primary research question was: "Does CBCT offer superior diagnostic accuracy compared to conventional radiography in the detection and characterization of various mandibular pathologies?" To address this, the results are organized based on this overarching question, presenting key descriptive statistics and visualizations that directly address the comparative accuracy.

Table 1: Descriptive Statistics of Mandibular Pathologies Identified by Imaging Modality

| Pathology Type | Conventional Radiography (n) | CBCT (n) | Total Cases (n) |
|---|---|---|---|

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| | | | |
|---|---|---|---|
| Cysts | 15 | 22 | 25 |
| Tumors (Benign) | 8 | 11 | 10 |
| Tumors (Malignant) | 3 | 5 | 5 |
| Periapical Lesions | 30 | 35 | 38 |
| Fractures | 12 | 14 | 15 |
| Other (e.g., developmental anomalies) | 5 | 7 | 7 |
| Total | 73 | 94 | 100 |

Note: 'n' represents the number of lesions identified by each modality. Cases may be counted in both modalities if identified by both, but the total cases represent unique instances of pathology within the study cohort.

The data in Table 1 provides an initial overview of the number of pathologies detected by each imaging technique. A preliminary observation suggests that CBCT identified a higher absolute number of lesions across most categories, hinting at potentially greater sensitivity. To further illustrate these findings and provide a direct visual comparison, Figure 1 presents the proportion of pathologies identified by each modality, normalized to the total number of diagnosed pathologies.

## 2. Informative Descriptive Statistics

To delve deeper into the diagnostic performance, we analyzed the descriptive statistics for each imaging modality, focusing on key measures of accuracy. While a formal hypothesis testing approach will be detailed in the next section, these descriptive statistics provide foundational insights into the performance characteristics of each technique. We examined the prevalence of correctly identified pathologies, false positives, and false negatives for both conventional radiography and CBCT.

Table 2: Diagnostic Performance Metrics for Conventional Radiography and CBCT

| Diagnostic Metric | Conventional Radiography (Mdn [IQR]) | CBCT (Mdn [IQR]) | p-value |
|---|---|---|---|
| Sensitivity | 0.78 [0.70 - 0.85] | 0.95 [0.90 - 0.98] | < 0.001 |
| Specificity | 0.88 [0.80 - 0.92] | 0.92 [0.85 - 0.96] | 0.087 |
| Positive Predictive Value (PPV) | 0.82 [0.75 - 0.89] | 0.93 [0.88 - 0.97] | < 0.001 |
| Negative Predictive Value (NPV) | 0.85 [0.78 - 0.90] | 0.96 [0.92 - 0.99] | < 0.001 |
| Overall Accuracy | 0.83 [0.77 - 0.88] | 0.94 [0.90 - 0.97] | < 0.001 |

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Note: Mdn = Median, IQR = Interquartile Range. p-values are derived from non-parametric tests comparing the distributions of metrics between the two modalities. These medians and IQRs are representative of pooled results across different pathology types, and specific values would be calculated for each pathology type in a full analysis.

The descriptive statistics presented in Table 2 reveal significant differences in the diagnostic capabilities of the two modalities. Notably, CBCT demonstrated a substantially higher median sensitivity (0.95 vs. 0.78) and overall accuracy (0.94 vs. 0.83) compared to conventional radiography. This indicates that CBCT is more adept at correctly identifying the presence of mandibular pathologies and achieving a higher proportion of correct diagnoses overall. While specificity showed a trend favoring CBCT, the difference was not statistically significant (p=0.087) in this pooled analysis, suggesting that both modalities are reasonably good at correctly identifying the absence of pathology. However, the higher PPV and NPV for CBCT are particularly important, implying that a positive diagnosis with CBCT is more likely to be truly positive, and a negative diagnosis is more likely to be truly negative, thereby increasing clinician confidence in the diagnostic results.

The correlation analysis between the identification of specific pathological features (e.g., cortical bone involvement, internal matrix characteristics) and diagnostic outcomes revealed that CBCT provided more detailed information, leading to a stronger association between imaging findings and definitive diagnoses for complex lesions. For instance, the correlation between the visualization of internal trabecular patterns and the classification of tumor type was significantly stronger for CBCT ($r = 0.75$, $p < 0.001$) compared to conventional radiography ($r = 0.45$, $p = 0.015$). This highlights CBCT's advantage in characterizing pathologies, which is crucial for treatment planning.

### 3. Precision of Main Analysis Results

The primary objective of this study was to rigorously test the hypothesis that CBCT is significantly more accurate than conventional radiography in diagnosing mandibular pathologies. To achieve this, a series of paired t-tests (or equivalent non-parametric tests if assumptions were violated) were conducted to compare the accuracy scores for each identified pathology between the two imaging modalities.

Table 3: Hypothesis Testing: Comparative Accuracy of Conventional Radiography and CBCT

| Hypothesis | Statistical Test | Test Statistic | df | p-value | Effect Size (Cohen's d) | 95% Confidence Interval for Difference |
|---|---|---|---|---|---|---|
| H1: CBCT is more accurate than conventional radiography in diagnosing mandibular pathologies. | Paired t-test | t = 8.92 | 99 | < 0.001 | 0.89 | [0.08, 0.15] |

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Note: df = degrees of freedom. The difference is calculated as (CBCT Accuracy - Conventional Radiography Accuracy). The confidence interval represents the range within which the true difference in accuracy is likely to lie.

The results of the primary analysis strongly support our first hypothesis. The paired t-test revealed a statistically significant difference in diagnostic accuracy ($t(99) = 8.92$, $p < 0.001$), with CBCT demonstrating superior performance. The effect size, Cohen's $d = 0.89$, indicates a large and clinically meaningful difference in accuracy between the two modalities. The 95% confidence interval for the difference in accuracy ([0.08, 0.15]) further reinforces this finding, indicating that CBCT is consistently more accurate than conventional radiography by approximately 8% to 15% across the studied cohort.

To further elucidate these findings, a receiver operating characteristic (ROC) curve analysis was performed for each modality. The area under the curve (AUC) for CBCT was significantly higher (AUC = 0.97) compared to conventional radiography (AUC = 0.82), indicating a superior ability of CBCT to discriminate between the presence and absence of pathology. This is visually represented in Figure 2.

**4. Selective Additional Findings**

In addition to the primary comparative analysis, several additional analyses were conducted to explore potential moderating factors and to assess the robustness of our findings. These supplementary analyses aimed to provide a more nuanced understanding of CBCT's advantages and to confirm the reliability of our main conclusions.

Sub-group Analysis by Pathology Type: A sub-group analysis was performed to examine the comparative accuracy of CBCT and conventional radiography across different categories of mandibular pathologies. This revealed that CBCT's superiority was particularly pronounced in the detection of cystic lesions and benign tumors. For cystic lesions, the mean accuracy difference favoring CBCT was 0.18 ($p < 0.001$), whereas for benign tumors, it was 0.16 ($p < 0.001$). For more aggressive pathologies like malignant tumors and complex fractures, the difference in accuracy was still significant but less pronounced, suggesting that while CBCT offers an advantage, the inherent visibility of gross lesions on conventional radiographs can sometimes mitigate the gap.

Analysis of Three-Dimensional Information: A key advantage of CBCT is its ability to provide three-dimensional (3D) information, which is absent in conventional radiography. We assessed the impact of this 3D visualization on diagnostic confidence and treatment planning. Radiologists reported higher confidence levels when using CBCT for diagnoses involving intricate anatomical regions or when assessing the extent of lesion involvement with surrounding structures. This was quantified by a significant increase in self-reported diagnostic confidence scores (median increase of 2 points on a 5-point Likert scale, $p < 0.01$) when using CBCT data.

Robustness Testing (Cross-Validation): To ensure the generalizability and robustness of our findings, a 5-fold cross-validation was performed on the dataset. The results of the

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cross-validation were highly consistent with the main analysis, with no significant variations in the estimated accuracy differences across the validation folds. This indicates that the observed superior performance of CBCT is not an artifact of the specific sample partitioning and is likely to hold true for similar patient populations.

These additional findings collectively strengthen the argument for CBCT's utility. The specific advantages in diagnosing cystic formations and benign tumors, coupled with enhanced diagnostic confidence due to 3D visualization and the robustness of the results, underscore the significant clinical benefits of adopting CBCT for the diagnosis of mandibular pathologies.

## 5. Coherent Summary of Results

In summary, this comparative study comprehensively evaluated the diagnostic accuracy of conventional radiography and CBCT in the identification of mandibular pathologies. The findings consistently demonstrate that CBCT offers a statistically significant and clinically meaningful advantage over conventional radiography. Our primary research question, "Does CBCT offer superior diagnostic accuracy compared to conventional radiography in the detection and characterization of various mandibular pathologies?", is unequivocally answered in the affirmative.

Key findings indicate that CBCT exhibits substantially higher sensitivity, positive predictive value, negative predictive value, and overall accuracy. This is visually supported by ROC curve analysis, which shows a significantly larger area under the curve for CBCT, signifying its superior ability to discriminate between pathological and non-pathological conditions. The effect size analysis further validates this, indicating a large and impactful difference in diagnostic performance.

Furthermore, additional analyses revealed that CBCT's superiority is particularly pronounced in the diagnosis of cystic lesions and benign tumors, and its ability to provide three-dimensional information significantly enhances diagnostic confidence and aids in assessing lesion extent. Robustness testing through cross-validation confirmed the reliability of these findings.

These integrated results strongly suggest that CBCT should be considered the imaging modality of choice for a more accurate and comprehensive diagnosis of mandibular pathologies, facilitating improved treatment planning and patient outcomes. The subsequent discussion section will further explore the implications of these findings and their impact on clinical practice.

## CONCLUSION

This study has successfully undertaken a comparative investigation into the accuracy of conventional radiography and Cone Beam Computed Tomography (CBCT) in diagnosing various jaw pathologies, leading to several significant key findings. Firstly, CBCT consistently demonstrated a clear superiority in visualizing fine structural details, such as

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osteolytic lesions, complex bone deformities, and intricate anatomical relationships, which are often missed or poorly defined on conventional radiographs. This directly addresses the research question regarding differences in diagnostic accuracy for morphological abnormalities, where CBCT excels in providing a more detailed depiction. Secondly, the study confirmed that a statistically higher diagnostic accuracy was observed in cases of complex jaw pathologies, including mandibular or maxillary tumors with unclear soft tissue invasion, when utilizing CBCT compared to conventional radiography. This finding explicitly reinforces the hypothesis that CBCT provides more comprehensive diagnostic information for more intricate pathologies, thereby expanding our understanding of the inherent limitations of conventional radiography in reconstructing three-dimensional abnormalities, which can often lead to potential interpretation errors and less accurate assessments of lesion extent. Thirdly, this study highlighted the significant potential of CBCT for enhanced pre-operative planning. Its ability to provide an accurate three-dimensional overview of jaw pathologies drastically improves the visualization of anatomical relationships, nerve involvement, and lesion margins, enabling surgeons to design more precise surgical approaches and predict outcomes with greater confidence. The integration of these findings forms a coherent narrative that underscores a paradigm shift in jaw pathology diagnostic imaging, where CBCT not only complements but, in many instances, surpasses the capabilities of conventional radiography in delivering essential diagnostic information.

The substantive contributions of this research to the existing literature and clinical practice are paramount. Theoretically, we have quantified the differences in spatial resolution and fine detail detection capabilities between the two modalities within the context of jaw pathology diagnostics, providing robust empirical evidence that supports theoretical claims about CBCT's superiority in generating high-detail, three-dimensional images. This enriches our understanding of how the physical characteristics of imaging technology directly correlate with diagnostic accuracy in specific pathologies. Empirically, this study offers strong validation for the growing clinical perception of CBCT's superiority in evaluating complex jaw pathologies. By objectively measuring accuracy, we advance the field's comprehension by quantitatively demonstrating where and why CBCT is more advantageous in detecting and characterizing abnormalities, which directly impacts patient diagnosis and outcomes. Beyond highlighting CBCT's strengths, the research also reinforces the understanding of conventional radiography's complementary role, remaining crucial for initial screening and specific conditions, thereby emphasizing that modality selection must be guided by specific clinical indications. We have also contributed to research methodology by developing stringent protocols for the comparative diagnostic accuracy assessment, providing a model for subsequent similar investigations. The practical implications of this research are highly relevant for clinicians, who should proactively consider CBCT as the primary imaging modality for suspected jaw pathologies, especially those involving deformities, tumors, or when three-dimensional structural assessment is critical. The need for accurate and comprehensive diagnoses is paramount in managing jaw pathologies, which often have significant implications for patients' function, aesthetics, and quality of life. Through judicious use, CBCT can lead to faster and more accurate diagnoses, reducing the need for costly additional examinations or misdirected procedures, thereby optimizing resource allocation and cost-effectiveness. The richer diagnostic information derived from CBCT should be systematically integrated into multidisciplinary treatment planning processes, as

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accurate planning is crucial for minimizing complications, accelerating recovery, and achieving optimal functional and aesthetic outcomes.

While this research has provided valuable insights, several gaps and new questions arise, paving the way for the most promising future research directions. Firstly, a more in-depth evaluation of CBCT accuracy with a broader spectrum of resolutions and a comprehensive characterization of artifacts is essential. Prospective studies employing experimental designs to vary CBCT acquisition parameters and assess their impact on lesion detection and characterization, along with rigorous analysis of artifacts that may influence interpretation, would be highly valuable. Secondly, a new emerging question is the extent to which CBCT can detect very subtle or early pathological changes in the jaw that might be missed by other modalities. Longitudinal studies in high-risk populations or radiomics analyses of CBCT data could yield novel insights. Thirdly, exploring the synergy between CBCT and other imaging modalities, such as MRI for enhanced soft tissue visualization, or the use of image fusion techniques for more comprehensive depiction, as well as the potential of CBCT in digital dentistry, requires further investigation. Future research should focus on integrating CBCT with other advanced imaging technologies and assessing their impact on treatment outcomes within the realm of digital dentistry. In conclusion, this study underscores that CBCT represents a significant advancement in diagnostic imaging for jaw pathologies, offering unprecedented levels of detail and spatial accuracy that substantially enhance clinicians' ability to diagnose and manage these conditions. The long-term impact of these findings lies in the potential to revolutionize diagnostic approaches, leading to more effective patient management and improved treatment outcomes, while simultaneously fostering continuous innovation in medical imaging technology, shaping the future of head and neck radiology and dentistry.

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