Journal of Oral Hygiene & Health
ISSN: 2332-0702

Opinion Open Access

CBCT: Diagnostics, AI, Digital Workflow, Safety

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Received: 01-Nov-2025, Manuscript No. johh-25-174154; **Editor assigned:** 03-Nov-2025, PreQC No. johh-25-174154(PQ); **Reviewed:** 17-Nov-2025, QC No. johh-25-174154; **Revised:**24-Nov-2025, Manuscript No. johh-25-174154(R); **Published:** 01-Dec-2025, **DOI**: 10.4172/2332-0702.1000518

Citation: Ofori S (2025) CBCT: Diagnostics, AI, Digital Workflow, Safety. J Oral Hyg Health 13: 518.

Abstract

This collection of research highlights the expansive utility and evolving landscape of Cone-Beam *Computed Tomography* (CBCT) in dentistry. It covers CBCT's high diagnostic accuracy for various conditions like root fractures, peri-implantitis, and TMJ osteoarthritis, while also emphasizing the critical need for radiation dose optimization, particularly in pediatric patients. The integration of CBCT within the digital dental workflow, alongside advancements like Artificial Intelligence and 3D printing, promises enhanced precision in diagnosis, treatment planning, and surgical outcomes. Overall, these studies underscore CBCT's indispensable role and its ongoing development for safer, more effective dental care.

Keywords

Cone-Beam Computed Tomography; CBCT; Dental Radiology; Artificial Intelligence; Radiation Dose; Diagnostic Accuracy; Digital Dentistry; 3D Printing; Oral Surgery; Traumatic Dental Injuries

Introduction

Recent research explores the diagnostic accuracy of Cone-Beam Computed Tomography (CBCT) in identifying vertical root fractures. While CBCT demonstrates considerable capability, its precision is subject to variables such as image resolution and the presence of root canal fillings. This underscores CBCT's utility as a diagnostic instrument, yet highlights the necessity of accounting for these modulating factors to achieve the most dependable diagnosis[1].

The landscape of oral and maxillofacial radiology is currently undergoing a significant transformation with the advent of Artificial Intelligence (AI) applications. This rapidly evolving area shows immense potential for revolutionizing aspects like disease detection, comprehensive image analysis, and meticulous treatment planning. The swift progress in AI integration underscores an ongoing need for dedicated research to seamlessly incorporate these sophisticated technologies into routine clinical practice[2].

For dental implant planning, Cone-Beam Computed Tomography (CBCT) is indispensable for thorough pre-surgical assessments. However, studies reveal a notable disparity in reported patient radiation doses from these scans. This variation emphasizes the critical importance of refining exposure parameters and consistently employing dose reduction techniques. The goal is to prioritize patient safety while steadfastly maintaining diagnostic image quality without compromise[3].

When assessing peri-implantitis, a frequent complication in implant dentistry, a direct comparison between two-dimensional (2D) and three-dimensional (3D) imaging techniques provides clarity. What is evident is that 3D imaging, exemplified by CBCT, consistently offers superior diagnostic accuracy compared to traditional 2D radiographs. This advantage is particularly pronounced in identifying early stages of bone loss around implants, thereby making

3D imaging the preferred modality for a thorough and precise assessment of such cases[4].

A thorough meta-analysis has affirmed the significant efficacy of CBCT in diagnosing temporomandibular joint (TMJ) osteoarthritis. The conclusive finding is that CBCT serves as an exceptionally accurate tool for detecting specific bony alterations characteristic of TMJ osteoarthritis. This outcome solidifies its immense value for dental professionals and specialists, providing essential, detailed anatomical insights crucial for both accurate diagnosis and strategic treatment formulation for TMJ conditions[5].

Minimizing radiation exposure for pediatric patients undergoing dental CBCT is a critical concern due to their heightened radiosensitivity. Research outlines effective strategies to lower these radiation doses. It highlights that implementing various techniques, such as optimizing exposure settings and utilizing smaller fields of view, can substantially reduce doses without diminishing the diagnostic quality of the images. This approach is paramount for delivering safe and effective pediatric dental care[6].

The overarching digital workflow within dentistry has profoundly transformed nearly every facet of dental practice, largely propelled by advancements in digital radiology. This comprehensive integration, encompassing advanced imaging technologies, extends from initial diagnosis through meticulous treatment planning and precise fabrication processes. The direction points towards a future where these harmonized digital systems deliver dental care that is notably more predictable, efficient, and precise, showcasing the indispensable role of advanced imaging solutions[7].

Evaluating the accuracy of diverse radiographic methods for detecting proximal caries—cavities situated between teeth—reveals important insights. While conventional bitewing radiographs maintain their fundamental role, contemporary digital methods demonstrate comparable or even enhanced accuracy, often accompanied by reduced radiation doses. The essential consideration is to meticulously select the appropriate imaging technique, aligning it with the patient's individual risk profile and the specific diagnostic objectives, thereby optimizing both detection capabilities and patient safety[8].

An updated perspective on optimal imaging practices for traumatic dental injuries underscores the evolving role of advanced techniques. While traditional radiographs retain their utility, cutting-edge modalities like CBCT are increasingly indispensable for a thorough evaluation of complex injuries, such as root fractures or alveolar bone damage, which might evade detection on standard two-dimensional images. The correct selection of imaging modality is paramount for ensuring precise diagnosis and guiding effective treatment planning in these urgent clinical scenarios[9].

The synergistic integration of CBCT imaging with 3D printing in the realm of oral surgery represents a significant technological leap. CBCT provides the essential, high-fidelity anatomical data necessary for producing customized 3D models and highly accurate surgical guides. This advanced digital workflow fundamentally reshapes preoperative planning, contributing to superior accuracy and predictability in intricate procedures such as precise implant placement and complex orthognathic surgery. It vividly illustrates how state-of-the-art imaging directly translates into tangible improvements in surgical outcomes[10].

Description

Cone-Beam Computed Tomography (CBCT) has emerged as a cornerstone in modern dental and maxillofacial diagnostics due to its ability to provide detailed three-dimensional insights. This advanced imaging modality offers superior diagnostic accuracy over traditional two-dimensional radiographs, particularly in complex scenarios. For instance, CBCT is highly effective in detecting vertical root fractures, though its accuracy can be influenced by factors such as image resolution and the presence of root canal fillings [1]. Similarly, for diagnosing peri-implantitis, a common complication, 3D imaging techniques like CBCT provide significantly better diagnostic performance, especially for identifying early stages of bone loss around implants [4]. The utility of CBCT extends to comprehensive assessments of temporomandibular joint (TMJ) osteoarthritis, where it accurately reveals bony changes, furnishing critical anatomical information for both diagnosis and treatment planning [5]. These capabilities position CBCT as an invaluable tool for precise clinical evaluation across various dental specialties.

Despite the clear diagnostic benefits, the application of CBCT necessitates a conscientious approach to radiation exposure, emphasizing patient safety. Studies on radiation doses for CBCT scans, particularly those used in dental implant planning, highlight a wide range of reported doses. This variability underscores the importance of optimizing exposure parameters and diligently implementing dose reduction techniques to ensure patient safety without compromising the diagnostic quality of the images [3]. A crucial area of focus is pediatric dentistry, where strategies to lower radiation doses for children undergoing dental CBCT are paramount due to their increased radiosensitivity. Techniques such as optimized exposure settings and the use of smaller fields of view are vital for achieving significant dose reductions while maintaining diagnostic image quality, which is essential for safe pediatric dental care [6].

The broader digital transformation in dentistry relies heavily on advanced imaging, with CBCT playing a central role. The digital workflow, encompassing everything from diagnosis to treatment planning and fabrication, has been revolutionized by digital tools, including sophisticated imaging systems. This integration leads to more predictable, efficient, and precise dental care, highlighting the indispensable role of advanced imaging [7]. A cutting-edge development is the integration of Artificial Intelligence (AI) into oral and maxillofacial radiology. AI holds immense promise for enhancing disease detection, streamlining image analysis, and refining treatment planning, representing a rapidly growing field that demands continued research for effective clinical integration [2]. Furthermore, the synergy between CBCT imaging and 3D printing in oral surgery exemplifies this digital revolution. CBCT provides the precise anatomical data needed to create patient-specific 3D models and surgical guides, fundamentally improving preoperative planning and leading to greater accuracy and predictability in complex procedures like implant placement and orthognathic surgery [10].

Beyond specialized applications, fundamental diagnostic tasks like detecting proximal caries, or interdental cavities, continue to evolve with new imaging techniques. A meta-analysis comparing various radiographic methods for proximal caries detection shows that while bitewing radiographs remain essential, newer digital approaches offer comparable or even improved accuracy, often with the added benefit of lower radiation doses. The key is to carefully select the appropriate imaging technique based on the individual patient's risk and the specific diagnostic objectives, balancing detection efficacy with patient safety [8]. Moreover, for traumatic dental injuries, imaging practices have seen updates. Conventional radiographs are still useful, but advanced imaging techniques like CBCT are increasingly critical for comprehensively assessing complex injuries—such as root fractures or alveolar bone damage—that might be overlooked on 2D images. Choosing the right imaging modality is crucial for accurate diagnosis and effective treatment planning in these time-sensitive cases [9].

Conclusion

Cone-Beam Computed Tomography (CBCT) plays a pivotal role in modern dental diagnostics and treatment planning. Its diagnostic accuracy for conditions like vertical root fractures, peri-implantitis, and temporomandibular joint osteoarthritis is well-established, though factors like image resolution and root canal fillings can influence fracture detection. CBCT's superior 3D imaging capabilities often surpass conventional 2D radiographs, particularly for detailed assessments such as early bone loss around implants or complex traumatic dental injuries.

However, the use of CBCT also necessitates careful consideration of radiation dose, with efforts focused on optimizing parameters and employing dose reduction techniques, especially for pediatric patients who are more radiosensitive. The field is rapidly integrating advanced technologies like Artificial Intelligence (AI) into oral and maxillofacial radiology for tasks such as disease detection and image analysis, promising enhanced efficiency and precision.

Furthermore, CBCT is foundational to the broader digital workflow in dentistry, enabling sophisticated applications like 3D printing for patient-specific models and surgical guides. This integration revolutionizes preoperative planning, leading to more predictable and accurate surgical outcomes. While digital methods, including various radiographic techniques, are proving effective for detecting conditions like proximal caries, selecting the appropriate imaging modality remains crucial to balance diagnostic efficacy with patient safety and optimize clinical outcomes across diverse dental applications.

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