



Recent Advances in Radiographic Imaging in Dentistry: A Brief Review

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ABSTRACT

Recent advances in radiographic imaging in dentistry have significantly enhanced diagnostic accuracy and treatment planning. Techniques such as digital radiography, cone beam computed tomography (CBCT), and intraoral scanners provide high-resolution images with reduced radiation exposure. These technologies facilitate early detection of dental anomalies, precise assessment of anatomical structures, and improved visualization for restorative procedures. Additionally, software advancements enable enhanced image processing, 3D reconstruction, and integration with other digital tools, streamlining workflows. Overall, these innovations contribute to safer, more efficient dental care and improved patient outcomes, marking a transformative era in dental radiographic practices.

Keywords: *Dental imaging, CBCT, OPG, Radiography.*

Introduction

Radiographic imaging is a cornerstone of modern dentistry, serving as a vital tool for diagnosis, treatment planning, and patient management. By providing detailed views of dental and maxillofacial structures, imaging techniques enable dentists to identify issues such as caries, periodontal diseases, and other anomalies that may not be visible during a physical examination. This enhanced visualization is essential for delivering precise and effective care.^{1,2}

The shift from traditional film-based radiography to digital imaging has revolutionized dental practices. Digital radiography offers immediate access to high-quality images with significantly reduced radiation exposure for patients. These images can be easily manipulated and shared, improving both diagnostic efficiency and patient education. Additionally, Cone-Beam Computed Tomography (CBCT) has emerged as a game-changer, providing three-dimensional views that are invaluable for complex procedures like implant planning and orthodontic assessments.^{2,3}

Continuous advancements in radiographic technology are crucial for refining diagnostic accuracy and treatment outcomes. Innovations such as artificial intelligence (AI) in image analysis enhance the identification of pathologies, reducing human error and streamlining workflows. Furthermore, portable imaging devices and augmented reality promise to expand access to imaging and improve procedural guidance.³

In summary, the role of radiographic imaging in dentistry is indispensable, and ongoing technological

advancements are vital for enhancing diagnostic capabilities and ensuring the delivery of high-quality patient care. Embracing these developments will shape the future of dentistry, driving improvements in oral health outcomes.^{2,3}

Evolution of Radiographic Techniques

The evolution of radiographic techniques in dentistry reflects significant advancements in technology and diagnostic capabilities. Historically, conventional film-based radiography dominated the field, where dental practitioners relied on X-ray films to capture images of the oral cavity. This method, while effective, had limitations, including prolonged processing times, lower image quality, and higher radiation exposure for patients. As time progressed, the need for more efficient and precise diagnostic tools became apparent, paving the way for the transition to digital imaging.

The introduction of digital radiography marked a paradigm shift in dental imaging. This technology produced images that could be viewed instantaneously on a computer screen, significantly reducing the time required for diagnosis. Digital images also boasted superior quality and allowed for enhanced contrast and manipulation, enabling clinicians to discern subtle pathologies that might have gone unnoticed on film. Furthermore, radiation exposure was reduced, leading to safer patient experiences.

As the field continued to evolve, new imaging modalities emerged. Intraoral radiography became widely used for capturing detailed images of individual teeth and surrounding structures, facilitating targeted assessments. Panoramic radiography provided a broader view of the entire jaw, allowing for efficient evaluation of multiple teeth and surrounding bone in a single image. This technique proved invaluable for treatment planning, especially in orthodontics and oral surgery.

The introduction of Cone-Beam Computed Tomography represented a revolutionary leap forward, enabling three-dimensional imaging of the dental and maxillofacial region. CBCT offered unprecedented detail and accuracy, especially for complex cases such as implant placement and assessing bone structure.

In summary, the evolution from conventional film to digital imaging and the subsequent development of advanced radiographic techniques have transformed dental practice, enhancing both diagnostic capabilities and patient care.⁴⁻⁶

2D vs 3D Dental Imaging

2D dental imaging involves capturing flat images of teeth and surrounding structures using X-rays. It's commonly used for routine diagnostics, including detecting cavities, assessing gum health, and evaluating fractures. While 2D images provide essential information quickly and are typically less expensive, they have limitations. Depth perception is lacking, which can result in overlooked underlying issues.

In contrast, 3D dental imaging, particularly through techniques like cone beam computed tomography (CBCT), offers a comprehensive view of the oral environment. This advanced imaging captures multiple angles to create a three-dimensional representation of teeth, bone structure, and soft tissues. One significant advantage of 3D imaging is its ability to provide detailed anatomical information, crucial for planning complex procedures like dental implants, orthodontics, and surgery.

The enhanced accuracy of 3D imaging helps in diagnosing conditions that might be missed in 2D scans, such as hidden dental infections or impacted teeth. However, while 3D imaging is typically more expensive and requires specialized equipment, its long-term benefits often outweigh the costs.

In summary, 2D imaging is useful for routine assessments, while 3D imaging excels in complex cases, providing more precise diagnostics and planning capabilities for modern dental care.^{7,8}

Digital Radiography

Digital radiography has significantly transformed the practice of dentistry by offering numerous advantages over traditional film-based radiography. One of the most critical benefits is the reduction in radiation exposure for patients. Digital sensors are far more sensitive to X-rays than traditional film, allowing for the acquisition of high-quality images with lower doses of radiation. This reduction is particularly vital in pediatric dentistry, where minimizing exposure is a primary concern.⁹

Another significant advantage of digital radiography is the immediate availability of images. In traditional methods, images require time-consuming development, delaying diagnosis and treatment. In contrast, digital images can be viewed almost instantaneously on a computer screen, allowing dentists to assess conditions promptly and make informed decisions about treatment. This rapid feedback loop enhances the overall efficiency of dental practices, reducing wait times for patients and facilitating quicker diagnoses.

Digital radiography also boasts enhanced image quality compared to traditional film. The images produced are sharper and more detailed, allowing for greater diagnostic accuracy. Dentists can manipulate digital images by adjusting brightness, contrast, and magnification, making it easier to identify subtle pathologies that might otherwise go unnoticed. Additionally, digital images can be easily archived, shared, and integrated into electronic health records, improving continuity of care and collaboration among dental professionals.

There are two primary types of digital radiography: direct and indirect sensors. Direct sensors utilize a digital sensor that captures the X-ray image and converts it directly into an electronic signal. This method provides high-resolution images with minimal processing time. On the other hand, indirect sensors use a two-step process, where X-rays first hit a phosphor plate that stores the image, which is then scanned to convert to a digital format. While indirect sensors may take longer for image acquisition, they offer flexibility and are often more cost-effective.

In summary, the benefits of digital radiography over traditional methods are profound, offering reduced radiation exposure, immediate image availability, and superior image quality. The availability of different sensor types further enhances clinicians' options, fostering improved diagnostic capabilities in dentistry.⁹⁻¹⁰

Cone-Beam Computed Tomography (CBCT)

CBCT represents a groundbreaking advancement in dental imaging technology that allows for the acquisition of three-dimensional images of the dental and maxillofacial region. Unlike conventional computed tomography (CT), which utilizes a fan-shaped beam, CBCT employs a cone-shaped X-ray beam that collects data quickly and efficiently, resulting in comprehensive volumetric images. This innovative imaging technique has become increasingly significant in dental practice due to its ability to provide precise anatomical details and support complex treatment planning.¹¹

One of the primary advantages of CBCT is its capacity for 3D visualization. This multidimensional perspective allows clinicians to assess the spatial relationships between teeth, bone structures, nerves, and surrounding tissues. The ability to visualize anatomy in three dimensions significantly enhances diagnostic accuracy, particularly in intricate cases such as impacted teeth, root canal anatomy, and temporomandibular joint disorders. By providing a comprehensive view of the craniofacial region, CBCT facilitates improved diagnosis and treatment planning, especially for orthodontic and implant procedures.

CBCT has numerous surgical applications as well. For instance, in implant dentistry, it allows for precise assessment of bone density and volume, crucial factors for successful implant placement. Surgeons can simulate procedures and anticipate potential complications, leading to better surgical outcomes. Additionally, CBCT is valuable in orthodontics for evaluating tooth eruption patterns and planning comprehensive treatment approaches.

Despite its numerous advantages, CBCT is not without limitations. One notable challenge is the higher costs associated with CBCT acquisition and maintenance compared to traditional imaging modalities. This investment can be a barrier for many dental practices, particularly smaller ones. Furthermore, the volume of data generated by CBCT scans can pose challenges in data management and storage. Practitioners must ensure they have the necessary systems in place to handle and securely store large image files.¹²

Another limitation is the interpretation of CBCT images, which requires specialized training and experience. The complexity of 3D data can lead to increased difficulty in accurately identifying pathologies and anatomical variations compared to traditional 2D imaging.

In conclusion, Cone-Beam Computed Tomography has revolutionized dental imaging by providing enhanced 3D visualization, leading to improved diagnosis and treatment of complex cases. While it offers numerous advantages in surgical applications, the technology also presents challenges in terms of cost, data management,

and interpretation. Ultimately, CBCT represents a valuable tool in modern dentistry, supporting clinicians in achieving optimal patient outcomes.^{11,12}

Recent advances in radiographic imaging technologies, such as MRI, ultrasound, tuned aperture computed tomography (TACT), and subtraction radiography, have significantly enhanced diagnostic capabilities across various medical fields. Each modality offers unique benefits and continues to evolve with innovative techniques and improved imaging quality.

MRI (Magnetic Resonance Imaging): MRI has seen substantial advancements with the development of faster imaging sequences, higher field strength magnets (3T and beyond), and improved contrast agents. These innovations have led to better resolution images and shorter scan times. Techniques like functional MRI (fMRI) enable the assessment of brain activity, while diffusion tensor imaging (DTI) allows for the visualization of white matter tracts in the brain. Additionally, the integration of artificial intelligence (AI) in MRI can aid in image interpretation, enhancing diagnostic accuracy and efficiency.¹³

Ultrasound: Ultrasound imaging has advanced with the introduction of high-frequency transducers and 3D/4D imaging capabilities. Enhanced Doppler techniques provide improved visualization of vascular structures and flow dynamics. Point-of-care ultrasound (POCUS) has gained popularity, allowing rapid bedside assessments in emergency and critical care settings. The development of elastography provides new insights into tissue stiffness, assisting in the evaluation of liver fibrosis and tumors.¹⁴

Tuned Aperture Computed Tomography (TACT): TACT is an emerging imaging technique that combines elements of conventional computed tomography with the ability to tune the aperture (field of view) based on specific imaging needs. This approach allows for improved spatial resolution and contrast in imaging soft tissues. TACT has shown promise in applications such as breast imaging, where it can detect subtle lesions that may not be visible with standard mammography.¹⁵

Subtraction Radiography: Subtraction radiography is an advanced imaging technique that enhances the visibility of structures by removing overlapping images or shadows from surrounding tissues. Recent advancements include digital subtraction techniques that utilize image processing algorithms to optimize clarity. This method is particularly beneficial in vascular imaging by clearly visualizing blood vessels, or in dentistry, aiding in the identification of caries and other dental anomalies by highlighting the differences between images taken at different times.

In conclusion, the recent advances in MRI, ultrasound, tuned aperture computed tomography, and subtraction radiography reflect the ongoing evolution of imaging technologies, improving diagnostic accuracy and patient care. As these modalities continue to develop, they promise to provide even greater insights into human anatomy and pathophysiology, ultimately enhancing clinical outcomes.¹⁶

Conclusion

Recent advances in dental imaging, such as enhanced 3D technologies and AI integration, have significantly improved diagnostic accuracy and treatment planning. With innovations like cone beam computed tomography (CBCT) and digital scanning, dentists can obtain detailed, high-resolution images to identify complex dental issues more effectively. These advancements not only enhance patient outcomes but also streamline workflows in dental practices, making procedures faster and more efficient. As technology continues to evolve, the future of dental imaging holds the promise of even greater precision and improved patient care.

References

1. Shah N, Bansal N, Logani A. Recent advances in imaging technologies in dentistry. *World J Radiol.* 2014 Oct 28;6(10):794-807. doi: 10.4329/wjr.v6.i10.794. PMID: 25349663; PMCID: PMC4209425.
2. Vandenberghe B, Jacobs R, Bosmans H. Modern dental imaging: a review of the current technology and clinical applications in dental practice. *Eur Radiol.* 2010 Nov;20(11):2637-55. doi: 10.1007/s00330-010-1836-1. Epub 2010 Jun 11. PMID: 20544352.
3. de Magalhães AA, Santos AT. Advancements in Diagnostic Methods and Imaging Technologies in Dentistry: A Literature Review of Emerging Approaches. *J Clin Med.* 2025 Feb 14;14(4):1277. doi: 10.3390/jcm14041277. PMID: 40004807; PMCID: PMC11856960.
4. Kim IH, Singer SR, Hong DJ, Mupparapu M. Fundamentals of Radiographic Interpretation for the Dentist. *Dent Clin North Am.* 2021 Jul;65(3):409-425. doi: 10.1016/j.cden.2021.02.001. Epub 2021 May 3. PMID: 34051923.
5. Masthoff M, Gerwing M, Masthoff M, Timme M, Kleinheinz J, Berninger M, Heindel W, Wildgruber M, Schülke C. Dental Imaging - A basic guide for the radiologist. *Rofo.* 2019 Mar;191(3):192-198. English, German. doi: 10.1055/a-0636-4129. Epub 2018 Jun 18. PMID: 29913523.
6. Nasseh I, Al-Rawi W. Cone Beam Computed Tomography. *Dent Clin North Am.* 2018 Jul;62(3):361-391.
7. Schmidt JC, Gutekunst CJ, Dagassan-Berndt D, Schmidlin PR, Walter C. Comparison of Two-Dimensional and Three-Dimensional Radiographs Using Clinically Relevant Parameters. *Dent J (Basel).* 2019 May 1;7(2):50. doi: 10.3390/dj7020050. PMID: 31052379; PMCID: PMC6630924.
8. Schmidt JC, Gutekunst CJ, Dagassan-Berndt D, Schmidlin PR, Walter C. Comparison of Two-Dimensional and Three-Dimensional Radiographs Using Clinically Relevant Parameters. *Dent J (Basel).* 2019 May 1;7(2):50. doi: 10.3390/dj7020050. PMID: 31052379; PMCID: PMC6630924.

9. Jayachandran S. Digital Imaging in Dentistry: A Review. *Contemp Clin Dent*. 2017 Apr-Jun;8(2):193-194. doi: 10.4103/ccd.ccd_535_17. PMID: 28839401; PMCID: PMC5551320.
10. Van der Stelt PF. Filmless imaging: The uses of digital radiography in dental practice. *J Am Dent Assoc*. 2005;136:1379–87.
11. Jaju PP, Jaju SP. Clinical utility of dental cone-beam computed tomography: current perspectives. *Clin Cosmet Investig Dent*. 2014 Apr 2;6:29-43. doi: 10.2147/CCIDE.S41621. PMID: 24729729; PMCID: PMC3979889.
12. Baccher S, Gowdar IM, Guruprasad Y, Solanki RN, Medhi R, Shah MJ, Mehta DN. CBCT: A Comprehensive Overview of its Applications and Clinical Significance in Dentistry. *J Pharm Bioallied Sci*. 2024 Jul;16(Suppl 3):S1923-S1925. doi: 10.4103/jpbs.jpbs_19_24. Epub 2024 May 2. PMID: 39346317; PMCID: PMC11426588.
13. Niraj LK, Patthi B, Singla A, Gupta R, Ali I, Dhama K, Kumar JK, Prasad M. MRI in Dentistry- A Future Towards Radiation Free Imaging - Systematic Review. *J Clin Diagn Res*. 2016 Oct;10(10):ZE14-ZE19. doi: 10.7860/JCDR/2016/19435.8658. Epub 2016 Oct 1. PMID: 27891491; PMCID: PMC5121829.
14. Reda R, Zanza A, Cicconetti A, Bhandi S, Miccoli G, Gambarini G, Di Nardo D. Ultrasound Imaging in Dentistry: A Literature Overview. *J Imaging*. 2021 Nov 14;7(11):238. doi: 10.3390/jimaging7110238. PMID: 34821869; PMCID: PMC8624259.
15. Webber RL, Horton RA, Tyndall DA, Ludlow JB. Tuned-aperture computed tomography (TACT). Theory and application for three-dimensional dento-alveolar imaging. *Dentomaxillofac Radiol*. 1997 Jan;26(1):53-62. doi: 10.1038/sj.dmfr.4600201. PMID: 9446991.
16. Ort MG, Gregg EC, Kaufman B. Subtraction radiography: techniques and limitations. *Radiology*. 1977 Jul;124(1):65-72. doi: 10.1148/124.1.65. PMID: 325600.



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