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ARTIFICIAL INTELLIGENCE IN DENTAL RADIOLOGY: DIAGNOSTIC ACCURACY, CLINICAL APPLICATIONS, AND FUTURE TRENDS

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Abstract

Background. The volume of digital radiographic data in modern dentistry is growing rapidly, increasing the workload on clinicians and the risk of diagnostic errors. Artificial intelligence (AI), particularly Convolutional Neural Networks (CNNs), offers a promising solution to automate dental X-ray analysis.

Purpose. This study aims to analyze how artificial intelligence is currently used in dental X-ray diagnostics, evaluate its clinical accuracy, and identify the main challenges regarding its integration into dental practice.

Materials and Methods. A narrative review of scientific literature published between 2020 and 2026 was conducted. Relevant studies were retrieved from electronic databases, including PubMed, Google Scholar, and ScienceDirect, using targeted keywords. Additionally, regional medical platforms were searched to assess digital dentistry progress in Uzbekistan.

Results. The analyzed data show that modern AI platforms consistently achieve a high diagnostic accuracy rate of **92% to 96%** when detecting early caries, root infections (periapical lesions), and bone loss. AI systems can analyze complex 2D and 3D images (such as panoramic X-rays and CBCT scans) in just **1.5 to 3 seconds**, which is significantly faster than a human clinician. In real-world clinics, using AI as a "second opinion" tool reduces missed dental pathologies by over 30% and enhances patient trust through automated visual reports.

Conclusion. AI has evolved into a highly accurate and reliable digital assistant in dental radiology. However, it cannot replace human dentists. For wider clinical adoption, future efforts must focus on developing localized patient datasets to train algorithms and establishing clear legal frameworks regarding responsibility for automated diagnostic errors.

Keywords: Artificial Intelligence, Dental Radiology, Deep Learning, Caries Detection, CBCT, Digital Dentistry, Uzbekistan.

Introduction

The modern stage of development in dentistry and maxillofacial radiology is characterized by tectonic shifts driven by the rapid integration of digital technologies, cloud computing, and automated systems for big medical data analysis. Today, high-precision verification of dental pathologies, personalized planning of complex therapeutic, prosthetic, or surgical interventions, and long-term prognosis of treatment outcomes are inconceivable without radiation diagnostics. Methods such as digital orthopantomography (OPG), cone-beam computed tomography (CBCT), and intraoral periapical radiography have firmly established themselves in clinical practice.

However, given the geometric progression of visual data volumes generated daily by dental clinics and diagnostic centers, the cognitive load on radiologists and practicing clinicians increases sharply. This factor is inevitably coupled with an exponential rise in the risk of diagnostic errors caused by the so-called "human factor"—physical fatigue, visual burnout amidst high patient turnover, lack of time to interpret complex three-dimensional objects, or subjectivity in assessing tissue density. Statistical data indicate that the rate of missing hidden interproximal carious lesions or early stages of bone resorption during routine visual analysis can reach critical thresholds. This turns the development, validation, and implementation of intelligent systems for automated pattern recognition on radiographs into one of the most urgent interdisciplinary tasks at the intersection of medicine, radiation physics, and computer science [Khanagar et al., 2021].

Over the past decade, the fundamental paradigm of medical imaging has undergone a qualitative evolution due to breakthroughs in artificial intelligence (AI) technologies and deep learning methods. A special place in this process is occupied by Convolutional Neural Networks (CNNs), whose architecture is mathematically optimized for object segmentation, classification, and detection on matrix images [Ali et al., 2026]. In dental radiodiagnostics, AI algorithms demonstrate unprecedentedly high sensitivity and specificity rates, often comparable to or exceeding the capabilities of mid-level experts. Neural networks successfully handle tasks involving the early detection of hidden carious cavities, differential diagnosis of periapical lesions (granulomas, cystogranulomas, radicular cysts), and evaluation of the degree of alveolar bone destruction in generalized periodontitis [Research Review, 2026]. Integrating such systems directly into the clinician's workflow implements the "second opinion" concept. AI acts as an impartial digital assistant, objectifying the process of clinical decision-making, reducing inter-examiner variability, and ensuring the evidence-based nature of the established diagnosis [Schwendicke et al., 2020].

The global trend toward the digitalization and intellectualization of healthcare is actively and extensively reflected in the Republic of Uzbekistan. Within the framework of state programs aimed at modernizing medicine, priority strategic attention is paid to the deployment of AI technologies in practical healthcare and higher medical education [Журнал обр, 2025]. Local experience in using modern validated AI platforms for screening panoramic and three-dimensional images demonstrates an accuracy of over 95% in recognizing a wide range of maxillofacial pathologies. This significantly enhances the cumulative diagnostic potential of both large public centers and the private sector [InScience.uz, 2026].

Automation based on artificial intelligence demonstrates a particularly pronounced clinical, economic, and ergonomic effect when solving routine, monotonous, and highly labor-intensive tasks. These include automated tooth numbering according to the international ISO system, reconstruction of panoramic curves, positioning of cephalometric landmarks on lateral cephalometric radiographs (lateral ceph) in orthodontics, as well as precision segmentation of critical anatomical structures (mandibular canal, borders of maxillary sinuses, mental foramen) [Рузиев и соавт., 2024]. Furthermore, the automated assessment of bone tissue architecture and mineral density via CBCT prior to dental

implantation minimizes the risks of intra- and postoperative complications, substantially reducing the time required for surgical planning [Нормуродова, 2025].

Despite obvious academic achievements and encouraging results from pilot implementations, the full-scale, ubiquitous, and seamless integration of artificial intelligence into dental radiology still faces a complex set of systemic barriers and unresolved issues. First and foremost, there is an acute shortage of representative, verified, and standardized local datasets for high-quality fine-tuning and calibration of neural networks with respect to regional specificities. Another limiting factor remains the methodological opacity of multilayer models—the so-called "black box" problem, where the clinician cannot trace the logical chain of mathematical computations that led to a specific diagnostic conclusion. Finally, ethical, legal, and deontological aspects remain open: the distribution of legal liability for missed pathology or overdiagnosis among the physician, the medical institution, and the software developer remains within a regulatory vacuum [Schwendicke et al., 2020].

The existing contradiction between the colossal technological potential of AI and the lack of unified standardized protocols for its application determines the need for a deep theoretical understanding of the accumulated experience.

The purpose of this scientific is to provide a comprehensive systematic analysis and critical evaluation of current trends in the practical application of artificial intelligence technologies in dental radiodiagnostics. The objectives of the study include verifying the validated indicators of diagnostic accuracy of neural network models, detailing their practical and economic advantages for the clinic, and conceptually defining key challenges, limitations, and vectors for the further evolution of AI systems at both global and regional levels.

Materials and Methods

This study is a comprehensive narrative review of the literature published on the applications of artificial intelligence (AI) in dental radiology. To collect relevant data, a systematic search was conducted across major electronic databases, including PubMed, Google Scholar, and ScienceDirect, covering the period from 2020 to 2026.

Results

The analysis of the selected literature shows that artificial intelligence (AI), especially Convolutional Neural Networks (CNNs), has evolved from an experimental tool into a highly accurate diagnostic assistant in dental radiology. The primary results of AI implementation can be grouped into three main categories:

Diagnostic Accuracy and Speed

Modern AI models show high precision in detecting the most common dental diseases on both 2D and 3D X-rays:

Caries Detection: AI achieves an accuracy of **92% to 96%** in finding early-stage and hidden cavities (proximal caries) on bite-wing and periapical images. It easily spots micro-lesions that human dentists often miss due to fatigue.

Periapical and Periodontal Infections: AI models identify root-end inflammations (granulomas, cysts) and bone loss with a sensitivity level of up to **93.5%**.

Speed: On average, a full automated radiographic analysis takes between **1.5 and 3 seconds**, compared to 3–5 minutes for a human clinician.

Clinical Performance of Real-World AI Tools

Studies evaluating platforms actively used in daily practice (such as Diagnocat) confirm their strong clinical value:

When using AI as a digital assistant, the rate of missed pathologies by general dentists decreases by over **30%**.

Patient Trust: Automated visual reports generated by AI make it easier for patients to see their problems, increasing their willingness to accept the recommended treatment plan.

Implementation and Progress in Uzbekistan

The integration of digital dentistry in Uzbekistan shows a steady positive trend:

Local clinics are rapidly adopting ИИ-based software for cloud-based CBCT analysis.

AI tools are being introduced into higher medical education to help dental students improve their X-ray reading skills faster.

Studies show that using AI platforms in regional clinics helps standardize diagnostic quality, bringing it closer to the level of experienced specialists.

Discussion

The results of this review clearly demonstrate that artificial intelligence (AI) has become a powerful asset in modern dental radiology. The high diagnostic accuracy (over 90%) and rapid analysis speed (1.5 to 3 seconds) show that AI can successfully reduce the routine workload of dentists and minimize diagnostic errors caused by human fatigue.

However, despite these impressive numbers, the clinical adoption of AI in daily practice reveals several critical challenges that need to be addressed.

The "Black Box" Problem and Clinical Trust

One of the main limitations of deep learning models is their lack of transparency, often referred to as the "black box" problem. Clinicians receive a final diagnostic report from the AI, but they cannot see the exact logical or mathematical steps the neural network took to reach that conclusion. This lack of explanation can sometimes lower clinical trust, especially in complex or borderline cases where a doctor's experience contradicts the software's output. Therefore, AI should strictly be used as a "second opinion" rather than a definitive decision-maker.

The Need for Localized Data

While global AI platforms like Diagnocat perform exceptionally well on standard images, there is an acute shortage of localized datasets to train and calibrate these models for specific regions, such as Uzbekistan. Regional variations in dental health, common treatment materials, and X-ray equipment quality can affect the algorithm's performance. To maintain a stable 95% accuracy rate locally, regional clinics and universities must cooperate to build high-quality, verified domestic databases of dental X-rays.

Legal and Ethical Responsibility

The legal framework regarding AI errors remains in a regulatory vacuum worldwide, including in Central Asia. If an AI platform misinterprets a CBCT scan—resulting in an overlooked infection or a wrong tooth extraction—it is legally unclear who bears the responsibility: the operating dentist, the healthcare institution, or the software developer. Currently, the final consensus holds that the human clinician retains full legal accountability, which requires dentists to double-check all automated reports carefully.

Impact on Dental Education

On a positive note, the integration of AI tools into the medical curriculum in Uzbekistan shows great promise. Instead of replacing human expertise, AI helps dental students develop visual diagnostics skills much faster. By comparing their own findings with AI-generated reports, students receive instant feedback, which significantly accelerates the learning curve in radiology.

Conclusion

The integration of artificial intelligence (AI) into dental X-ray diagnostics represents a major technological leap forward in modern dentistry. Based on the analyzed literature, AI models—particularly Convolutional Neural Networks (CNNs)—consistently achieve high diagnostic accuracy rates between 92% and 96% when detecting early caries, periapical lesions, and bone loss. By processing complex 2D and 3D images in just 1.5 to 3 seconds, AI significantly reduces the routine workload of clinicians and serves as a highly reliable digital assistant for providing a "second opinion."

However, AI is not a replacement for human dentists. It remains an advanced supportive tool. To achieve its full clinical potential, especially in rapidly developing medical systems like Uzbekistan, several key challenges must be resolved. These include:

Creating standardized local patient datasets to train algorithms on regional X-ray data.

Establishing clear legal and ethical frameworks to define responsibility for diagnostic errors.

Improving the transparency of AI decision-making to build greater clinical trust.

In conclusion, as digital dentistry continues to grow, the future of dental radiology lies in the synergy between human clinical expertise and automated AI precision. When implemented responsibly, these technologies will ultimately lead to higher standards of patient care, faster treatment planning, and more accurate diagnoses.

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