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A Review on AI in Dental Radiography: A New Era of Diagnosis

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Abstract: ***Artificial Intelligence (AI) is rapidly transforming dental radiology by enhancing diagnostic accuracy, workflow efficiency, and clinical decision-making.***
Utilizing machine learning, deep learning, convolutional neural networks (CNNs), and advanced image-processing algorithms, AI systems can automatically detect dental anomalies such as caries, periodontal disease, periapical lesions, cysts, tumors, and maxillofacial fractures from 2D and 3D radiographs. Applications extend to cephalometric analysis, bone age assessment, implant identification, forensic dentistry, and radiation dose optimization.
AI-powered platforms also support education, training, and predictive analytics, enabling early intervention and personalized care. Despite these advances, challenges persist, including the need for large, diverse annotated datasets, standardization of reporting, ethical concerns, algorithmic bias, and the "black-box" nature of deep learning models. With continued collaboration among clinicians, radiologists, and AI developers, AI can serve as an augmentative tool that improves patient outcomes, streamlines workflows, and drives the evolution of precision dentistry.
Keywords: Artificial Intelligence, Dental Radiology, Convolutional Neural Networks, Diagnostic Accuracy, Image Analysis.

I. INTRODUCTION

Artificial Intelligence (AI), first introduced by John McCarthy at the Dartmouth Conference in 1956, is an advanced branch of computer science that aims to simulate human cognitive functions such as reasoning, problem-solving, learning, and decision-making. It encompasses subfields like machine learning, deep learning, natural language processing, robotics, cognitive computing, and expert systems, which collectively enable computers to recognize patterns, process language, and perform tasks traditionally requiring human intelligence.[1]

Within dentistry, AI has rapidly emerged as a transformative tool, particularly in oral and maxillofacial radiology, where it enhances diagnostic precision, accelerates clinical workflows, and supports treatment planning. AI systems can automatically detect anomalies such as dental caries, periapical lesions, periodontal bone loss, oral cysts, maxillary sinus perforations, oral cancers, and even lymph node metastasis by analyzing 2D and 3D radiographic data.[2] With the integration of digital radiography, intraoral scanning, and CAD/CAM-generated datasets, computers are now capable of identifying anatomical landmarks and pathological features with high accuracy.

This not only facilitates early disease detection but also reduces human error, improves prognostic assessments, and allows clinicians to focus more on treatment than on labor-intensive image analysis. While AI currently operates within the realm of artificial narrow intelligence designed for specific pattern-recognition and classification tasks—it holds promise for advancing toward more generalized forms of intelligence that can complement human expertise.[4] By combining accurate 3D imaging with AI algorithms, dentistry is moving toward a new era of precision diagnostics, predictive treatment planning, and enhanced patient outcomes.[5]

This review aims to provide a comprehensive overview of AI techniques, their applications in dental radiography, and the clinical challenges that shape their integration into routine practice.

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II. AI ARCHITECTURES

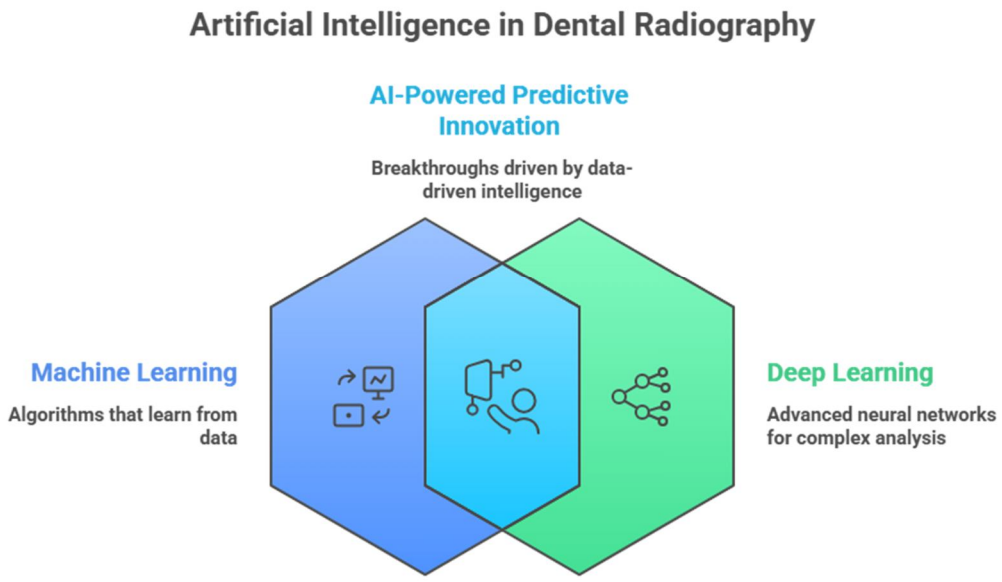


Figure 1: Classification of Artificial intelligence in Dental Radiography

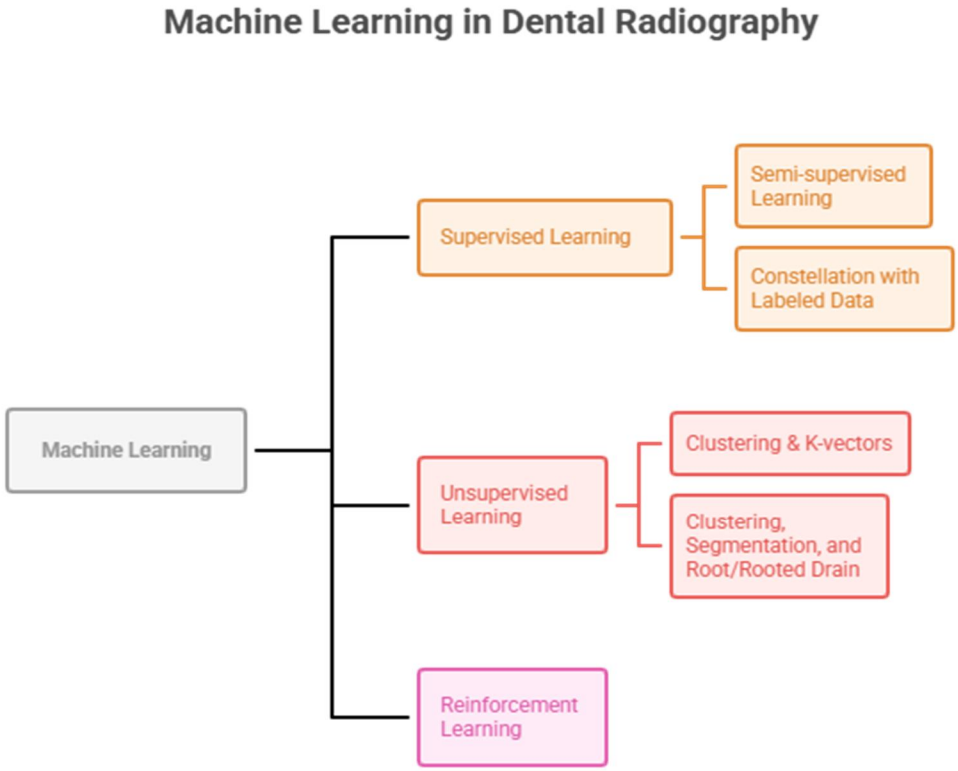


Figure 2: Classification of Machine Learning in Dental Radiography

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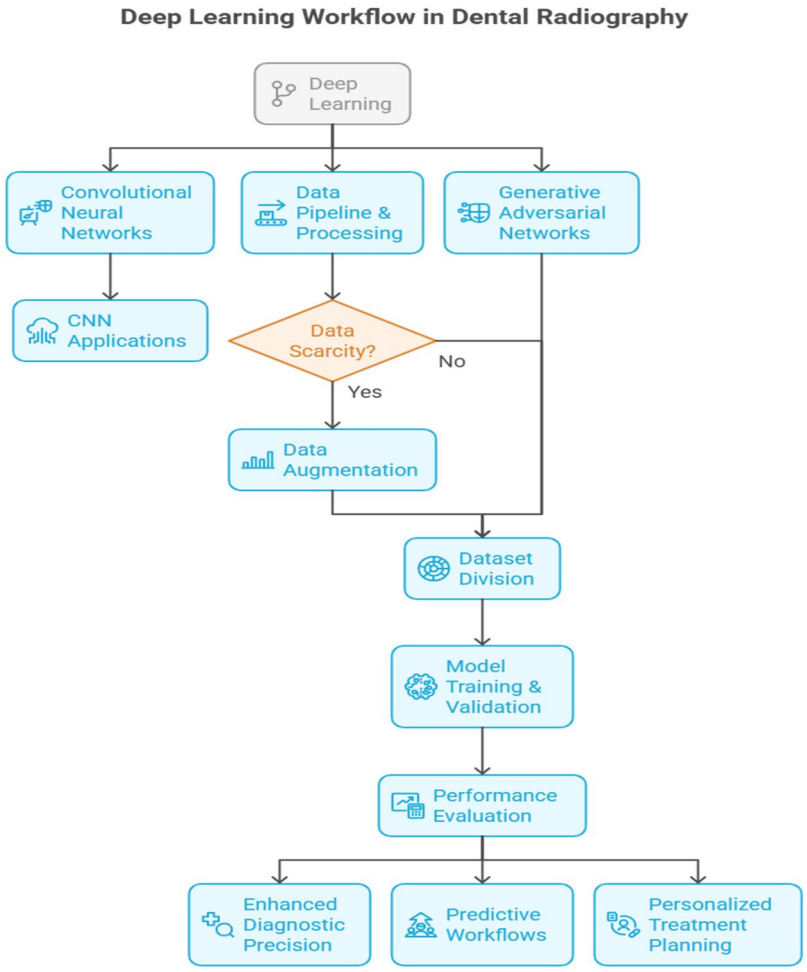


Figure 3: Classification of Deep Learning in Dental Radiography

Applications of AI architectures in Dental Radiology[6,7,8,9,10]

Tools	Architecture	Uses
Qure.ai	ML & DL	Diagnostic precision; insurance workflows
Logicon	Pattern Recognition	Caries detection via density analysis
Word2Vec/BERT	NLP	Analyzes radiology run; data extraction
Dentavision	Deep Learning	Image enhancemeent; corrects contrast/lighing
Videa Perio Assist	Deep Learning	Periodontal disease classification, risk assenm
Overjet	ML. Deep Learning	Bone loss analysis implant planning
Denti.Al Detect	Deep Learning	Bone-density/mplant assessment
ODONTO-ID	Knowledge-based	Bone-densityimplant assessment
	Knowledge-based	Enhances forensic odontological analysis

Table 1: Tools in Dental Radiology

III. CLINICAL HORIZONS OF AI IN DENTAL RADIOGRAPHY

Artificial intelligence has emerged as a transformative force in dental radiography, offering remarkable accuracy and versatility across diagnostic, educational, forensic, and imaging domains.[11] AI-driven software has been reported to achieve performance levels exceeding 90% in identifying conditions such as missing teeth, root canal fillings, and carious lesions, thereby surpassing conventional diagnostic limitations and providing significant promise for real-time clinical use.[12] Advanced models are increasingly capable of detecting a wide spectrum of dental anomalies, including periodontal diseases, periapical pathologies, cysts, and tumors, while also aiding in cephalometric analysis and orthodontic planning. Beyond disease detection, AI contributes to radiographic interpretation by performing precise image analysis tasks such as tooth segmentation, localization, and bone quality assessment, which are critical for both osteoporosis diagnosis and implant planning. In orthodontics, AI assists in estimating bone age from radiographs, streamlining treatment decisions that were traditionally manual and time-consuming.[13] Its role extends to workflow enhancement, where automation reduces the need for repeated scans, improves patient throughput, and minimizes clinical workload.[14] In academia, AI systems enrich dental education by visualizing X-ray analyses for students, fostering a deeper understanding of radiographic interpretation. Moreover, in forensic dentistry, AI has shown promise in automating age and sex estimation as well as post-mortem identification, providing objective and reproducible outcomes compared to traditional subjective approaches.[15] Equally important is AI's contribution to image quality improvement, where algorithms are used for denoising low-dose scans and reducing metal artifacts from implants and restorations that often obscure anatomical details.[16] Collectively, these diverse applications underline AI's potential not only in augmenting diagnostic accuracy and clinical efficiency but also in advancing education, forensic reliability, and patient-centered care in dentistry.[17]

IV. CHALLENGES AND LIMITATIONS IN AI-DRIVEN DENTAL RADIOGRAPHY

While artificial intelligence offers tremendous opportunities in dental radiography, its adoption is accompanied by several challenges that need careful consideration. One of the foremost issues is the requirement for large, diverse, and accurately annotated datasets, as the diagnostic accuracy of AI models is highly dependent on the quality and representativeness of the data used for training.[18] This necessitates the active involvement of experienced oral and maxillofacial radiologists in the annotation process to ensure clinical reliability. Additionally, the lack of standardized reporting formats across dental radiographic systems creates inconsistencies that limit the broader applicability of AI tools.[19] Ethical and legal concerns also pose significant barriers, particularly regarding patient data privacy, informed consent, and the potential for algorithmic bias that may disproportionately affect certain populations.[20] Another pressing issue is the "black-box" problem inherent to deep learning models, where the complexity of decision-making processes makes it difficult for clinicians to understand how a diagnosis was reached. To address this, explainable AI approaches such as Class Activation Mapping (CAM) and newer techniques like Eigen-CAM—are being developed to highlight the image regions that AI models focus on, thereby improving transparency and trust.[21] AI frameworks such as YOLOv8, designed for real-time object detection, have already been applied to dental X-rays for identifying caries, root canal treatments, and implants, offering valuable support for both clinicians and students in early diagnosis and training.[22] However, alongside these advances comes the rising concern of cybersecurity, particularly with the widespread use of digital imaging formats like DICOM in clinical environments.[23] Reports of maliciously altered images being introduced into diagnostic systems show the urgent need for robust security protocols to protect both patient safety and clinical integrity.[24] Collectively, these challenges highlight that while AI has the potential to revolutionize dental radiography, its safe, ethical, and standardized integration requires ongoing research, regulatory oversight, and collaboration between technologists and clinicians.[25]

V. CONCLUSION

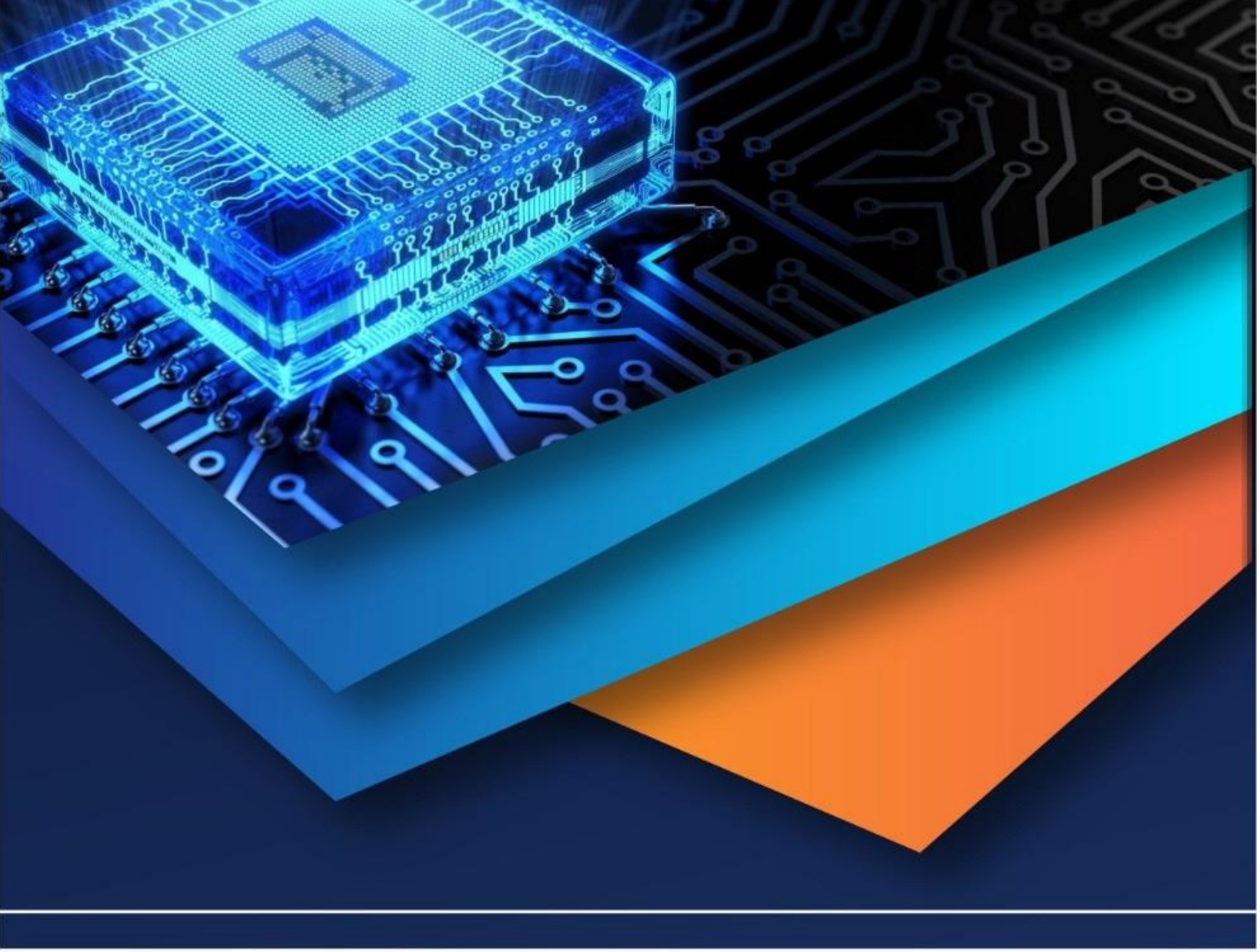
The integration of artificial intelligence into dental radiography is steadily transforming diagnosis, patient care, and clinical efficiency by real-time diagnostic support and smooth integration with existing imaging systems. Beyond detection, AI's predictive analytics enable early identification of potential dental problems, fostering proactive and evidence-based interventions, while its automated interpretation systems play a valuable role in training and educating new dentists by strengthening radiographic diagnostic skills. Importantly, AI is not positioned as a replacement for oral and maxillofacial radiologists, but rather as an augmentative tool that enhances their expertise, automates repetitive tasks, and provides reliable second opinions to improve accuracy and patient outcomes. The path forward lies in strong collaboration between radiologists, dentists, and AI specialists, ensuring that the technology is harnessed ethically, effectively, and innovatively to maximize its benefits and drive the future of dental care.

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