Review Article

The Digital Dentist: A Descriptive Review of Application of Artificial Intelligence in Dentistry

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Abstract Artificial intelligence (AI) is rapidly transforming the field of dentistry by enhancing diagnostic accuracy, optimizing treatment planning, and improving clinical efficiency. This narrative review highlights current applications of AI across various dental specialties, including oral medicine and radiology, oral and maxillofacial surgery, prosthodontics, conservative dentistry and endodontics, pediatric and preventive dentistry, orthodontics, periodontics, implantology, public health dentistry, and oral pathology. AI-based systems demonstrate high accuracy in detecting dental caries, periodontal disease, fractures, oral lesions, and maxillofacial pathologies through advanced image analysis and machine learning algorithms. Furthermore, AI facilitates digital workflows such as CAD/CAM prosthesis design, orthodontic treatment planning, surgical outcome prediction, tele-dentistry, epidemiological surveillance, and virtual clinical assistance. While AI strengthens clinical decision-making and patient-centered care, challenges related to data quality, ethical considerations, and clinical validation remain. Continued research and regulatory oversight are essential to ensure the safe and effective integration of AI into routine dental practice.

Keywords: Artificial intelligence; Convolutional neural network; Artificial neural network; Dentistry; Machine learning

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INTRODUCTION

Artificial intelligence (AI) represents a paradigm shift in healthcare, characterized by computational systems capable of learning from data, recognizing complex patterns, and supporting human decision-making. Unlike conventional rule-based software, AI systems continuously improve their performance through exposure to large datasets, enabling adaptive and predictive capabilities.[1] Although the term "artificial intelligence" was formally coined by John McCarthy in 1956, the conceptual foundation of AI predates this milestone. Early computational models developed by McCulloch and Pitts in 1943 laid the groundwork for neural networks by simulating neuronal behavior using mathematical logic.[2] The Dartmouth Conference in 1956 marked the formal emergence of AI as a scientific discipline, initiating decades of research that ultimately led to modern machine learning and deep learning systems.[3] In dentistry, the convergence of digital imaging, electronic health records, and computational power has accelerated the integration of AI-based technologies. AI applications now extend beyond radiographic interpretation to encompass treatment planning, workflow automation, risk prediction, and population-level oral health surveillance. These developments suggest that AI has transitioned from an experimental innovation to a clinically relevant adjunct in dental practice. Consequently, this narrative review aims to critically examine contemporary AI applications in dentistry and explore their implications for clinical care, research, and future adoption.

APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN DENTISTRY

AI in Oral Medicine and Radiology: Artificial intelligence plays a pivotal role in the diagnosis and management

of oral lesions, including premalignant and malignant mucosal changes.[4] AI algorithms analyze large volumes of clinical data, radiographs, and patient histories to enhance diagnostic precision and enable early disease detection. Zhang et al. employed a convolutional neural network (CNN) with a label-tree cascade structure for tooth detection and classification on periapical radiographs, achieving precision rates exceeding 95%.[5] Mohammad-Rahimi et al., in a systematic review of 42 studies, reported caries detection accuracy ranging from 68.0% to 99.2%, influenced by variations in imaging quality and dataset characteristics.[6] Deep learning has demonstrated performance comparable to expert clinicians in detecting periapical pathologies, temporomandibular disorders, and oral mucosal lesions.[7,8] Despite high accuracy, AI systems may still exhibit false positives and negatives, emphasizing the need for clinician oversight.

AI in Oral and Maxillofacial Surgery: AI-assisted machine learning models facilitate accurate identification of anatomical landmarks and maxillofacial abnormalities, enabling reproducible three-dimensional analyses.[9] CNN-based models such as Faster R-CNN have shown high potential in detecting and classifying maxillofacial fractures on CT images [10,11]. AI has also been applied to predict postoperative outcomes, such as facial swelling following third molar extraction, achieving predictive accuracies of up to 98%.[12] Additionally, AI-driven robotic surgery systems offer enhanced precision, although challenges remain in replicating complex human motor functions.[13,14]

AI in Prosthodontics and Crown and Bridge: In prosthodontics, AI-enhanced CAD/CAM systems optimize prosthesis design by learning from previous clinical data and predicting material behavior.[15] Studies report superior marginal integrity, reduced fabrication time, and higher accuracy for AI-designed crowns compared to conventional techniques.[16,17] Recent developments include generative adversarial networks (GANs) capable of designing prosthetic teeth with natural morphology, demonstrating promising feasibility for clinical applications.[18]

AI in Conservative Dentistry and Endodontics: AI models have shown high accuracy in detecting dental caries, tooth surface loss, and root canal morphology.[19,20] Neural networks have demonstrated superior performance compared to human evaluators in proximal caries detection and working length determination.[21]

Deep learning systems are increasingly used for detecting vertical root fractures and complex root canal anatomies, supporting improved endodontic outcomes.[22,23] AI Applications in Pediatric and Preventive Dentistry: AI-based tools assist in early diagnosis, behavior management, and preventive care in pediatric dentistry. [24] Smartphone-based AI applications enable parents to screen for caries at home, improving early intervention and accessibility. Machine learning models have been applied to predict early childhood caries, assess dental age, detect supernumerary teeth, and analyze salivary biomarkers, demonstrating promising diagnostic performance.[25]

AI in Orthodontics and Dentofacial Orthopedics: It significantly enhances cephalometric analysis, malocclusion diagnosis, and treatment planning by automating landmark identification and integrating multiple diagnostic inputs.[26]

Deep learning algorithms such as YOLOv3 have demonstrated high accuracy in cephalometric landmark detection. AI models also assist in extraction decision-making, aligner therapy planning, and temporomandibular joint disorder diagnosis, with reported accuracies exceeding 90% in some studies.[27]

AI in Periodontics and Implantology: CNN-based systems have been widely used for detecting periodontal bone loss, assessing soft tissue changes, and diagnosing peri-implantitis. These tools enable precise quantification of bone loss and disease staging, supporting improved treatment planning.[28]

AI in Public Health Dentistry: In dental public health, AI supports epidemiological surveillance, remote diagnosis, tele-dentistry, and population-level risk prediction.[29]AI-powered virtual dental assistants streamline administrative workflows, enhance patient communication, and improve clinical efficiency. Machine learning-based telehealth systems enable continuous monitoring of vulnerable populations and contribute to improved access to dental care.[30]

AI in Oral and Maxillofacial Pathology: It has demonstrated high sensitivity and specificity in detecting oral cancers, cysts, tumors, and maxillary sinus pathologies using panoramic and CBCT imaging.[31] CNN-based models perform comparably to specialists, facilitating early diagnosis and improved prognosis. (Table 1)

Dental Specialty	AI Applications	AI Models Used	Reported Outcomes
Oral Medicine & Radiology	Caries detection, lesion classification, tooth numbering	CNN, ANN	Accuracy up to 99%
Oral & Maxillofacial Surgery	Fracture detection, outcome prediction	Faster R-CNN, DL	Comparable to specialists
Prosthodontics	Crown design, shade matching	ML, GAN	Improved marginal fit
Endodontics	Root morphology, working length	CNN, ANN	Accuracy up to 96%
Pediatric Dentistry	ECC prediction, tooth detection	ML, CNN	Early diagnosis support
Orthodontics	Cephalometric analysis, extraction decisions	YOLOv3, ANN	>90% landmark accuracy
Periodontics	Bone loss assessment, implant evaluation	CNN	Reliable disease staging
Public Health Dentistry	Epidemiology, tele-dentistry	ML	Population-level insights
Oral Pathology	Tumor and cyst detection	CNN	Sensitivity ~83%

TABLE 1: Summarization of applications of Artificial Intelligence Across Dental Specialties

MERITS AND DEMERITS OF USE OF ARTIFICIAL INTELLIGENCE IN DENTISTRY

In diagnostics, AI demonstrates high accuracy and the ability to detect dental pathologies at an early stage, thereby supporting timely clinical intervention and improving patient outcomes. However, these benefits are constrained by dataset bias, as AI performance is highly dependent on the quality, diversity, and representativeness of training data, which may limit generalizability across populations. With respect to workflow management, AI contributes to enhanced efficiency through automation of routine tasks such as image analysis, record management, and appointment scheduling. Despite these advantages, high initial costs related to infrastructure, software acquisition, and maintenance pose significant barriers to widespread adoption, particularly in resource-limited settings. In treatment planning, AI enables predictive modelling and data-driven decision-making, allowing clinicians to anticipate treatment outcomes and optimize personalized care. Nonetheless, a major limitation is limited explainability, as many AI systems function as "black boxes," making it difficult for clinicians to interpret how specific recommendations are generated. From a public health perspective, AI facilitates the analysis of large-scale datasets, aiding in disease surveillance, risk assessment, and population-level planning. These applications raise ethical and privacy concerns, including issues related to data security, patient consent, and responsible data use. In dental education, AI-powered tools such as virtual simulations and adaptive learning platforms enhance clinical training and skill acquisition. However, excessive dependence on technology may reduce hands-on clinical exposure and critical thinking skills if not appropriately integrated with traditional teaching methods.[32] (Table 2)

Aspect	Advantages	Limitations
Diagnostics	High accuracy, early detection	Dataset bias
Workflow	Time-efficient, automation	High initial cost
Treatment Planning	Predictive outcomes	Limited explainability
Public Health	Large data analysis	Ethical & privacy concerns
Education	Simulation-based learning	Dependence on technology

TABLE 2: Advantages and Limitations of AI in Dentistry

SCOPE OF ARTIFICIAL INTELLIGENCE IN DENTISTRY

Artificial intelligence in dentistry encompasses diagnostic, therapeutic, educational, and administrative domains. Its scope includes early disease detection, automated image analysis, predictive treatment planning, digital prosthesis fabrication, robotic surgery, tele-dentistry, public health surveillance, and dental education. By enhancing precision, efficiency, and patient-centered care, AI represents a transformative force across all dental specialties.

CONCLUSION

Artificial intelligence is emerging as a transformative adjunct in dentistry, offering substantial improvements in diagnostic accuracy, treatment planning, and clinical efficiency across multiple specialties.

By leveraging advanced machine learning algorithms and large-scaledatasets, AI systems assist clinicians in identifying subtle pathological changes, predicting treatment outcomes, and streamlining digital workflows. Despite these advantages, the successful integration of AI into routine dental practice depends on careful validation, ethical governance, and clinician training. AI systems should complement—not replace—clinical expertise, ensuring that decision-making remains patient-centered and evidence-based. Future research should prioritize longitudinal clinical trials, standardized datasets, and transparent regulatory frameworks to ensure the safe, equitable, and effective use of artificial intelligence in dentistry.

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