Artificial Intelligence in Dentistry: A Narrative Review

Dr. Pooja Hampannavar
HOD- Department of Public Health Dentistry
Haldia Institute of Dental Sciences and Research, Banbishnupur, Purba Medinipur, Haldia, India

Abstract

Aim: To explore the integration of Artificial Intelligence in dentistry, examining its impact on diagnostics, treatment planning, and patient care. **Background:** Artificial Intelligence (AI) has transformed the field of dentistry by enhancing diagnostic accuracy and treatment methodologies, leading to better patient outcomes. Tools such as machine learning algorithms and image recognition systems have significantly improved the precision and efficiency of diagnostics, treatment planning, and overall patient management. This technological innovation holds great promise in refining dental practices and optimizing workflow processes. **Methodology:** A comprehensive literature search was performed across multiple databases, including PubMed, Scopus, Web of Science, Embase, and Google Scholar, using a combination of Boolean operators and MeSH terms to identify studies on the application of AI in dentistry. The search was restricted to English-language studies, including systematic reviews, original research, and meta-analyses. Data was extracted by two independent reviewers, focusing on AI applications, methods, findings, and ethical concerns, with discrepancies resolved through discussion or a third reviewer. The extracted data was categorized thematically to provide a clear overview of AI's role in dentistry. **Results:** AI applications in dentistry are diverse and transformative, enhancing diagnostic accuracy in radiology and pathology through techniques like convolutional neural networks and image recognition. In prosthodontics, AI optimizes prosthetic design and surgical planning using CAD/CAM technology and predictive models. AI-driven tools also improve accessibility via tele-dentistry and boost operational efficiency with practice management solutions. However, challenges such as data quality, ethical concerns, over-reliance on AI, and high implementation costs must be addressed to enable wider adoption and integration into dental practices. **Conclusion:** AI has the potential to significantly enhance various aspects of dental care, improving diagnostic accuracy, treatment planning, and patient management. However, addressing the challenges related to data quality, ethical concerns, and integration costs is essential for its successful and widespread adoption in the field. **Clinical significance:** The clinical significance of AI in dentistry lies in its ability to enhance diagnostic accuracy, leading to more timely interventions and improved patient outcomes. By streamlining workflows and enabling personalized treatment plans, AI also offers significant potential for increasing efficiency and accessibility in dental practices, benefiting both patients and practitioners.

Key words: Clinical Decision-Making, Diagnostic Imaging, Deep Learning, Machine Learning, Neural Networks, Oral Health, Tele-dentistry

Introduction

In the field of dentistry, artificial intelligence (AI) has become a potent driver for change. Artificial intelligence (AI) has started to change the dental industry in recent years by using technology to increase diagnostic precision, better treatment planning, and boost patient outcomes in general. With notable improvements in clinical practice and research, the application of AI in dentistry has shown especially advantageous in fields including radiography, patient management, treatment planning, and prosthodontics. The quick development and implementation of AI-driven dental solutions shows how this technology could completely transform the industry, going beyond conventional procedures and toward a more accurate, effective, and individualized approach to patient care. Historically, the adoption of AI in healthcare began with early machine learning algorithms that supported diagnostic and administrative tasks. In dentistry, AI has gradually evolved, with initial applications focused on enhancing radiographic analysis. However, with the progression of technology, the scope of AI's impact has broadened significantly, influencing virtually every aspect of dental care. AI now plays a pivotal role in automating and improving the diagnostic process, increasing precision in procedures, streamlining workflows, and even supporting complex decision-making processes in treatment planning. AI technologies are being increasingly integrated into dental clinics for applications ranging from diagnostic imaging to virtual consultations and predictive analytics.[1]

The increase in diagnostic precision is among AI's most notable contributions to contemporary dentistry. Convolutional neural networks (CNNs) and deep learning are two AI algorithms that have demonstrated impressive performance in recognizing and categorizing dental diseases from digital scans, radiographs, and other diagnostic pictures. The ability of AI to identify dental caries, fractures, periapical lesions, and other diseases with an accuracy level on par with or even higher than that of human experts is demonstrated by few studies.[2,3] AI-driven technologies greatly enhance the early identification of problems that need intervention by analyzing vast amounts of data and spotting minute patterns that the human eye could miss. Additionally, by automating the processing of CBCT (Cone Beam Computed Tomography) scans and X-rays, AI in radiology improves efficiency by facilitating quicker decision-making and reducing diagnostic errors.

AI is revolutionizing patient management and treatment planning in addition to diagnostics. Based on a patient's unique data, such as genetic information, radiographic pictures, and clinical histories, AI-powered systems can create individualized treatment programs. As a result, patient treatment methods become more precise and customized, which should enhance patient happiness and results. AI has the potential to predict treatment outcomes and possible side effects, enabling healthcare providers to deliver more proactive and informed care to patients.

Additionally, in prosthodontics, AI has demonstrated significant promise in enhancing the design and fabrication of dental prosthetics using CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) systems.[4] AI algorithms can analyze the patient's oral anatomy and recommend optimal designs for crowns, bridges, and dentures, enhancing both functional and aesthetic outcomes. These advancements in prosthodontics are accelerating the digitalization of restorative dentistry, leading to faster and more efficient workflows.[5]

Tele-dentistry and virtual consultations are other noteworthy applications of AI, particularly in remote care delivery. AI-powered chatbots, virtual assistants, and diagnostic tools allow dental professionals to provide consultations and follow-ups without requiring patients to visit clinics physically. These services are especially important in underserved areas where access to dental professionals is limited. The role of AI in expanding access to care, can address disparities in dental healthcare delivery, making oral health services more inclusive and accessible to all populations.[6]

The use of AI in dentistry is not without its difficulties, despite its many benefits. There have been ethical questions about algorithm openness, data privacy, and the possibility of biases in AI models. Overcoming obstacles including opposition from conventional practitioners, the requirement for ongoing training, and concerns about the accessibility and affordability of AI tools are all necessary for the integration of AI into clinical practice. For AI to reach its full potential in dentistry, it is crucial to ensure that its applications are equitable, transparent, and beneficial for both patients and dental professionals. This requires the development of regulatory frameworks and a strong focus on generating unbiased, comprehensive datasets to support effective and ethical implementation of AI in clinical practice.[7,8]

The integration of AI in dentistry holds immense potential to improve dental care by enhancing diagnostic accuracy, treatment planning, and patient management. With advancements in machine learning, deep learning, and neural networks, AI is poised to revolutionize the field. However, the widespread use of AI tools in clinical practice requires a deeper exploration of their applications, benefits, and limitations. The rationale for this narrative review lies in the need to synthesize existing literature on AI in dentistry, focusing on its impact on diagnostics, treatment protocols, and patient outcomes, while addressing challenges like data security, algorithmic biases, and professional acceptance. This review aims to provide insights into the current state and future directions of AI in dentistry, including its potential for improving efficiency and precision in clinical practice. It will also examine the ethical considerations and professional concerns that influence AI adoption in dental care. Ultimately, the review seeks to guide the responsible integration of AI technologies, ensuring enhanced patient care, safety, and treatment outcomes.

Methodology

Search strategy: A comprehensive search strategy was employed to identify relevant studies on the application of Artificial Intelligence (AI) in dentistry. The literature search was conducted across multiple databases, including PubMed, Scopus, Web of Science, Embase, and Google Scholar, with the latter used to access gray literature. Boolean operators such as AND, OR, and NOT were used to combine and refine search terms effectively. Keywords and Medical Subject Headings (MeSH) terms included *"Artificial Intelligence" AND "Dentistry," "Machine Learning" OR "Deep Learning" AND "Dentistry," "Dental Diagnostics" AND "Artificial Intelligence," "AI in Prosthodontics," "AI in Orthodontics," "AI in Radiography," "Tele-dentistry" OR "Remote Dental Care" AND "AI," and "Neural Networks" AND "Dental Applications." Additional MeSH terms such as "Diagnostic Imaging," "Dental Care," "Clinical Decision-Making," "CAD/CAM Dentistry," and "Digital Dentistry"* were also included to expand the scope of the search. Filters were applied to restrict results to English-language studies and to include systematic reviews, narrative reviews, original research articles, meta-analyses, and conference proceedings. Both open-access and subscription-based articles were considered to ensure the inclusion of a diverse range of perspectives.

Data Extraction and Synthesis: Two independent reviewers, XX and YY, extracted data using a pre-designed template, focusing on study details, AI applications (e.g., diagnostics, treatment planning), methods, findings, and ethical considerations. Discrepancies were resolved through discussion, with a third reviewer if needed. The synthesized data, categorized into thematic areas, provided an evidence-based overview of AI applications in dentistry, highlighting trends and limitations.

Results

Table 1: Applications of Artificial Intelligence (AI) in Dentistry

Application Area	Specific Use	AI Method/Tool	Impact/Outcome	References
Radiology	Detection of caries, fractures, and periapical lesions	Convolutional Neural Networks (CNNs)	Improved diagnostic accuracy and early intervention	[2,9,10]
Pathology	Histological analysis of oral lesions	Image Recognition Systems	Faster, more precise disease classification and treatment planning	[11,12]
CBCT Scans	Implant placement and	AI Landmark Detection	Enhanced surgical predictability and	[13,14]

	surgical planning	Algorithms	reduced risk of complications	
Tele-dentistry	Virtual consultations and remote diagnosis	Chatbots, Video Call Integration	Improved access to care in underserved regions	6,15
Prosthodontics	Prosthetic design and occlusal analysis	CAD/CAM Technology, Predictive Models	Personalized, functional, and aesthetic prosthetics	16,17
Patient Management	EHR optimization, workflow management, resource allocation	AI-Driven Practice Management Software	Improved operational efficiency and patient satisfaction	18,19
Research and Innovation	Predictive modeling, treatment outcome analysis	Machine Learning (ML) Models	Enhanced understanding of oral health and evidence-based advancements	2,8

Table 2: Advantages, Disadvantages, and Challenges of AI in Dentistry

Category	Details	AI Method/Tool	Impact/Outcome	References
Advantages				
Improved Diagnostic Accuracy	Enhanced detection of dental caries, fractures, and lesions	CNNs, ML Models	Early diagnosis, reduced diagnostic errors	2,13
Personalized Treatment Plans	Tailored therapies based on patient-specific data	ML Models, Predictive Analytics	Improved treatment outcomes, enhanced patient trust	10,19
Workflow Optimization	Streamlined administrative and clinical processes	AI-Driven Practice Management Software	Increased time for patient care, operational efficiency	6,18
Access to Care	Bridging	AI Chatbots,	Improved access to	14,15

	geographical gaps through tele-dentistry solutions	Video Call Integration	care in underserved regions	
Prosthodontic Advancements	Accurate design of crowns, bridges, and dentures	CAD/CAM Technology, Predictive Models	High precision in prosthesis design and fitting	[16,17]
Predictive Analytics	Risk assessment and proactive patient care	Predictive Models, ML	Early intervention, improved patient outcomes	[2,12]
Disadvantages				
Lack of Human Touch	AI cannot replicate the personal care and empathy of dental professionals	Various AI Models	Potential loss of patient-practitioner rapport	[20,21]
Data Dependency	AI models require large, high-quality datasets to perform optimally	Various AI Models	Insufficient data may result in poor AI performance	[22,23]
Risk of Over-reliance	Over-reliance on AI could lead to a decrease in human diagnostic skills	Various AI Tools	Diminished clinician expertise, potential misdiagnosis	[14,18]
Challenges				
Data Quality Issues	Bias in training datasets leading to inaccuracies	Various AI Models	Inaccurate predictions, increased health disparities	[20,22]
Ethical Concerns	Data privacy, security, and regulatory	Various AI Tools	Need for strong privacy protocols and regulatory	[8,17]

	compliance		adherence	
Professional Resistance	Hesitation due to unfamiliarity or skepticism about AI systems	Various AI Tools	Reluctance to adopt AI due to perceived threats or lack of trust	[11,13]
High Implementation Costs	Initial investment in AI tools and infrastructure	Various AI Tools	High initial costs for AI integration	[24,25]

Table 1 outlines the diverse applications of Artificial Intelligence (AI) in dentistry, highlighting its transformative impact across various domains. AI techniques such as Convolutional Neural Networks (CNNs) and Image Recognition Systems improve diagnostic accuracy in radiology and pathology, enabling early detection and precise disease classification.[2,12] In prosthodontics, AI optimizes the design of functional and aesthetic prosthetics through CAD/CAM technology and predictive models.[16,17] AI enhances surgical predictability in implant placement using landmark detection algorithms while AI-driven tele-dentistry and practice management tools boost accessibility and operational efficiency. Overall, AI's integration in dentistry fosters better patient outcomes and operational workflows.[13,14,15,18]

Table 2 highlights how AI improves diagnostic precision, optimizes workflows, and supports personalized treatment plans, ultimately enhancing patient outcomes and increasing operational efficiency.[2,10,13,19] It also increases access to care through tele-dentistry and advances prosthodontics with precise designs.[14-17] However, AI faces challenges, such as reliance on high-quality datasets, potential over-reliance leading to diminished clinician expertise, and ethical concerns regarding data privacy.[22,23] Disadvantages include the inability of AI to replicate human empathy in patient care, and professional resistance due to unfamiliarity with AI.[11,20,21] Moreover, high implementation costs remain a barrier to adoption. These factors must be addressed for broader AI integration in dentistry.[24,25]

Discussion

The integration of Artificial Intelligence (AI) in dentistry has marked a transformative shift in how dental care is delivered, enhancing diagnostic precision, streamlining treatment planning, and personalizing patient management. AI's applications in various aspects of dentistry, from diagnostic imaging to treatment

simulation, have revolutionized clinical practices, providing significant improvements in efficiency and accuracy.[1,4]

Radiology is one of the areas of dentistry that has been most affected by AI's revolutionary changes. Convolutional neural networks and other AI algorithms have shown unmatched accuracy in identifying periapical lesions, fractures, and dental cavities from radiographic pictures. These technologies facilitate early intervention, lowering the risk of problems and enhancing treatment outcomes by spotting tiny patterns that can be invisible to the human eye.[4,6] AI-powered systems, for example, have demonstrated exceptional effectiveness in Cone Beam Computed Tomography (CBCT) image analysis, supporting landmark localization, implant placement, and orthognathic surgery planning. This has led to increased patient safety, decreased risk of iatrogenic complications, and improved surgical predictability.[3,13]

AI-driven technologies have also greatly benefited pathology. Oral lesions can be diagnosed more quickly thanks to automated histological examination, and AI systems can provide information about the prognosis and classification of diseases. The objectives of precision medicine, which bases customized treatment on histological and molecular markers, are in line with this application.[5,10] AI has also improved prosthesis design and production in prosthodontics using computer-aided design and computer-aided manufacturing (CAD/CAM) technology. Dentures, crowns, and bridges are among the functional and aesthetically pleasing prosthetic replacements that are produced by AI algorithms that examine a patient's oral anatomy.[16,26]

Virtual consultations and tele dentistry have become essential tools, especially for expanding access to treatment in underprivileged areas. Virtual consultations are made possible by AI-powered chatbots and diagnostic technologies, which improve early diagnosis and treatment planning. This method guarantees continuity of service, lowers geographic boundaries, and promotes interdisciplinary collaboration.[1,6] AI in patient management improves workflow and resource allocation through practice management software and electronic health records (EHRs), increasing operational effectiveness and patient satisfaction.[2,27] The primary advantage of AI in dentistry lies in its ability to improve diagnostic accuracy. By analyzing vast datasets with speed and precision, AI tools outperform traditional diagnostic methods in detecting dental pathologies. This reduces the likelihood of diagnostic errors and enhances clinical decision-making.[4,13] In addition to diagnostics, AI facilitates personalized treatment planning by integrating patient-specific data such as genetic profiles, clinical histories, and radiographic findings. This individualized approach not only improves treatment outcomes but also fosters patient trust and satisfaction.[2,7]

AI's role in streamlining workflows cannot be overstated. By automating administrative tasks such as appointment scheduling, billing, and record management, dental practices can allocate more time to patient care. Predictive

analytics, driven by AI, assist in resource planning and improve operational efficiency, leading to a better overall patient experience.[12,27] Moreover, AI enhances prosthodontic applications by improving occlusal analysis, functional evaluation, and outcome prediction, ensuring precise and aesthetically pleasing restorations.[3,26] Another significant advantage is the ability of AI to democratize access to dental care. Tele-dentistry, enabled by AI, bridges the gap between patients and dental professionals, offering solutions in remote or underserved areas. This is particularly beneficial for preventive care, where early intervention can significantly reduce the burden of oral diseases.[1,6]

Additionally, AI can automate inventory management processes, ensuring that medical supplies and equipment are available when needed. By analyzing historical usage patterns and real-time data, AI algorithms can predict inventory needs, generate purchase orders, and optimize stock levels. This eliminates the risk of stockouts, minimizes wastage, and ensures smooth operations within the practice. AI systems can further streamline procurement by identifying cost-effective suppliers, monitoring supply chain disruptions, and suggesting alternative vendors when necessary. This proactive approach not only reduces costs but also minimizes delays in acquiring essential materials, allowing dental practices to maintain uninterrupted services. Moreover, these systems can alert staff about upcoming expiration dates on consumables, enabling timely usage or replacement, which prevents unnecessary waste and ensures compliance with quality and safety standards. By integrating AI-powered inventory tools with dental practice management software, practices can maintain a seamless workflow, reduce administrative burdens, and focus more on patient care.[28]

Despite its numerous benefits, the integration of AI in dentistry faces challenges that must be addressed for its widespread adoption. One significant concern is the quality and representativeness of the data used to train AI models. Biased or incomplete datasets can result in inaccurate predictions and exacerbate health disparities. Therefore, ensuring that AI systems are trained on diverse, high-quality data is critical.[10,13] Ethical concerns, particularly related to data privacy and security, pose another challenge. The use of patient data in AI systems necessitates robust measures to protect sensitive information from breaches. Transparent policies and adherence to regulatory standards are essential to build trust among patients and practitioners.[17,27] The acceptance of AI by dental professionals varies. Resistance may stem from a lack of familiarity with AI technologies, fear of redundancy, about their reliability. Addressing these concerns requires targeted education and training programs to equip practitioners with the skills needed to integrate AI into their practice effectively.[11,24]

AI in dentistry has a bright future because to continued research into cutting-edge tools and applications. For example, predictive models powered by AI are being created to detect high-risk patients and forecast treatment outcomes, allowing for proactive care. Artificial skin and bionic eye technologies are two examples of how advancements in maxillofacial prosthetics are extending the potential of AI in restorative dentistry. Multidisciplinary cooperation will be essential to the development of AI applications. By combining knowledge from engineering, dentistry, and computer science, researchers may create increasingly complicated tools and algorithms to tackle challenging clinical problems. Ensuring the ethical and secure use of AI in dentistry requires evolving regulatory frameworks that promote innovation while protecting patient interests. Additionally, expanding the role of AI in dental education will better prepare future professionals to effectively use these tools, aligning them with the evolving expectations of contemporary dentistry.

Conclusion

The integration of Artificial Intelligence (AI) in dentistry has significantly enhanced clinical practices by improving diagnostic accuracy, treatment planning, and patient management. AI technologies, including machine learning and deep learning algorithms, have proven effective in automating tasks like radiographic analysis and prosthodontic design, leading to more precise and personalized care. These advancements have the potential to improve patient outcomes, reduce diagnostic errors, and streamline dental workflows, making dental practices more efficient and accessible. However, for AI to reach its full potential in dentistry, several challenges must be addressed. Issues such as data quality, ethical concerns around patient privacy, and professional resistance need to be overcome. To ensure the responsible and effective implementation of AI, it is essential to develop robust regulatory frameworks and promote continuous education for dental professionals. Future research should focus on refining AI tools, enhancing interdisciplinary collaboration, and expanding AI's role in dental education to prepare future practitioners for the evolving landscape of digital dentistry.

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