



Advancing Dental Education with Artificial Intelligence: Opportunities, Challenges, and Future Trends: A Narrative Review

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ABSTRACT:

Artificial Intelligence (AI) is reshaping dental education by enhancing diagnostic accuracy, clinical skill acquisition and administrative efficiency, through tools such as machine learning, intelligent tutoring systems, virtual simulations and personalized learning platforms. It also accelerates knowledge acquisition and strengthens clinical decision-making skills, thereby improving educational outcomes. However, successful integration requires addressing challenges such as equitable access, ethical considerations, faculty preparedness and curriculum adaptation to align with modern pedagogical frameworks. This review explores the current applications of AI in dental education, evaluates its impact on student learning, clinical practice and highlights the opportunities and challenges of its effective implementation.

Introduction

Artificial Intelligence (AI) has rapidly emerged as one of the most impactful and revolutionary technology in dentistry, outpacing even the disruptive impact of 3D printing. It has evolved from simple rule-based systems of the mid-20th century to advanced models capable of complex decision-making.¹⁻⁴ AI has achieved a profound influence on both the clinical and educational dimensions of dentistry in less than half the time it took for earlier technologies to disrupt the field. The COVID-19 pandemic accelerated this shift, while the release of advanced systems like ChatGPT now marks a critical turning point in traditional dental learning and clinical

practice. Research constantly demonstrates that, in dentistry, AI has shown great potential in diagnosis, treatment planning, and management.⁵ For instance, literature on fostering artificial intelligence in dental education demonstrates that it can help in the premature detection of oral diseases, assist in treatment planning, improve patient education and make administrative processes more efficient.⁶ Smartphone-based 3D scanning and AI-driven diagnostic and therapeutic applications are already becoming common in dentistry, though their development and refinement continue to advance.



Role of AI in becoming an important part of dental education is also highlighted in recent studies which indicates that by introducing new learning methods diagnostic accuracy, clinical skills and decision-making can be improved.^{6,7} Lin et al.⁸ examined the learning strategies of high-performing undergraduate dental students in dental materials science, highlighting methods such as memorization, peer learning, resource searching, study planning, class engagement and mnemonics. Today, these strategies can be strengthened through modern technologies, underscoring the need for dental curricula to be grounded in sound pedagogy and aligned with student learning approaches. Tools such as personalized learning systems, intelligent tutoring platforms and machine Learning-based diagnostic software allow students to learn more effectively and connect their theoretical knowledge with clinical practice.^{7,9} However, its integration into dental education also brings several challenges which include updating the curriculum, improving AI literacy among teachers and students, addressing ethical issues related to data privacy, ensuring equal access to technology and developing suitable infrastructure.⁹ Careful planning, evidence-based approaches and involvement of dental professionals are essential to successfully integrate AI in education while maintaining high academic and clinical standards. This review synthesizes application AI in dental education currently, their impact on learning and practice, and offers recommendations for ethical, effective implementation.

Methodology

This article presents a narrative review of Artificial Intelligence (AI) in dentistry, focusing on its integration into dental education and evaluate its impact on student learning, clinical practice and highlighting the opportunities and challenges of its effective implementation.

Inclusion Criteria

1. Articles, reviews, conference paper and notes published in English language were considered
2. Studies focusing on applications of Artificial intelligence (AI) in dental education were included, specifically those addressing its role in learning enhancement, diagnostics, simulation-based training, patient management

and clinical decision-making within dental curricula.

3. Peer-reviewed publications, including systematic reviews, meta-analyses, empirical studies, case studies and narrative reviews were considered to ensure scientific rigor and comprehensive coverage.
4. Articles published between 2016-2025 were included to capture both foundational concepts and recent advancements in AI integration within dental education.

Exclusion Criteria

1. Publications in languages other than English were omitted to maintain uniformity in language interpretation and analysis.
2. Studies dealing only with the clinical use of AI in dentistry (e.g., patient treatment)
3. Articles that addressed general technology or digital tools without a specific focus on AI or machine learning in dental education.

A meticulous investigation of pertinent literature search was carried out using major academic databases, including PubMed, web of science, Science Direct and Google Scholar. The search employed keywords such as “*Artificial Intelligence in dental education,*” “*AI in dentistry,*” “*AI challenges in dental education,*” and “*Dental training technology.*” A structured data extraction form was then used to collect key information from each study, covering publication details, study design, specific AI applications (e.g., diagnostic tools, simulation training), key findings, educational benefits and identified challenges.

The search strategy employed operators such as Boolean operators (AND, OR) to refine queries. For instance: (“Artificial Intelligence” OR “Machine Learning”) AND (“dental education” OR “challenges in dentistry”).

Use Of Artificial Intelligence and Its Influence in Dental Education

The amalgamation of AI in dental curriculum is extensive, strengthening both theoretical learning and practical training. AI-based teaching systems allow real-time analysis of large datasets, helping students gain a clearer understanding of oral health conditions and improving diagnostic accuracy. For instance, AI



algorithms applied to dental radiographs can guide students in accurately detecting cavities, periodontal disease, and other pathologies. This technological support offers valuable experience in interpreting complex diagnostic information, minimizes the reliance on extensive clinical hours and helps students develop early diagnostic skills⁹⁻¹⁰.

Artificial Intelligence (AI) is remodelling dental education through innovations in simulation, personalized learning, decision support and administrative efficiency. AI-powered virtual reality (VR) and augmented reality (AR) tools provide students with a risk-free environment to practice procedures such as root canals and extractions, adapting in real time to student performance and enhancing psychomotor skills and clinical decision-making. Studies report that VR/AR-based training can improve task proficiency by nearly 30%.¹¹⁻¹².

AI-based learning tools and smart tutoring systems further personalize education by assessing student strengths and weaknesses, tailoring content and presenting case-based scenarios. It has shown to improve conceptual understanding by up to 25% and reduce the time required to achieve procedural proficiency by

A comprehensive summary of applications of Artificial intelligence (Table 1) as published in the literature from 2016 to 2025, is provided as follows:

30%.¹²⁻¹³ Kavadella et al.¹⁴ evaluated the implementation of ChatGPT in the educational process both quantitatively and qualitatively and concluded that students using ChatGPT for their learning assignment performed better in knowledge examination than their fellow students who used the literature research methodology. Students quickly adopted its language model and recognized its limitations and opportunities and incorporated it creatively, efficiently and effectively.

In clinical training, machine learning algorithms assist students in planning their treatment by integrating patient history with clinical data, thereby strengthening diagnostic reasoning and minimizing errors. Applications extend to surgical planning as well; such as implant positioning using CBCT segmentation.¹⁵⁻¹⁶

Beyond clinical and educational functions, AI also streamlines administrative processes including scheduling, billing and data management, reducing the manual workload for educators and allowing them to concentrate more on mentorship and interactive teaching. Tools such as automated ICD coding and virtual patient assistants prepare students for technology-driven clinical environments.¹⁷⁻¹⁸

S.NO.	AUTHOR	ARTICLE TYPE	APPLICATION AREA	OBJECTIVE	METHODOLOGY	KEY FINDING
1	Tyagi et al ¹⁹ . 2025	SYSTEMATIC REVIEW	AI tools in Dentistry.	To investigate the integration of AI technologies into dental practice.	Literature was identified through an extensive search of electronic databases, including PubMed, Medline, Google Scholar, Scopus, and Web of Science, covering publications from 2019 to 2024.	Findings highlight the promising role of AI in improving clinical outcomes and patient care.
2	Claman et al ⁹ .,2024	Review article	AI in dental education.	To propose a model for adopting AI in	Conceptual framework development	Successful AI adoption in dental



				dental education through academic leadership and innovation.	based on literature review, academic practices, and leadership strategies in dental education.	education requires strong academic leadership, innovation culture, and structured implementation models.
3	Alsalleeh et al ¹³ , 2024	Original research	Potential of AR as a tool for teaching.	Efficacy of AR as a pedagogical tool for enhancing dental students' comprehension of root canal anatomy.	Forty-three third-year dental students answered questions on root canal anatomy using CBCT and AR model. Response times and feedback were recorded and analyzed.	AR improved accuracy & speed (4 min vs 15 min). Students preferred AR as compared to CBCT. However, Few reported discomfort.
4	Zhu et al., 2023 ²⁰	Original Study	Artificial intelligence in the diagnosis.	To develop an AI framework to diagnose multiple dental diseases on Panoramic radiographs, and to evaluate its performance.	An AI framework was built using two deep convolutional networks, BDU-Net and nnU-Net. Diagnostic performance was evaluated on a separate dataset, independently assessed by dentists of three seniority levels.	AI showed promising accuracy in detecting caries, bone loss, periapical lesions.
5	Mladenovic et al.,2023 ²¹	Original research	Artificial Intelligence in the analysis.	Explore AI application in analysing children's CBCT scans by dental students	Paediatric Dentistry subject teacher delivered a 30 minutes training in the AI environment for all final-year students enrolled in five-year dentistry	The median overall score was significantly higher for final year students trained in AI environment. AI improved, efficiency and accuracy in interpretation and it can



					program. The median overall numerical score for AI performance-related questions was analysed statistically.	be suggested as educational support tool.
6	Thurzo et al, 2022 ²²	Prospective, Single-arm, Single-centre Study	Dental Education & Biosafety during COVID-19.	Assess biosafety settings in dental care/education under SARS-CoV-2 variants	Implemented strict biosafety protocols in educational settings; prospective monitoring	Protocols reduced transmission risk; feasible in dental education; highlighted challenges in pandemic-adapted teaching.
7	LeResche, 2022 ²³	Review article	Future of General Dentistry & Education.	Discuss changing landscape of dentistry and implications for education	Summary and key findings from the four panels of the 2021 Arcora Distinguished Professorship in Dentistry Symposium at the University of Washington, themed 'The Changing Face of Dentistry.	Shift toward technology-driven, patient-centred approaches; highlights need for adapting clinical and translational research in dental education.
8	Islam et al., 2022 ⁷	Literature Review	Adopting artificial intelligence in dental education.	Explores opportunities and challenges facing dental education with a specific focus on incorporating the use of artificial intelligence (AI).	Used Bolman and Deal's Reframing Organizations model known as the Four Frames model. It serves as a road map for building infrastructure within dental schools for the adoption of AI.	AI effective in diagnosis, planning, and prediction; future potential high but challenges include validation & ethics.



9	Siddiqui et al.,2022 ²⁴	Literature review	Artificial intelligence in dentistry, orthodontics and Orthognathic surgery.	To accentuate the uses of artificial intelligence in dentistry, particularly in orthodontics and orthognathic surgery.	Extensive search of electronic data base.	AI has popularized over past few decades It has been found useful for diagnosis in restorative dentistry, orthodontics oral pathology and oral surgery.
10	Shah et al.,2021 ²⁵	Review Article	Endodontics – Case difficulty assessment & AI.	The article aims to show how new technology can help dentists figure out how hard a root canal case is and make better treatment decisions.	the methodology involves a comprehensive literature review, analysis of existing tools and technologies, and a discussion of their clinical relevance and future perspectives.	New digital tools and AI can help dentists assess the difficulty of root canal cases, improve treatment planning, and support education and research.
11	Gandedkar et al.,2021 ²⁶	Insight / Narrative Review	Orthodontics – VR, AR & AI in education/research.	Discuss role of VR, AR, and AI in orthodontics	the authors conducted a comprehensive analysis of existing literature and studies related to the application of VR, AR, and AI in orthodontics.	VR/AR useful for immersive learning; AI promising for analysis and education
12	Endres et al.,2020 ²⁷	Original Study	AI algorithm for Periapical Disease Detection in Dental Radiographs.	To investigate the ability of Oral and Maxillofacial surgeons to assess the presence of periapical radiolucencies compared to deep algorithm	Findings of 24 Oral and Maxillofacial surgeons reviewing radiographs were compared with a deep learning algorithm developed by the author using 2,902 de-identified	Dentists misdiagnosed 31% of cases while the algorithm, validated on clinical data, shows promise in aiding OMF surgeons' detection of periapical lucencies.



					panoramic images	
13	Schwendick et al., 2019 ²⁸	Scoping Review	Dental Imaging Diagnostics (AI)	To examine the methodologies and outcomes of studies applying Convolutional Neural Networks to dental imaging.	Thirty-six studies (2015–2019) from South Korea, the USA, Japan, and China focused on general dentistry.	Convolutional Neural Networks effectively detect caries, bone loss, and pathology, but more rigorous and standardized studies are needed to confirm their safety and generalizability.
14	Lee et al., 2018 ²⁹	Original Study	Diagnosis and prediction using AI.	To develop a Convolutional Neural Network(CNN) based computer-assisted system and evaluate its accuracy and potential in diagnosing and predicting periodontally compromised teeth.	Pretrained and self-trained Convolutional Neural Networks(CNN) with periapical radiographs were used to optimize the algorithm and weights.	Convolutional Neural Network(CNN) achieved high accuracy in diagnosis & prognosis prediction; useful in decision support for periodontal treatment.
15	Moayeri et al., 2016 ³⁰	Original study	Implication of machine learning techniques in the prediction of success of dental implants.	Method to Predict Success of Dental Implants	A combined model using W-J48, SVM, Neural Network, K-NN, and Naïve Bayes was optimized to predict dental implant success.	Diagnosis of patients whose implant does not lead to success is very important in implant surgery. The presented model can help surgeons to make a more reliable decision on level of success of implant operation prior to surgery.
16	Elendu et al., 2024 ³¹	Narrative Review	Simulation-based training(SBT) in medical education.	To provide an overview of the historical development of Simulation	A comprehensive literature review was conducted across PubMed,	Simulations based methods enhanced student learning, clinical reasoning and hands-on skill acquisition



				in medical education, highlighting key milestones and advancements.	Google Scholar, and Web of Science to collect studies on the impact of SBT in medical education.	compared to traditional approaches
17	Zhu et al., 2024 ³²	Original Study	Assisted diagnosis of mid-palatal suture maturation stage in cone-beam computed tomography.	To validate the ability of Convolutional Neural Network(CNN) models in assessing the maturation stage of the mid-palatal suture.	ResNet50 was trained to detect the CBCT plane with a complete midpalatal suture, while multiple CNN models classified its maturation stages, evaluated using standard metrics and visualised with Grad-CAM.	Classification accuracies of 95.2%, 88.1%, and 75.4% for two, three and five-stage tests exceeded the average of three experienced orthodontists.
18	Tadinada et al.,2023 ³³	Original study	Technology-driven curriculum for Dental Education.	To apply organizational development framework for agile, tech-based dental curriculum	Case analysis of curriculum redesign using Organisational Development framework	It is essential to design agile and efficient curricula through hybrid courses that ensure effective learning across all delivery modes.
19	Joda et al.,2022 ³⁴	Narrative Review	Workflows in reconstructive dentistry.	To discuss personalized digital workflows in reconstructive dentistry	A comprehensive literature review was conducted to collect studies on workflow impacts in reconstructive dentistry.	Digital workflows enhance personalization and efficiency, the integration of AI expected.
20	Ara Shaikh et al, 2022 ³⁵	Original study	Impact of Machine Learning and Artificial Intelligence for making a Digital Classroom in	To better understand the vast potential of artificial intelligence in education, both during the COVID-19 era	10 articles were evaluated by conducting internet searches with keywords such as artificial intelligence, learning during a	AI-supported classrooms improved accessibility & sustainability in pandemic education.



			education during Covid -19.	and in future learning contexts.	pandemic, and machine learning. A phenomenological method, aligned with a qualitative approach, was then applied to ensure the findings addressed the research questions.	
21	Saghiri et al.,2021 ³⁶	Scoping Review	Integration of artificial intelligence and virtual teaching models in dental education.	To review role of AI and immersive tools in dental education.	Embase, PubMed, Web of Science, and Cochrane Library were searched for studies published between 2018 and 2021.	An improved understanding of virtual teaching model and AI domains is needed to enable dental students to adapt to changes within and beyond their dental training education.
23	Tekkeşin et al.,2021 ³⁷	Literature review	Digital technologies in oral and maxillofacial pathology.	To assess the impact of emerging technologies on education, training, and diagnostic workflows in oral and maxillofacial pathology.	A comprehensive search was conducted to collect studies on digital technologies used on Oral and Maxillofacial Pathology.	The pandemic accelerated digital adoption in education, work and pathology, making the way for broader use of effective digital practices.



The literature analysis highlights that Artificial Intelligence (AI) is reshaping dental education across both theoretical and practical domains. In theoretical education, AI contributes to analysing complex patient data, generating treatment plans and designing interactive simulations that strengthen conceptual understanding. It also supports the development of soft skills, research and scientific publications, thereby broadening the academic scope of dental training. On the practical side, AI facilitates tele monitoring of patients, offers immersive virtual training environments and enhances student evaluation methods, ultimately leading to improved clinical competencies and patient outcomes. These innovations are fundamentally altering traditional workflows in dental education, shifting the focus from conventional didactic teaching toward more personalized, technology-driven approaches. However, this transformation must be guided by ethical considerations, transparency, and careful handling of training datasets to ensure that AI applications remain reliable, unbiased, and aligned with professional standards. The incorporation of Artificial Intelligence (AI) into education offers transformative potential across diagnostics, skill development and personalized learning. Quantifiable benefits such as increased diagnostic accuracy, faster clinical proficiency and improved student engagement make AI a valuable educational tool. Going forward, successful AI integration will require transparent, explainable tools, curriculum reforms, educator training and ethical frameworks. AI should be positioned not as a replacement for dental educators but as an aid that enhances teaching and learning.

LIMITATIONS AND CHALLENGES OF AI IN DENTAL TRAINING

Significant barriers in integrating AI in to Dental education remain which include limited access to quality dental datasets, technical issues like the “black box” nature of AI models, accountability, faculty resistance, high costs and risks of over-reliance on AI.³⁸⁻⁴⁰ Faculty preparedness also plays a pivotal role; many instructors lack sufficient training in AI concepts and applications, limiting their ability to effectively integrate these tools into the curriculum^{7,41}. Financial constraints further exacerbate these challenges, as high implementation costs can restrict access to AI systems, particularly in resource-limited institutions^{14,24}.

Student interactions with AI introduce additional concerns. Over-dependence on AI tools may reduce the development of essential clinical reasoning skills.^{39,42,43} Moreover, many AI algorithms demonstrate poor generalizability across diverse populations, oral health conditions and curricular frameworks, potentially leading to biased outcomes or inequitable educational experiences⁴²⁻⁴⁴. The integration process also demands significant infrastructural modifications, including hardware, software and secure data storage solutions, which can be logistically and financially challenging.^{40-41,45} Finally, the legal and ethical dimensions of AI-assisted education and diagnosis particularly questions surrounding accountability and liability adding another layer of complexity for educators and institutions.³⁹⁻⁴¹

Future Directions

The future of AI in dental education is expected to evolve through several promising advancements. Multimodal diagnostics, which integrate data from radiographs, wearable health monitors and genetic profiles, can offer comprehensive and personalized insights into oral health conditions¹¹

Robotic dentistry will likely play a larger role in surgical precision and prosthetic fabrication, enabling minimally invasive procedures and improved clinical outcomes⁴⁰ The integration of Tele-dentistry with AI holds great potential for reaching underserved populations and providing remote diagnosis and monitoring, particularly in rural or low-resource settings.¹⁷ Furthermore, Explainable AI (XAI) is critical for building clinician trust by making AI decisions transparent and interpretable.³⁹⁻⁴⁰ Lastly, policy reforms and interdisciplinary collaboration are essential to establish ethical guidelines, promote faculty training, and ensure scalable and responsible AI integration in dental curricula^{29,41}.

Conclusion

The integration of Artificial Intelligence (AI) into dental education represents a transformative shift, offering opportunities to enhance learning, clinical reasoning and skill development. Incorporating Artificial Intelligence into dental curricula is no longer optional but an urgent necessity. By leveraging AI through competency-based pedagogical frameworks, flipped classrooms, simulations and case-based learning, dental curricula can promote deeper engagement and critical thinking among



students. While the immediate focus should be on generative and analytic AI applications which is already influencing knowledge dissemination, academic writing and interpretation of scientific texts, these skills also lay the foundation for broader competencies in clinical reasoning and patient management. Faculty development and the evolution of educator roles are equally essential, ensuring that instructors serve as AI-literate facilitators who guide ethical and informed decision-making rather than merely delivering content. By ensuring that students gain a solid understanding of AI principles, ethical considerations and practical applications, dental schools can prepare graduates who are not only clinically competent but also technologically adaptable. When implemented responsibly, AI can empower the next generation of dental professionals to deliver smarter, safer and more patient-centred care, positioning dental education at the forefront of technological innovation. Experts agree that such curriculum reform must be underpinned by sound pedagogy, interdisciplinary collaboration and a commitment to responsible innovation, positioning AI as a transformative tool that complements rather than replaces human expertise in dental education and practice.

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