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Review Article

Generative Artificial Intelligence in Dental Education: Current Applications, Benefits, Challenges, and Future Directions

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Abstract

Generative artificial intelligence (AI) has emerged as a rapidly evolving technology with growing applications in healthcare education. Large language models, such as ChatGPT, Gemini, Claude and Microsoft Copilot, are increasingly being used to support learning, assessment, scientific writing and educational content development. In dental education, these technologies offer opportunities to enhance access to information, facilitate self-directed learning, provide personalized educational support, and improve student engagement.

This narrative review summarizes the current applications of generative AI in dental education and discusses its potential benefits, challenges, and future implications. Current evidence suggests that AI can support theoretical learning, clinical reasoning, assessment, feedback, and research-related activities. However, important concerns remain regarding the accuracy and reliability of AI-generated information, hallucinations, academic integrity, bias, data privacy, and excessive dependence on automated systems.

The successful integration of generative AI into dental curricula requires the development of AI literacy, ethical guidelines, and evidence-based implementation strategies. Although AI technologies have considerable potential to enhance educational processes, they should complement rather than replace educators, critical thinking, clinical reasoning, and hands-on clinical training. Continued research is needed to evaluate the long-term educational impact of AI and to establish best practices for its responsible use in dental education.

Keywords

ChatGPT; dental curriculum; higher education; large language models

Background

Artificial intelligence (AI) has emerged as one of the most transformative technologies in healthcare and education. The rapid growth of healthcare data, advances in machine learning algorithms, and increasing computational power have accelerated the integration of AI into clinical practice, healthcare systems, and professional education [1-4].

In dentistry, AI applications have expanded considerably over the past decade. AI-based systems have demonstrated promising performance in radiographic interpretation, disease detection, risk assessment, treatment planning, and prediction of clinical outcomes [5-8]. The increasing digitalization of dental practice through electronic health records, digital imaging, intraoral scanning, and computer-aided design and manufacturing technologies has created an environment in which AI can

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be readily integrated into both clinical and educational settings [9-11].

Among recent developments, generative artificial intelligence has attracted particular attention. Unlike conventional AI systems that primarily analyze or classify data, generative AI is capable of producing new content, including text, images, audio, and computer code. Large language models (LLMs), such as ChatGPT, Gemini, Claude, and Microsoft Copilot, represent the most widely adopted examples of generative AI in education. These systems can engage in natural language conversations, answer questions, summarize information, generate educational materials, assist with scientific writing, and provide individualized learning support. Their accessibility and ease of use have contributed to their rapid adoption among students and educators worldwide [12, 13].

The potential educational applications of generative AI are particularly relevant to dental education. Dental training requires the acquisition of extensive theoretical knowledge alongside the development of clinical reasoning, communication abilities, and practical skills. Generative AI technologies may support these learning processes by providing personalized explanations, facilitating self-directed learning, generating practice questions, assisting with case-based learning, and offering immediate feedback to learners [14, 15]. These capabilities have the potential to enhance educational efficiency and increase student engagement while supporting diverse learning styles and educational needs. Consistent with these potential benefits, a recent systematic review and meta-analysis including 22 studies and 8,491 healthcare students reported generally positive attitudes toward AI technologies despite only moderate levels of AI-related knowledge, highlighting the growing importance of AI-related competencies in healthcare education [16]. Furthermore, recent studies have identified a discrepancy between the widespread use of AI tools among healthcare students and the limited availability of formal AI instruction, emphasizing the need for structured AI literacy and ethics training within healthcare curricula [17].

Despite these opportunities, the integration of generative AI into dental education remains accompanied by important challenges. Concerns have been raised regarding the reliability and accuracy of AI-generated information, the phenomenon of hallucinated content, academic integrity, plagiarism, algorithmic bias, data privacy, and the potential for excessive dependence on automated systems [18, 19]. Furthermore, the educational implications of widespread AI adoption remain incompletely understood, particularly with respect to critical thinking, clinical reasoning, and the long-term development of professional competencies.

As generative AI technologies continue to evolve, dental educators face the challenge of balancing innovation with responsible implementation. Understanding the potential benefits, limitations, and future applications of these technologies is essential for their effective integration into dental curricula. Therefore, the aim of this narrative review is to provide a comprehensive overview of current applications of generative artificial intelligence in dental education, discuss its educational benefits and limitations, and explore future directions for the responsible incorporation of AI technologies into dental training.

Review Methodology

This narrative review was conducted to provide a comprehensive overview of the current applications, benefits, challenges, and future directions of generative artificial intelligence (AI) in dental education. A literature search was performed in PubMed, Scopus, Web of Science, and Google Scholar to identify relevant publications. The search was conducted in June 2026 and included articles published between 2020 and 2026, reflecting the rapid development of generative AI technologies during this period. Although the primary search focused on publications from 2020 to 2026, earlier landmark studies were included when considered essential for providing background and contextual information.

The search strategy combined keywords related to artificial intelligence and dental education using Boolean operators. The principal search terms included "artificial intelligence", "generative artificial intelligence", "large language models", "ChatGPT", "dental education", "dental students", "medical education", "assessment", "curriculum", "personalized learning", and "AI literacy". Additional relevant publications were identified through manual screening of the reference lists of selected articles.

Peer-reviewed original research articles, systematic reviews, scoping reviews, narrative reviews, and relevant guidance documents published in English were considered for inclusion. Studies primarily addressing clinical applications of AI without an educational focus, conference abstracts, editorials, letters, and publications lacking sufficient methodological or educational relevance were excluded.

The identified literature was screened for relevance based on titles, abstracts, and full texts where appropriate. Publications were selected according to their relevance to the objectives of this review, with emphasis on studies addressing the educational applications of generative AI, its benefits, challenges, ethical considerations, and future implementation within undergraduate dental education. Owing to the narrative nature of this review and the heterogeneity of the available literature, the findings were synthesized descriptively rather than through a formal systematic review process.

Narrative Synthesis

Current Applications

One of the most widespread applications of generative artificial intelligence in dental education is the support of theoretical learning. Large language models (LLMs), such as ChatGPT, Gemini, Claude, and Microsoft Copilot, can

provide instant access to information and generate explanations adapted to different levels of learner knowledge. Students may use these systems to clarify difficult concepts, summarize educational materials, review lecture content, and obtain additional explanations for complex topics in oral biology, dental anatomy, pathology, prosthodontics, and other dental disciplines [13, 20]. Unlike conventional search engines, generative AI systems can provide interactive responses and engage in conversational learning. Students can ask follow-up questions, request simplified explanations, and receive personalized educational support. This interactive approach may facilitate self-directed learning and improve understanding of theoretical content, particularly when learners encounter challenging concepts that require additional clarification [14, 15].

Generative AI has also demonstrated potential as a personalized educational assistant. Traditional educational approaches often provide identical learning materials to all students regardless of their prior knowledge, learning preferences, or academic performance. In contrast, AI-powered tutoring systems can adapt explanations, examples, and learning strategies according to individual learner needs. Previous educational research has suggested that AI may function as a virtual educational assistant capable of supporting personalized learning and facilitating communication between students and educators [21]. Such systems may provide customized study plans, generate targeted review questions, and identify areas requiring additional attention. By delivering immediate feedback and individualized support, AI-assisted learning environments may enhance student engagement, promote self-directed learning, and improve educational efficiency [22]. These capabilities are particularly relevant in dental education, where students are required to master large volumes of theoretical knowledge while simultaneously developing clinical competencies across multiple disciplines.

Assessment represents another important area of AI implementation in dental education. Generative AI systems can create multiple-choice questions, short-answer assessments, case-based scenarios, and formative quizzes. These tools may assist educators in developing educational content while providing students with additional opportunities for self-assessment and exam preparation [12]. The growing role of AI in educational assessment has also been highlighted in recent reviews of medical education literature, which identified assessment and feedback among the most rapidly developing applications of AI technologies [23]. AI-generated feedback can also support learning by identifying errors, suggesting improvements, and providing explanations for incorrect responses. Such immediate feedback may promote active learning and encourage students to identify knowledge gaps before formal examinations. Recent guidance in health professions education has emphasized the growing role of AI in assessment, highlighting its potential to support formative assessment, generate personalized feedback, and enhance learner engagement while maintaining alignment with established educational principles [24, 25].

Generative AI technologies are increasingly being explored as tools for case-based learning and clinical reasoning development in dental education. By enabling interactive discussions of patient cases, differential diagnoses, treatment options, and potential clinical outcomes, AI systems may support the development of diagnostic and problem-solving skills. Additionally, AI-generated clinical scenarios can expose students to a broader range of cases than those encountered during routine training. However, because AI-generated recommendations may occasionally be inaccurate or incomplete, faculty supervision and critical evaluation remain essential components of the learning process [18, 19].

The use of generative AI for scientific writing and research-related activities has increased substantially among healthcare students. Dental students may use AI systems to summarize scientific articles, identify relevant literature, improve language quality, generate outlines, and assist with manuscript preparation [12]. While these applications may improve productivity and reduce the time required for literature review and academic writing, concerns regarding fabricated references, inaccurate citations, and authorship transparency remain. Importantly, responsibility for the accuracy and integrity of AI-generated content remains with the human author, regardless of the extent of AI assistance during the writing process [26].

Benefits

Generative AI offers several potential benefits for dental education. One of its major advantages is the ability to provide rapid access to information while simultaneously supporting self-directed learning. Large language models can answer student queries, summarize complex topics, generate explanations tailored to different levels of prior knowledge, and assist students in identifying knowledge gaps, developing study plans, generating review materials, and practicing examination questions. These capabilities may reduce barriers to learning, promote learner autonomy, and improve learning efficiency by providing educational support at any time and place [13, 14, 15, 20].

Another important advantage is the ability of AI systems to provide personalized educational support. By adapting explanations, examples, and feedback according to individual learner needs, AI-assisted learning environments may improve comprehension of difficult concepts and accommodate different learning styles and educational backgrounds [22]. In addition, generative AI systems can provide immediate feedback by answering questions, explaining mistakes, suggesting areas for improvement, and generating self-assessment exercises. Such timely feedback may facilitate knowledge retention and help students address misconceptions before they become established [12].

Generative AI may also support evidence-based learning by facilitating access to scientific literature and assisting students in navigating large volumes of information. AI-powered systems can summarize articles, explain research findings, and support literature exploration, thereby encouraging the integration of scientific evidence into clinical decision-making when combined with appropriate critical appraisal skills [13, 20].

Furthermore, interactive AI systems may increase student engagement by transforming passive learning into a more dynamic and personalized educational experience. Conversational interfaces encourage students to actively explore topics, ask questions, and seek clarification without concerns about judgment or time limitations, potentially enhancing motivation and satisfaction with the learning process [13, 22].

Finally, early exposure to AI technologies may help dental students develop digital competencies that will become increasingly important in contemporary dental practice. As digital workflows, artificial intelligence, and computer-aided technologies continue to expand within dentistry, AI integration into undergraduate education may contribute not only to improved learning outcomes but also to better preparation for future professional practice [27]. The generally positive attitudes reported among healthcare students further suggest a favorable environment for the incorporation of AI-assisted educational technologies into healthcare curricula [16].

Challenges and Limitations

Despite their considerable educational potential, generative AI technologies are associated with several important limitations and challenges that must be considered when integrating them into dental education. One of the most frequently discussed concerns is the accuracy and reliability of AI-generated information. Large language models may produce responses that appear scientifically plausible but contain factual errors, incorrect interpretations, or entirely fabricated content, a phenomenon commonly referred to as “hallucination” [18, 19, 26]. Such outputs arise because LLMs generate text based on probabilistic predictions rather than true understanding or verification of factual accuracy. Similarly, AI systems may generate nonexistent or inaccurate references and may not consistently distinguish between verified scientific evidence and generated content. In healthcare education, where accuracy is essential, reliance on incorrect information may negatively affect knowledge acquisition, clinical reasoning, and future decision-making. These limitations highlight the importance of critical appraisal skills, information literacy, and independent verification of AI-generated content using reliable scientific sources [28].

The growing use of generative AI has also raised concerns regarding academic integrity and professional development. Students may use AI systems to generate assignments, essays, reports, or examination responses with minimal personal input, potentially compromising learning objectives and creating challenges for educators attempting to assess actual knowledge and competencies. Concerns have also been raised regarding the misuse of AI-generated content for academic dishonesty, including automated assignment generation and unfair academic advantage [25]. Furthermore, excessive reliance on AI-generated answers may discourage independent reasoning, critical thinking, and problem-solving. As a result, students may become increasingly dependent on automated systems, potentially affecting the development of essential competencies required for clinical practice, including diagnostic reasoning, professional judgment, and evidence-based decision-making. Similar concerns regarding plagiarism, information reliability, algorithmic bias, and excessive dependence on AI technologies have been highlighted in recent reviews examining the educational applications of ChatGPT [29].

Additional challenges relate to bias, transparency, privacy, and equitable access. Because generative AI systems are trained on large datasets that may contain cultural, linguistic, or socioeconomic biases, their outputs may unintentionally reflect or amplify these biases. Moreover, the decision-making processes of many AI models remain insufficiently transparent, creating concerns regarding accountability and trustworthiness. Privacy and security issues also require careful consideration, particularly when AI systems are used in conjunction with clinical cases or patient-related information. Finally, differences in technological access, digital literacy, language proficiency, and familiarity with AI tools may influence how effectively students can utilize these technologies, potentially contributing to educational inequalities. Consequently, the successful implementation of AI in dental education requires not only technological availability but also appropriate ethical guidelines, institutional oversight, and structured educational initiatives aimed at developing AI literacy among both students and educators.

Future Perspectives

The rapid development of generative artificial intelligence is expected to further transform dental education in the coming years. One of the most important future priorities is the incorporation of AI literacy into dental curricula. Similar to evidence-based dentistry and digital dentistry, AI-related competencies may become an essential component of undergraduate education. Students should develop an understanding of the principles underlying AI systems, their potential applications, limitations, ethical implications, and appropriate use in clinical and educational settings. Recent evidence has demonstrated that healthcare students often exhibit positive attitudes toward AI despite possessing only moderate levels of knowledge regarding its principles and applications, highlighting the need for structured AI education and literacy training within healthcare curricula

[16,17]. Consistent with these findings, survey-based studies among dental students have also reported favorable attitudes toward AI technologies while simultaneously highlighting concerns regarding their limitations and responsible use. For example, a study conducted among Iranian dental students reported strong support for AI applications in dentistry, particularly in diagnostic tasks, although most participants did not believe that AI could replace dentists and emphasized the importance of incorporating AI-related education into dental curricula [30]. Similar findings have been observed among dental students in Turkey, where participants demonstrated awareness of AI applications in dentistry and expressed optimism regarding their future professional value, while also recognizing potential risks and the need for appropriate educational training [31].

Another promising direction involves the development of AI-powered virtual tutors and personalized learning environments. Future educational systems may provide individualized learning pathways based on student performance, learning preferences, and educational needs. By continuously monitoring progress and adapting educational content, AI-driven tutoring systems may improve learning efficiency and provide targeted support for students experiencing academic difficulties. Furthermore, the integration of generative AI with virtual reality (VR), augmented reality (AR), and simulation technologies may create immersive learning environments that support clinical reasoning, treatment planning, and preclinical skill development. AI-assisted virtual simulations may allow students to repeatedly practice clinical procedures in safe and controlled environments, potentially enhancing skill acquisition and confidence before clinical patient encounters [25].

Generative AI may also contribute to the future of assessment in dental education through adaptive examinations, automated formative assessment, and AI-assisted feedback systems that provide more individualized evaluation of student performance. However, despite these opportunities, successful implementation of AI technologies requires the establishment of clear ethical and educational guidelines. Dental schools should develop policies addressing academic integrity, transparency of AI use, verification of AI-generated information, data privacy, and the responsible application of AI technologies in both educational and research activities. Faculty development programs may also be necessary to ensure that educators are adequately prepared to integrate AI into teaching and assessment practices.

Despite the rapid expansion of AI applications in education, significant gaps remain regarding long-term educational outcomes, ethical governance, and best practices for implementation, highlighting the need for continued research and evidence-based policy development [23]. Ultimately, the future of AI in dental education should focus on augmentation rather than replacement. Although AI technologies have considerable potential to enhance learning, improve educational efficiency, and support competency development, they cannot replace the essential roles of educators, critical thinking, professional judgment, and hands-on clinical experience. The most effective educational models will likely combine the strengths of AI technologies with the expertise of educators and the human-centered nature of dental training.

Conclusion

Generative artificial intelligence has the potential to significantly influence the future of dental education by enhancing access to knowledge, supporting personalized learning, and facilitating more efficient educational processes. The growing adoption of AI technologies by students and educators highlights their increasing relevance within contemporary dental curricula. However, important concerns regarding reliability, ethical use, academic integrity, data privacy, and overreliance on AI-generated content must be carefully addressed.

To maximize its educational value, AI should be integrated through structured, evidence-based, and ethically responsible approaches that promote AI literacy and critical evaluation skills. While these technologies offer substantial opportunities to improve learning and educational support, they should complement rather than replace educators, clinical training, and independent reasoning. Continued research is needed to evaluate the long-term educational impact of AI and to establish best practices for its effective and responsible implementation in dental education..

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Ethical compliance

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Conflict of interest

The authors declare that they have no conflict of interest and no affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

Author contributions

I.D. and D.K. contributed equally to the conception and design of the review, literature search, data interpretation, manuscript writing, critical revision, and approval of the final version of the manuscript.

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