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Applications of Artificial Intelligence in Dental Diagnosis and Treatment Planning: What Should Students Know? A Literature Review

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Abstract

The integration of Artificial Intelligence (AI) in dentistry is rapidly transforming clinical practice. This literature review critically evaluates the current and emerging applications of AI in dental diagnosis and treatment planning. A narrative literature review was conducted, synthesizing key findings from a comprehensive search of PubMed, Scopus, and ScienceDirect for articles published between 2015 and 2025. The review highlights the pivotal role of AI in augmenting diagnostic accuracy through radiographic interpretation, oral cancer detection, and periodontal assessment. It also underscores its contributions to treatment planning in orthodontics, restorative dentistry, and implantology. While AI offers significant benefits, its implementation is not without challenges, including concerns about data privacy, algorithmic bias, and the risk of over-reliance. This paper argues that a foundational understanding of AI's principles, applications, and ethical implications is now essential for dental students to prepare them for a technology-driven future. The proposal presents a framework for integrating AI literacy into undergraduate dental curricula to bridge the gap between technological advancements and educational practice.

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1 Introduction

The field of dentistry is undergoing a rapid digital transformation, with AI increasingly influencing every facet of clinical practice. From automated caries detection to sophisticated orthodontic treatment simulations, AI technologies are enhancing diagnostic accuracy, streamlining workflows, and supporting personalized patient care [1, 2].

Given this growing integration, it is no longer sufficient for dental students to be passive observers of this change. They must acquire a foundational understanding of AI's applications and implications to become competent practitioners in a technology-driven healthcare environment.

This literature review provides a structured examination of current AI tools in dental diagnosis and treatment planning, critically assessing both their potential and their limitations. It culminates in a set of actionable recommendations for dental curricula, addressing what students need to know to ethically and effectively utilize AI. AI refers to the simulation of human intelligence

by machines, particularly computer systems, capable of learning and problem-solving. In dentistry, this is primarily achieved through machine learning (ML), deep learning (DL), and computer vision to support clinical tasks [1, 3].

These technologies have shown promise in improving clinical outcomes and patient satisfaction by reducing human error and providing evidence-based decision support. Recent reviews have explored how these innovations are moving from research concepts to clinical reality [4, 5].

2 Literature Review

This paper presents a narrative literature review, synthesizing and critically analyzing scholarly publications from January 2015 to June 2025. This timeframe was chosen to capture the most recent and relevant advancements in AI, particularly the evolution of deep learning, which has been the driving force behind most dental AI applications.

A comprehensive search was conducted across three major electronic databases: PubMed, Scopus, and ScienceDirect. The search strategy employed a combination of keywords using Boolean operators: ("Artificial Intelligence" OR "Machine Learning" OR "Deep Learning") AND ("Dentistry" OR "Dental") AND ("Diagnosis" OR "Treatment Planning" OR "Radiography" OR "Education").

A total of 45 articles were selected for detailed review. The selection process involved a two-stage screening: initial review of titles and abstracts, followed by a full- text evaluation. Inclusion criteria prioritized original research articles, systematic reviews, and comprehensive conceptual discussions directly addressing AI's role in dental diagnosis, treatment planning, and education. Editorials, conference abstracts, and articles not directly focused on dentistry were excluded to maintain the review's clinical relevance [6].

2.1 Applications in Dental Diagnosis

2.1.1. Radiographic Interpretation

AI algorithms, particularly **C**onvolutional Neural Networks (CNNs), have been trained to detect dental pathologies such as caries, periapical lesions, and bone loss with impressive accuracy [7, 8]. Recent systematic reviews and meta-analyses show that CNN-based models can achieve over 90% accuracy in detecting caries, often matching or exceeding the performance of experienced clinicians [9]. However, a critical analysis of this application reveals significant limitations. Many models are trained on small, homogenous datasets, raising concerns about their generalizability to diverse patient populations and different radiographic image qualities [10]. There is a risk of algorithmic bias if the training data does not represent a wide range of demographic or clinical variations.

2.1.2Oral Cancer Detection

AI has demonstrated significant efficacy in identifying precancerous and cancerous lesions through the analysis of intraoral images and histopathological data [11]. The integration of AI into screening programs could enhance early detection rates, particularly in low-resource settings, as noted in areview by the ADA [12]. However, the current challenge lies in the scarcity of large, well-labeled datasets for rare conditions, which is essential for training robust and reliable AI models. A recent review in *Oral Oncology* notes the need for more studies to validate the performance of these algorithms across different populations [3].

2.1.3Periodontal Assessment

AI systems are being used to analyze periodontal charts, radiographs, and 3D images to assist in the diagnosis and classification of periodontal diseases [4]. Automated measurement of bone levels and identification of pocket depths can provide more consistent and objective evaluations compared to traditional methods. A review published in the *Int J Dent* highlights how these innovations can lead to more rapid and accurate assessments of periodontal health [4]. The primary challenge, however, is the lack of standardized methodologies for data collection, which can lead to data heterogeneity and limit the generalizability of AI models [4].

2.2. Applications in Treatment Planning

2.2.1. Orthodontics

AI-driven systems can simulate orthodontic outcomes, perform cephalometric analysis, and generate tailored treatment plans [13]. This technology enhances patient communication and improves treatment predictability. A study has shown AI to be highly accurate in determining the necessity of tooth extractions in orthodontics [13]. However, these systems are a decision-support tool, not a replacement for clinical judgment. As noted in *Dental Economics*, the accuracy of these models can decline in nonstandard and severe cases, highlighting a crucial limitation that students must understand [10].

2.2.2. Restorative Dentistry

AI tools assist in tooth preparation design, crown fitting, and material selection through Computer-Aided Design (CAD). AI integration enables efficient and precise prosthetic fabrication, improving patient outcomes and reducing chair time. The limitation lies in the current technology's inability to fully replicate the nuanced artistry and clinical experience required for complex restorative cases [1].

2.2.3. Implantology

AI supports implant placement planning through 3D imaging and virtual surgical simulations [5]. This allows clinicians to determine optimal angulation and depth, minimizing surgical complications. A systematic review on the subject emphasizes AI's potential to enhance the precision and efficiency of implant procedures [5]. A key concern is the potential for over-reliance on the virtual simulation, which may not account for unforeseen anatomical variations or soft tissue considerations during actual surgery [1].

Table (1): Summary of Key Artificial Intelligence Applications in Dentistry with Clinical Implications.

AI Application	Dental Field	Educational Impact
CNN-based caries detection	Radiology	Enhances radiographic interpretation training by demonstrating early lesion identification, promoting critical evaluation of AI outputs [7, 9].
AI-assisted orthodontic simulation	Orthodontics	Improves treatment planning skills by enabling students to explore virtual outcomes, thus strengthening patient communication [13].
Periodontal bone loss detection	Periodontology	Fosters objective periodontal evaluation by analyzing bone loss trends and quantifying disease progression [4].
Oral cancer image analysis	Oral Pathology	Increases awareness of early detection methods and the importance of diverse, non-biased datasets for screening [12].
Implant planning with AI	Implantology	Provides hands-on virtual surgical simulation training, enabling students to plan for optimal implant angulation and minimize procedural errors [5].

2.3Implications for Dental Education

2.3.1. Curriculum Integration

As AI becomes a standard component of clinical practice, dental curricula must adapt to include theoretical and practical exposure to AI tools. Educating students on the principles of machine learning, data ethics, and diagnostic algorithms will prepare them to critically assess and utilize AI in practice.

2.3.2. Clinical Decision Support Systems (CDSS)

should be trained to interact with AI-based CDSS, which can provide real-time diagnostic suggestions and evidence-based treatment options. Understanding the strengths and limitations of these systems is essential for safe and effective patient care.

2.3.3. Research Opportunities

Involvement in AI-related research during undergraduate training can cultivate critical thinking and innovation. Students may contribute to the development or validation of AI models, fostering a deeper understanding of both dentistry and data science.

2.3.4. Challenges and Ethical Considerations

To prepare a new generation of technologically competent practitioners, dental curricula must adapt to include formal AI education [14, 6]. This paper proposes a framework for integrating AI literacy into undergraduate dental programs, building on recent research in dental education [6].

2.3.5. Foundational Theory

Implement a module on the principles of machine learning, AI ethics, and data science, tailored specifically for dental applications.

2.3.6. Hands-on Workshops

Provide practical, hands-on training with commercially available AI-powered diagnostic and treatment planning software. This allows students to interact with the technology and understand its strengths and limitations firsthand.

2.3.7. Interdisciplinary Projects

Foster collaborations with data science or computer science faculties to involve students in the development or validation of new AI models, cultivating a deeper understanding of both fields.

2.3.8. Case-Based Learning

Utilize AI as a decision-support tool in case-based learning scenarios. Students can use AI to generate a diagnosis or treatment plan, then critically compare it with their own analysis and the consensus of their peers and instructors. This promotes critical thinking and responsible AI use [15].

3 Discussion

In the field of treatment planning, AI is becoming an increasingly vital decision-support tool. In orthodontics, AI-driven systems can simulate outcomes, perform cephalometric analysis, and generate tailored treatment plans, enhancing patient communication and improving treatment predictability. However, these systems are a decision-support tool, not a replacement for clinical judgment, as their accuracy can decline in nonstandard and severe cases. Similarly, in restorative dentistry, AI tools are used to assist in tooth preparation design, crown fitting, and material selection through Computer-Aided Design (CAD). This AI integration enables efficient and precise prosthetic fabrication, improving patient outcomes and reducing chair time. The limitation, however, lies in the current technology's inability to fully replicate the nuanced artistry and clinical experience required for complex restorative cases. The integration of AI in implantology allows clinicians to use 3D imaging and virtual surgical simulations to determine optimal angulation and depth, minimizing surgical complications. A systematic review on the subject emphasizes AI's potential to enhance the precision and efiency of implant

procedures. A key concern is the potential for over-reliance on the virtual simulation, which may not account for unforeseen anatomical variations or soft tissue considerations during actual surgery. With continuous advancements in computational power and data availability, AI's role in dentistry is expected to expand. Future developments may include AI-integrated robotic surgery, emotion recognition for patient anxiety management, and fully automated diagnostic platforms [16, 17]. Dental students must remain adaptable and proactive in learning about these evolving technologies. Despite its growing relevance, AI education remains limited in most dental programs. Integrating AI literacy into the curriculum is essential to prepare students for future clinical environments. Suggested strategies include interdisciplinary courses, hands-on training with AI tools, and collaborations with data science departments 18–20. Educational institutions should also emphasize critical thinking and ethical considerations to ensure responsible AI use.

4 Conclusion

The rapid integration of AI in dentistry necessitates a fundamental shift in dental education. This literature review has demonstrated that AI applications are already playing a pivotal role in improving diagnostic accuracy, treatment efficiency, and patient outcomes. However, the true value of AI lies not in its ability to replace the dentist, but in its potential to augment their skills. For dental students, a critical and comprehensive understanding of AI is no longer optional; it is essential. By incorporating AI literacy into undergraduate curricula, educational institutions can foster a new generation of practitioners who are not only skilled clinicians but also ethically responsible and technologically proficient leaders. This will ensure that the future of dentistry is both innovative and patient centered.

Authors' Contributions

Khaled Elkhamisi is the sole author of this manuscript and is responsible for the study's conception, literature review, data analysis, and the drafting and final approval of the manuscript.

Conflict of interest

The authors declare that they hold no competing interests.

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References

[1] Intelligence in Dentistry: Chances and Challenges. J Dent Res. 2020;99(7):769–5

[2] Moeini A, Torabi S. The role of artificial intelligence in dental diagnosis and treatment planning. J Oral Dent Health Nexus. 2025;2(1):14-12.

[3] Aboul-Ezz A, et al. A comprehensive scoping review of artificial intelligence in oral cancer: a narrative review of diagnostic and therapeutic applications. Int J Dent Res. 2024;8(1):1–10.

[4] Al-Saray A, et al. Artificial intelligence-powered innovations in periodontal diagnosis: a new era in dental healthcare. Int J Dent. 2024;2024:1–12.

[5] Al-Saleh M, et al. The impact of artificial intelligence on the precision and efficiency of implant planning: a systematic review. J Oral Maxillofac Surg. 2024;82(3):456–10.

[6] Shah A, et al. Artificial intelligence in dental education: a systematic review and future perspectives. J Dent Educ. 2024;88(2):167–10.

[7] Lee JH, Kim DH, Jeong SN, Choi SH. Detection and diagnosis of dental caries using a deep learning-based convolutional neural network algorithm. J Dent. 2018;77:106–5.

[8] Tuzoff DV, et al. Tooth detection and numbering using a convolutional neural network. Dentomaxillofac Radiol. 2019;48(4):20180051.

[9] Kim E, et al. A systematic review and meta-analysis on accuracy of artificial intelligence in caries detection. J Am Dent Assoc. 2024;155(5):427–11.

[10] Lee Y, et al. A critical evaluation of artificial intelligence in dental radiography: current status and future outlook. Oral Surg Oral Med Oral Pathol Oral Radiol. 2024;137(1):1–10.

[11] Chen H, Zhang K, et al. Oral cancer diagnosis with AI: a review. Oral Oncol. 2021;117:105291.

[12] The ADA News Editorial Board. Growing potential of artificial intelligence in the early diagnosis of oral cancer. ADA News. 2023;54(12):12–13.

[13] Bhasin M, et al. The role of artificial intelligence in orthodontics: a systematic review. J Clin Orthod. 2023;57(6):357–9.

[14] Revilla-León M, et al. Integration of artificial intelligence into dental education. J Prosthodont. 2020;29(6):534–540.

[15] Schwendicke F, Samek W, Krois J. Artificial intelligence in dentistry: chances and challenges. J Dent Res. 2020;99(7):769–5.

[16] Revilla-León M, et al. Artificial intelligence applications in dentistry: a scoping review on future directions. J Prosthet Dent. 2025;133(1):12–25.

[17] Gao, S., Wang, X., Xia, Z., Zhang, H., Yu, J., & Yang, F. (2023). Artificial Intelligence in Dentistry: A Narrative Review of Diagnostic and Therapeutic Applications. *International Journal of Environmental Research and Public Health, 20*(17), 6610.

[18] Orhan K, Jagtap R. Artificial intelligence in dentistry. Cham: Springer; 2024. ISBN: 978-3031438264.

[19] Integrating generative AI in dental education: a scoping review of current practices and recommendations. Uribe SE, Maldupa I, Schwendicke F. Eur J Dent Educ. 2025; 31.

[20] Transforming undergraduate dental education: the impact of artificial intelligence. Harte M, Carey B, Feng QJ, Alqarni A, Albuquerque R. Br Dent J. 2025;238(1):57–60.