Academia Journal of Medicine
Year 2026, Volume-9, Issue- 1 (January- June)

Artificial Intelligence in Dentistry: An Umbrella Review of Systematic Reviews

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ARTICLE INFO

Keywords: Artificial intelligence, dentistry, machine learning, deep learning, umbrella review, digital dentistry.

doi:10.48165/ajm.2026.9.01.23

ABSTRACT

Background: Artificial intelligence (AI) has rapidly emerged as a transformative technology in healthcare, including dentistry. AI-driven systems are increasingly being used for diagnostic imaging, treatment planning, and predictive analysis. Numerous systematic reviews have evaluated the role of AI across various dental specialties. However, a comprehensive synthesis of these reviews is lacking.**Objective:** This umbrella review aims to summarize and critically analyze the evidence from systematic reviews evaluating the applications and outcomes of artificial intelligence in dentistry.**Methods:** Electronic databases including PubMed, Scopus, and Google Scholar were searched for systematic reviews assessing artificial intelligence applications in dentistry. Reviews published in English that evaluated clinical, diagnostic, or educational applications of AI were included. Data extraction included author details, year of publication, focus area, and key findings. **Results:** A total of eight systematic reviews were included. The evidence suggests that AI is widely applied in dental radiology, orthodontics, pediatric dentistry, and implantology. AI-based systems demonstrated improved diagnostic accuracy in detecting dental caries, periodontal bone loss, and periapical lesions. Additionally, AI has shown promising potential in treatment planning and clinical decision support. However, limitations such as data heterogeneity, limited clinical validation, and ethical concerns were reported.**Conclusion:** Artificial intelligence demonstrates considerable potential to enhance diagnostic accuracy and clinical efficiency in dentistry. Despite encouraging findings, further high-quality clinical studies and standardized validation protocols are required before widespread integration of AI technologies in routine dental practice.

Introduction

Artificial intelligence refers to computer systems capable of performing tasks that typically require human intelligence, including learning, pattern recognition, and decision-making.[1] Advances in machine learning and deep learning algorithms have enabled the development of sophisticated AI systems capable of analyzing large datasets and identifying complex patterns.[2]

In dentistry, AI technologies have gained significant attention for their ability to enhance diagnostic accuracy, automate image interpretation, and support clinical decision-making. Applications of AI in dentistry include radiographic analysis, caries detection, orthodontic treatment planning, implant

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planning, and prediction of disease progression.[3,4]

Over the past decade, numerous systematic reviews have explored the use of artificial intelligence in various dental specialties. However, the findings from these reviews remain fragmented across different areas of dentistry. An umbrella review provides a higher level of evidence by synthesizing findings from multiple systematic reviews.

Therefore, the aim of this umbrella review was to synthesize the available evidence from systematic reviews investigating the applications and outcomes of artificial intelligence in dentistry.

Materials and Methods

This study was conducted as an umbrella review of systematic reviews to synthesize and critically evaluate the available evidence regarding the applications of artificial intelligence in dentistry. An umbrella review allows for the integration of findings from multiple systematic reviews to provide a comprehensive overview of the current evidence. The methodology followed general principles of evidence synthesis and reporting recommendations for overviews of systematic reviews.

A comprehensive literature search was performed to identify relevant systematic reviews evaluating the use of artificial intelligence in dental practice. The search was conducted in major electronic databases including PubMed, Scopus, and Google Scholar. The search st3rategy included combinations of keywords and Boolean operators such as "artificial intelligence," "machine learning," "deep learning," "dentistry," "oral health," and "systematic review." The search was restricted to articles published in the English language. Additionally, the reference lists of selected studies were manually screened to identify any additional relevant systematic reviews.

Studies were included if they met the following criteria: (1) systematic reviews or systematic reviews with meta-analysis focusing on artificial intelligence applications in dentistry; (2) studies evaluating clinical, diagnostic, educational, or treatment planning applications of artificial intelligence in dental specialties; and (3) studies reporting outcomes related to the performance or effectiveness of AI-based tools. Studies were excluded if they were narrative reviews, editorials, conference abstracts, or studies not specifically related to dentistry or artificial intelligence applications.

The study selection process was conducted in two stages. Initially, titles and abstracts of identified articles were screened to assess their relevance to the research question. Articles that met the preliminary eligibility criteria were then subjected to full-text evaluation. Reviews that fulfilled the inclusion criteria were selected for final analysis. Any discrepancies in study selection were resolved through discussion and consensus.

Data extraction was performed from each included systematic review to collect relevant information including author names, year of publication, study objectives, dental specialty involved, types of artificial intelligence techniques used, and key findings reported in the reviews. The extracted data were summarized and organized to identify major trends in the use of artificial intelligence across different fields of dentistry.

The methodological quality of the included systematic reviews was assessed using the AMSTAR-2 (A Measurement Tool to Assess Systematic Reviews) checklist. This tool evaluates critical domains such as the presence of a predefined protocol, adequacy of literature search strategy, risk of bias assessment, and transparency in reporting results. Based on these criteria, the methodological quality of each review was categorized as high, moderate, or low.

Finally, the findings from the included systematic reviews were synthesized descriptively to highlight the major applications of artificial intelligence in dentistry, including diagnostic imaging, orthodontic analysis, pediatric dentistry, implant planning, and disease detection. The results were presented in tabular and narrative formats to provide a clear overview of the current evidence and potential future directions of artificial intelligence in dental practice.

Results

A comprehensive literature search across PubMed, Scopus, and Google Scholar yielded a total of 72 potentially relevant records related to the application of artificial intelligence in dentistry. After the removal of 18 duplicate articles, 54 studies remained for title and abstract screening. During the screening process, 34 articles were excluded because they were narrative reviews, conference papers, or were not specifically focused on artificial intelligence applications in dentistry. The remaining 20 articles were assessed through full-text evaluation to determine their eligibility. Of these, 12 studies were excluded due to lack of systematic review methodology or insufficient data related to artificial intelligence in dental practice. Ultimately, 8 systematic reviews met the inclusion criteria and were included in the final umbrella review. **(Table 1)**

The included systematic reviews were published between 2020 and 2025, reflecting the growing interest in artificial intelligence applications within dental research. These reviews collectively evaluated a wide range of AI-based technologies including machine learning algorithms, deep learning models, convolutional neural networks (CNNs), and computer-aided diagnostic systems. The majority of the systematic reviews focused on the use of artificial intelligence in dental radiology, orthodontics, pediatric dentistry, implantology, and oral pathology. **(Table 2)**

Several systematic reviews highlighted the significant

role of artificial intelligence in diagnostic imaging. AI-based systems demonstrated high accuracy in detecting dental caries, periapical lesions, periodontal bone loss, and other dental abnormalities from radiographic images such as periapical radiographs, panoramic radiographs, and cone beam computed tomography (CBCT). Many studies reported that deep learning models were capable of analyzing radiographic images with diagnostic accuracy comparable to or, in some cases, higher than that of experienced clinicians. These findings indicate that AI-assisted diagnostic systems may help reduce diagnostic errors and improve efficiency in clinical practice.

Artificial intelligence was also widely applied in orthodontics, particularly in cephalometric analysis and treatment planning. Several reviews reported that AI-based software could automatically identify cephalometric landmarks and perform orthodontic measurements with high reliability. Automated landmark detection significantly reduces the time required for orthodontic diagnosis and minimizes human error, thereby improving the accuracy and consistency of orthodontic treatment planning.

In the field of pediatric dentistry, AI has been utilized for early detection of dental caries and risk prediction models. AI algorithms can analyze radiographic and clinical data to identify early signs of caries in primary teeth, enabling early intervention and preventive management. These technologies may contribute to improved oral health outcomes in pediatric patients by facilitating early diagnosis and timely treatment.

Applications of artificial intelligence were also reported in implant dentistry, where AI systems assist clinicians in evaluating bone quality, planning implant placement, and predicting implant success rates. Machine learning models can analyze patient-specific data and imaging information to support treatment planning and reduce potential complications associated with implant procedures.

The systematic reviews also reported emerging applications of artificial intelligence in oral pathology and disease prediction, where AI models are used to classify oral lesions and assist in early detection of oral cancers. These technologies demonstrate promising potential in improving diagnostic accuracy and facilitating early intervention. **(Table 3)**

Overall, the included systematic reviews consistently demonstrated that artificial intelligence has significant potential to enhance diagnostic accuracy, improve treatment planning, and support clinical decision-making in dentistry. However, several reviews emphasized that many AI systems are still in the developmental or experimental stage. Limitations such as limited dataset sizes, heterogeneity in study methodologies, and lack of standardized validation protocols were frequently reported. These limitations highlight the need for further clinical research and large-scale validation studies to ensure reliable implementation of artificial intelligence technologies in routine dental practice.

Table 1: Characteristics of Included Systematic Reviews

Author	Year	Country	Focus Area	Number of Studies Included	Key Findings
Tyagi M et al.[5]	2025	India	AI tools in dentistry	39	AI improved diagnostic accuracy and clinical decision support
Jha & Kukreja[6]	2025	India	Educational and clinical integration	7	AI enhances dental training and treatment planning
Saikia A et al.[7]	2025	India	AI potential dentistry	116	AI demonstrated strong potential in diagnostics, imaging analysis, and clinical decision support
Araidy S et al.[8]	2025	USA	AI applications in dentistry	23	AI showed strong potential in diagnostic imaging, disease detection, and treatment planning
Ahmed N et al.[9]	2021	Malaysia	AI techniques in dentistry	38	Machine learning effective in disease detection
Thurzo A et al.[10]	2022	Slovakia	AI applications in dentistry	497	AI widely used in orthodontics and imaging
Mahajan K et al.[11]	2023	India	Pediatric dentistry	13	AI useful in early caries detection
Khanagar SB et al.[12]	2021	Saudi Arabia	Performance of AI in dentistry	43	High sensitivity in radiographic diagnosis

Table 2: Applications of Artificial Intelligence in Dental Specialties

Dental Specialty	AI Application	Outcome
Oral Radiology	Detection of caries and periapical lesions	High diagnostic accuracy
Orthodontics	Cephalometric landmark identification	Reduced diagnostic time
Periodontology	Detection of bone loss	Improved disease diagnosis
Pediatric Dentistry	Early caries detection	Better preventive care
Implantology	Implant planning and bone assessment	Improved treatment planning
Oral Pathology	Lesion classification	Early disease detection

Table 3: Summary of Key Outcomes from Systematic Reviews

Outcome	Evidence from Reviews
Diagnostic accuracy	AI models demonstrated high accuracy in radiographic interpretation
Treatment planning	AI-assisted systems improved orthodontic and implant planning
Clinical decision support	AI tools supported clinicians in diagnosis and risk assessment
Disease prediction	AI helped predict caries risk and periodontal disease progression
Efficiency	AI reduced analysis time in radiographic and orthodontic evaluations

Discussion

Artificial intelligence has emerged as a transformative technology in modern healthcare, and its integration into dentistry has gained significant attention in recent years. The present umbrella review synthesized findings from multiple systematic reviews to provide a comprehensive overview of the current applications and outcomes of artificial intelligence in dental practice. The included reviews collectively demonstrate that AI technologies have the potential to significantly enhance diagnostic accuracy, treatment planning, and clinical decision-making across various dental specialties.

One of the most prominent areas where artificial intelligence has shown considerable promise is in dental radiology.[14] AI-based algorithms, particularly those utilizing deep learning and convolutional neural networks, have demonstrated high accuracy in detecting dental caries, periapical lesions, periodontal bone loss, and other oral pathologies from radiographic images.[15,16] These technologies enable automated analysis of radiographs and cone beam computed tomography scans, which can assist clinicians in identifying pathological changes more efficiently. By reducing diagnostic variability and improving consistency, AI-assisted systems may contribute to improved patient care and clinical outcomes.[17,18]

Another important application of artificial intelligence is in orthodontics, where AI-based software has been used for automated cephalometric landmark detection and orthodontic treatment planning. Traditional cephalometric analysis is a time-consuming process that requires precise identification of anatomical landmarks. Artificial intelligence systems can rapidly identify these landmarks and perform accurate measurements, thereby improving efficiency and minimizing human error. Such advancements may streamline orthodontic workflows and enhance the accuracy of treatment planning.[19-21]

Artificial intelligence has also demonstrated potential benefits in pediatric dentistry, particularly in the early detection and prediction of dental caries. Early diagnosis is critical in preventing the progression of dental diseases, especially in children. AI algorithms can analyze radiographic and clinical data to identify early carious lesions and assess risk factors for disease development. This capability supports preventive dentistry by enabling clinicians to implement timely interventions and improve oral health outcomes in pediatric populations.[22,23]

In implant dentistry, artificial intelligence has been explored for applications such as implant planning, evaluation of bone quality, and prediction of implant success rates. Machine learning models can analyze patient-specific anatomical data and imaging information to assist clinicians in selecting optimal implant placement strategies. These systems may help reduce surgical complications and improve treatment predictability.[24,25]

Despite the promising results reported across the included systematic reviews, several challenges remain regarding the widespread implementation of artificial intelligence in dentistry. One major limitation is the variability in the datasets used to train AI algorithms. Many studies rely on relatively small or heterogeneous datasets, which may limit the generalizability of their findings. Additionally, the lack of standardized validation methods for AI models makes it difficult to compare results across different studies.

Ethical and regulatory considerations also play a crucial role in the adoption of artificial intelligence in healthcare. Issues related to patient data privacy, transparency of algorithms, and accountability for clinical decisions must be carefully addressed before AI technologies can be fully integrated

into routine dental practice. Clinicians must remain actively involved in interpreting AI-generated results and ensure that these tools are used as supportive aids rather than replacements for professional judgment.[26,27]

Future research should focus on large-scale clinical studies and the development of standardized frameworks for evaluating AI technologies in dentistry. Advances in digital dentistry, combined with artificial intelligence and big data analytics, have the potential to revolutionize dental diagnosis and treatment planning. Continued collaboration between dental professionals, data scientists, and technology developers will be essential to ensure that AI technologies are implemented safely and effectively in clinical practice.

Overall, the findings of this umbrella review highlight the growing role of artificial intelligence in dentistry and its potential to enhance the efficiency, accuracy, and quality of dental care. However, further research and careful implementation strategies are necessary to fully realize the benefits of this emerging technology.

Conclusion

Artificial intelligence is increasingly becoming an important component of modern dentistry, with growing applications in diagnosis, treatment planning, and clinical decision-making. The findings of this umbrella review indicate that AI technologies, particularly machine learning and deep learning algorithms, have demonstrated promising potential in improving the accuracy of radiographic interpretation, early detection of dental diseases, orthodontic analysis, and implant treatment planning.

The evidence synthesized from the included systematic reviews suggests that artificial intelligence can enhance diagnostic efficiency, reduce human error, and support clinicians in providing more precise and personalized dental care. AI-based tools have shown particular effectiveness in dental imaging analysis and disease detection, highlighting their potential to improve overall clinical workflow and patient outcomes.

Despite these advantages, the integration of artificial intelligence into routine dental practice remains limited by several challenges. These include variability in datasets, lack of standardized validation methods, and concerns related to data privacy and ethical considerations. Therefore, further well-designed clinical studies and large-scale validation research are required to ensure the reliability and safety of AI-based technologies.

In conclusion, artificial intelligence represents a promising advancement in digital dentistry and has the potential to significantly improve diagnostic capabilities and treatment outcomes. Continued research, technological development, and responsible implementation will be essential for the successful integration of artificial intelligence into everyday dental practice.

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