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Applications of Artificial Intelligence in Dentistry with an Approach from Diagnosis to Surgery: A Systematic Review

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Abstract

Background: Artificial Intelligence (AI) has emerged as a transformative tool in modern dentistry, offering substantial improvements in diagnostic precision, treatment planning, and surgical outcomes. With increasing global interest and technological advancements, AI applications in dental practice are rapidly evolving. This systematic review aimed to comprehensively evaluate the current applications of AI in dentistry, spanning diagnostic procedures to surgical interventions, and assess the quality of existing literature using established appraisal tools.

Methods: Comprehensive search was conducted in PubMed, Scopus, Web of Science, Embase, IEEE Xplore, and the Cochrane Library without date restrictions through January 2025. Since all the included studies were systematic reviews, methodological quality was assessed using AMSTAR-2. The review followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines and a narrative synthesis was conducted. No meta-analysis was feasible due to heterogeneity.

Results: The findings demonstrated that AI has significantly contributed to numerous dental domains, especially diagnosis and surgical planning. AI technologies, such as deep learning, convolutional neural networks, and fuzzy logic have enhanced, image-based diagnosis, optimized treatment workflows, and supported clinical decision-making. In implantology, AI has improved implant type detection and design. In endodontics, AI has been effective in identifying root canal anatomy and lesions. AI also aided in the early detection of oral cancer and periodontal diseases. However, the studies noted several barriers, including limited data availability, lack of standardization, and computational constraints.

Conclusion: AI revealed substantial potential in advancing dental diagnostics, treatment planning, and surgical precision. While its benefits are evident, widespread implementation requires overcoming challenges related to data quality, algorithm interpretability, and ethical standards.

Keywords: Artificial intelligence, Deep learning, Dentistry, Endodontics, Implantology, Oral cancer

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Introduction

AI has emerged as a transformative technology in a wide range of scientific fields; causing transformation in traditional/conventional practices as well as increasing their effectiveness and accuracy (1). In dentistry, the applications of Artificial Intelligence (AI) are boosting; offering favorable solutions for different dental procedures, from diagnosis to surgical treatments. The aforementioned advances are powered by a wide range of algorithms and machine learning techniques; enabling clinicians to use data-driven insights to improve patient outcomes (2).

World Health Organization (WHO) and the World Dental Federation have recognized the potential of AI in healthcare; and thus, have emphasized its capability and ability to (i) enhance clinical decision-making, (ii) promote diagnostic accuracy, and (iii) improve patient management (3). Moreover, numerous studies and reports have highlighted better investment in dental AI technologies; principally in radiology, treatment planning and patient monitoring, emphasizing a paradigm shift towards more data-driven approaches to dental practice (4,5).

There are multifaceted applications of AI in different fields of dentistry; *e.g.*, diagnostic imaging interpretation, treatment planning, patient administration and surgical assistance (6). Additionally, AI algorithms seem to excel in the analysis of dental radiographs; facilitating early detection of carious lesions, periodontal diseases and oral cancers. In addition, AI can help orthodontists simulate treatment and predict outcomes (7). Besides, its role in surgical robotics and the use of computer to increase accuracy during procedures could emphasize the potential of AI as a diagnostic and therapeutic adjunct to invasive and non-invasive interventions (8).

Furthermore, the integration of AI in dentistry offers several benefits; *e.g.*, reducing diagnostic errors, improving treatment effectiveness and enhancing patient experience (9). By automating routine tasks and providing dental professionals with advanced analytical tools, AI may facilitate informed decision-making and strengthen productivity (10). However, challenges remain; specifically data privacy concerns, the need for comprehensive training amongst practitioners, and the potential dependence on technological systems that could impair professional judgment if not properly monitored (11).

Countries with advanced healthcare systems, *e.g.* the United States, Germany and Japan, have been pioneers in the integration of AI into dentistry. In the United States, AI tools have gained attention in both academic and clinical settings; enabling early disease diagnosis and personalized care strategies (12,13). Conversely, in developing countries, reports indicate delays in adoption, due to infrastructural challenges and limited access to technology. However, initiatives in countries, such as India and Brazil, show growing interest in using AI to address oral health inequalities; with varying degrees of success (14,15).

A growing body of evidence has examined the impact of AI in dentistry; documenting case reports, clinical trials, and systematic reviews. Besides, existing studies mainly focus on specific applications; *e.g.*, AI in radiology and orthodontics. Nonetheless, there seems to be a significant lack of comprehensive reviews that cover range of applications in different dental specialties, and the implications for clinical practice (16,17). While advances in AI applications are evident, there is a considerable research gap in systematically examining the entire spectrum of its use in dentistry; from diagnostic to surgical applications. Most existing studies seem to be fragmented and have focused on specific applications without a coherent understanding of how AI can synergistically improve overall dental practice (18).

Although numerous primary studies have evaluated AI in dental diagnostics and treatment planning, many recent publications are systematic reviews. Therefore, synthesizing these reviews provides higher-level evidence. However, no comprehensive overview of reviews exists that addresses the full clinical spectrum from diagnosis to surgery. The aim of the current systematic review was to analyze the various applications of AI in dentistry; specifically, from diagnostic processes to surgical interventions.

Materials and Methods

Study design

The present systematic review has adhered to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (19). This work is a systematic *overview of systematic reviews*, conducted

in accordance with PRISMA 2020 guidelines. Since the included studies were themselves systematic reviews, A Measurement Tool to Assess Systematic Reviews, Version 2 (AMSTAR-2) was used for methodological quality assessment. No protocol was registered in PROSPERO because overviews of reviews are generally not eligible for registration; this is explicitly stated here for transparency.

Search strategy

Searches were performed in PubMed, Scopus, Web of Science, Embase, Institute of Electrical and Electronics Engineers (IEEE) Xplore, and the Cochrane Library from inception to January 2025, without date restrictions. Full search strings were included in table 1. Database alerts were activated to capture new publications. Two independent reviewers conducted the search and screened the literature for eligibility based on the desired inclusion and exclusion criteria. In the search strategy, a combination of keywords and MeSH terms were used; *i.e.,* "Artificial Intelligence", "AI", "Dentistry", "Diagnosis", "Machine Learning", "Deep Learning", "Dental Imaging", and ''Computer-Aided Diagnosis". The Boolean operators "AND/OR" were employed to refine search results.

Inclusion and exclusion criteria

The inclusion and exclusion criteria for the systematic review are described in table 2.

Data extraction

Data extraction was performed using a standardized form, with the extracted data including authorship, year of publication, study design, sample size, methodology, AI techniques used, primary results and key findings. Two independent reviewers extracted the data, and disagreements were resolved by discussion or consultation with a third reviewer.

Quality assessment

The quality of the included studies was evaluated using the AMSTAR-2 (A Measurement Tool to Assess Systematic Reviews) checklist. Each domain of the checklist was examined to determine the presence of critical and non-critical weaknesses. The research question and inclusion criteria were clearly defined, and a comprehensive literature search strategy was reported. Study selection and data extraction were performed in duplicate, which reduced the risk of bias. However, the review reported limited information regarding the justification of excluded studies, and the assessment of publication bias was not sufficiently described. The methods for assessing the risk of bias in individual studies were clearly outlined, but the influence of risk of bias on the overall findings was not fully explored. Additionally, the review provided no detailed information on funding sources for the included studies, which was considered a non-critical weakness. No critical flaws were identified in the

Table 1. Search strategies used across all databases for identifying studies on artificial intelligence applications in dentistry

Database	Search Terms/Strategy
PubMed	((“Artificial Intelligence”[MeSH] OR “Artificial Intelligence” OR AI OR “Machine Learning” OR “Deep Learning”) AND (“Dentistry”[MeSH] OR Dentistry OR “Dental Imaging” OR “Computer-Aided Diagnosis” OR Diagnosis))
Scopus	TITLE-ABS-KEY[(“Artificial Intelligence” OR AI OR “Machine Learning” OR “Deep Learning”) AND (Dentistry OR “Dental Imaging” OR Diagnosis OR “Computer-Aided Diagnosis”)]
Web of Science	TS=[(“Artificial Intelligence” OR AI OR “Machine Learning” OR “Deep Learning”) AND (Dentistry OR “Dental Imaging” OR Diagnosis OR “Computer-Aided Diagnosis”)]
Embase	(‘artificial intelligence’/exp OR ‘artificial intelligence’ OR AI OR ‘machine learning’/exp OR ‘machine learning’ OR ‘deep learning’/exp OR ‘deep learning’) AND (‘dentistry’/exp OR dentistry OR ‘dental imaging’/exp OR ‘dental imaging’ OR diagnosis OR ‘computer aided diagnosis’)
IEEE Xplore	(“Artificial Intelligence” OR AI OR “Machine Learning” OR “Deep Learning”) AND (Dentistry OR “Dental Imaging” OR Diagnosis OR “Computer-Aided Diagnosis”)
Cochrane Library	(Artificial Intelligence OR AI OR “Machine Learning” OR “Deep Learning”) AND (Dentistry OR Diagnosis OR “Dental Imaging” OR “Computer-Aided Diagnosis”)

Table 2. Inclusion and exclusion criteria in the current study

Inclusion criteria	Exclusion criteria
Study type	
Original research articles, including clinical studies, prospective and retrospective studies, case series, and pilot studies	Conference abstracts, editorial letters, opinion pieces, letters to the editor, and technical notes without primary data
Subject area	
Studies focusing on AI applications in dentistry spanning diagnosis, treatment planning, and surgical procedures	Studies exclusively discussing AI applications outside dentistry (e.g., general medical AI, veterinary dentistry unless specifically relevant)
Population	
Human subjects or data derived from clinical cases; in vitro or simulated models may be included if relevant	Studies conducted on animals
Outcomes	
Studies that assessed diagnostic accuracy, treatment outcomes, surgical planning, or workflow improvements	Studies that did not assess diagnostic accuracy, treatment outcomes, surgical planning, or workflow improvements
Language	
Peer-reviewed articles published in English	Articles not published in English
Publication date	
Studies published from 2020 to 2025	Studies published before 2020

core AMSTAR-2 domains. Based on the AMSTAR-2 criteria and the pattern of observed weaknesses, the overall confidence rating in the results of the review was judged as High, indicating that no critical flaws and no more than one non-critical weakness were identified.

Data synthesis

A narrative synthesis was created to summarize the study findings on the themes of diagnosis, treatment planning, and applications of AI in dentistry.

Interpretation of results

Results were interpreted in the context of their clinical implications for dental practice and patient outcomes. Furthermore, the current review assessed the strengths and limitations of existing studies as well as how AI could improve or challenge traditional dental practices. In addition, gaps in the current literature were identified to suggest future research directions.

Reporting

The results of this systematic review were reported following PRISMA guidelines. The review includes a flow diagram detailing the search and selection process (Figure 1), and table (Table 3) summarizing the key characteristics and findings of the included studies. The systematic review is reported according to the guidelines provided by the statement of PRISMA (Supplementary File 1) (20).

Results

Description of the included studies

Following a thorough search in the selected databases based on the methods described in the corresponding section, 12 articles were selected from 302 related studies, which comprised review articles (n=12). Figure 1 demonstrates PRISMA flow diagram, and table 3 provides the characteristics of the included review studies. Moreover, the list of the excluded studies containing reasons provided in Supplementary file 2.

Quality assessment of the intended studies

The methodological quality of the included studies was evaluated using the AMSTAR-2 tool (Table 4). Out of the 12 studies, eight narrative reviews [Schwendicke *et al* (21); Shan *et al* (22); Ossowska

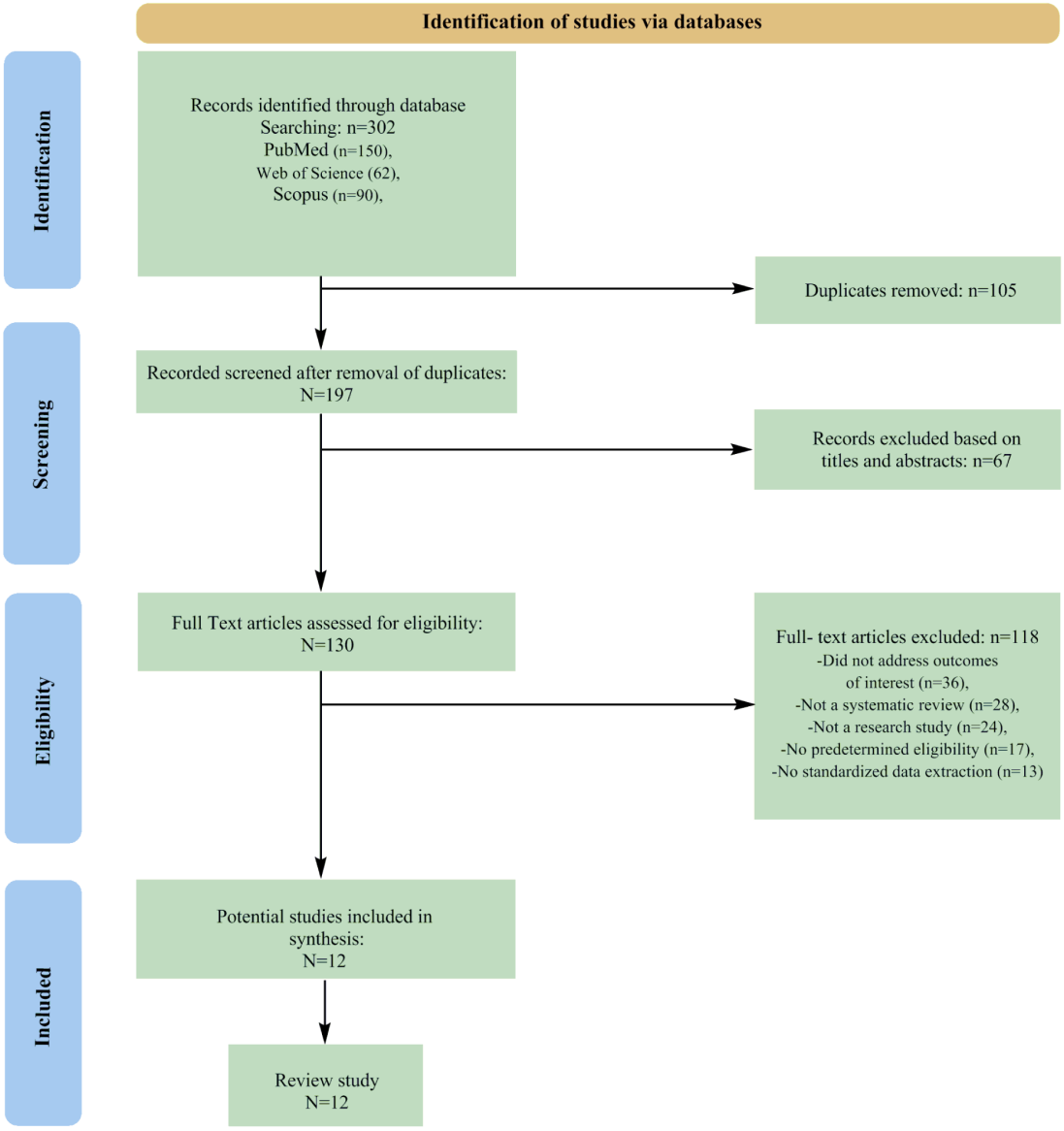


Figure 1. The PRISMA flow diagram.

Table 3. Characteristics of the included reviews in the present study

First author	Year	Country	Study design	Results
Schwendicke *et al* (21)	2020	Germany	- A narrative review method was used - Existing literature on artificial intelligence and its applications in dental practice was synthesized	- Several potential benefits of AI in dentistry were highlighted - Time-consuming tasks of dental professionals were reduced - Personalized, predictive, proactive, and collaborative services were provided - Significant barriers to adoption were identified: limited data availability and quality, lack of methodological rigor and standards, and ethical/practical concerns
Shan *et al* (22)	2021	China	- A comprehensive review of existing literature on AI applications in dentistry was conducted	- Accuracy and efficiency of dental diagnoses were significantly increased by AI algorithms - Visual guidance for treatments and disease prognosis were provided - Barriers related to data management, algorithm transparency, computational limits, and ethics were identified

Contd. table 3.

Ossowska *et al* (23)	2022	India	- Existing literature and research on AI technologies, particularly convolutional neural networks and artificial neural networks in endodontics, were reviewed	- AI and neural networks were rapidly advanced and increasingly relevant in dental practice - Efficiency and accuracy of diagnostic processes and treatment planning were increased
Ahmed *et al* (24)	2021	Saudi Arabia	- MeSH keywords related to AI and dentistry were utilized - An electronic search was conducted across PubMed/MEDLINE, Scopus, - ScienceDirect, Web of Science, and Cochrane Collaboration databases by two investigators	- Accurate patient management, diagnosis, prediction, and decision support were provided by AI - AI was shown to enhance smoothness, efficiency, and economy of dental care - Potential clinical failures were predicted and reliable solutions were suggested
Carrillo-Perez *et al* (11)	2022	Spain	- A systematic search was performed in MEDLINE/PubMed, Web of Science, and Scopus for English-language papers published in the last 20 years - Eligible papers were screened, and 120 papers were selected for final appraisal - Methodologies including deep learning, fuzzy logic, and other machine learning techniques were identified	- Disease detection and image processing methods were improved by integrated AI approaches - Advances in decision support systems and color modeling were facilitated
Ding *et al* (25)	2023	China	- Existing literature on AI technology, its evolution, and integration into dentistry was synthesized - Applications of AI across various dental fields were classified	- Diagnosis through radiographic or optical images was the main focus of AI applications - Decision-making in clinical cases was enhanced by AI - Limitations in data uniformity and computational power were acknowledged
Xie *et al* (26)	2024	China	- Articles related to AI in dentistry published between 2000 and 2023 were retrieved from the Web of Science Core Collection - Bibliometric parameters were extracted - Bibliometric analysis was performed using VOSviewer, Pajek, and CiteSpace software tools	- Publication volume on AI in dentistry was rapidly increased after 2019 - Leading institutions and prolific authors were identified - Research focus was placed on medical devices and clinical decision support systems
Shafi *et al* (18)	2023	Pakistan	- An extensive literature review on advanced computer vision, deep machine learning, and deep learning models for diagnosing dental diseases was conducted - The performance of various methods was evaluated based on general criteria - Influencing factors such as data availability and model interpretability were identified	- Automatic interpretation of dental images was significantly progressed by AI - Challenges such as limited data, class imbalance, and transparency issues were identified
Revilla-León *et al* (27)	2023	USA	- An electronic systematic review was conducted across MEDLINE/PubMed, EMBASE, Web of Science, Cochrane, and Scopus databases, including a manual search - Peer-reviewed studies on AI models for implant recognition, success prediction, and design optimization were included - Study quality was independently evaluated by two investigators using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist - Disagreements were resolved by consulting a third investigator	- High accuracy (93.8% to 98%) was shown by AI models in implant type detection - Variable performance (62.4% to 80.5%) was reported for implant success prediction - AI models for implant design optimization were evaluated

Contd. table 3.

Bonny *et al* (28)	2023	United Arab Emirates	- A comprehensive review and evaluation of AI technologies and algorithms in dentistry were performed - Their effectiveness was assessed across diagnosis, treatment planning, and prognosis prediction in 10 dental specialties	- Diagnostic accuracy and clinical decision-making were improved by AI technologies - Large data volumes were efficiently analyzed by AI, facilitating treatment planning
Asgary (29)	2024	Iran	- Various AI models and their applications in endodontics were examined - Effectiveness in analyzing root canal anatomy, detecting lesions, determining working length, predicting treatment success, and interpreting cone beam CT scans was evaluated	- Significant benefits were shown by AI models in root canal anatomy analysis and lesion detection - High accuracy was achieved in Cone Beam Computed Tomography (CBCT) scan analysis
Dashti *et al* (30)	2023	Iran	- Existing literature and current practices on AI application in dentistry were reviewed - AI technologies' role in analyzing radiographic and histopathological images and improving diagnostic accuracy was evaluated - Potential impacts on the demand for specialists were assessed	- More accurate and reliable diagnoses were provided by AI - Diagnostic accuracy in oral cancer and periodontal disease was improved - Potential decrease in demand for specialists due to AI was identified

et al (23); Ding *et al* (25); Shafi *et al* (18); Bonny *et al* (28); Asgary (29); Dashti *et al* (30)] and one bibliometric review [Xie *et al-(*26)] were rated as critically low. Two systematic reviews [Ahmed *et al* (24); Carrillo-Perez *et al* (11)] were rated as low to moderate, and one systematic review [Revilla-León *et al* (27)] was rated as moderate.

Key strengths of the studies were identified. Schwendicke *et al* (21) provided a clear narrative synthesis of AI applications, Shan *et al* (22) offered a broad overview of AI in diagnosis, and Ossowska *et al* (23) performed a targeted exploration of neural networks. Ahmed *et al* (24) and Carrillo-Perez *et al* (11) employed multi-database searches and described dual screening procedures. Ding *et al* (25) presented an organized classification) of AI applications. Xie *et al* (26) applied robust bibliometric tools. Shafi *et al* (18) provided a detailed technical evaluation of AI models, Revilla-León *et al* (27) performed protocol-like procedures with dual screening and risk-of-bias assessment using the JBI checklist, Bonny *et al* (28) synthesized multi-specialty evidence, Asgary (29) evaluated endodontic applications in detail, and Dashti *et al* (30) focused on diagnostic imaging accuracy.

Common methodological weaknesses were observed. Most studies did not report a protocol or pre-registration (domains 1), and many employed non-systematic or unspecified search strategies (domain 4). Risk-of-bias assessments were frequently omitted (domain 9), and publication bias was rarely analyzed (domain 15). Additionally, justification for the excluded studies (domain 7) and meta-analyses were limited in several reviews. It was noted that AMSTAR-2 was not fully applicable to bibliometric studies. Overall, the majority of included reviews were critically low in methodological quality, reflecting significant gaps in systematic review conduct and reporting.

Findings of the included studies

The included studies revealed that the use of AI in dentistry has collected significant attention in recent years, and has made significant contributions to various dental sub-branches; driven by its promise to enhance diagnostic accuracy, treatment effectiveness and patient outcomes. The AI applications in dentistry seem to enhance diagnostic accuracy, improve patient outcomes, and streamline practice management (Table 5).

The findings demonstrated that the applications of AI in dentistry were extensively studied across various domains from diagnosis to surgery. AI algorithms were reported to significantly increase the accuracy and efficiency of dental diagnoses, particularly

Table 4. AMSTAR-2 quality assessment of the included AI-focused reviews in dentistry, highlighting overall ratings, key strengths, and methodological weaknesses mapped to AMSTAR-2 domains

Study type	AMSTAR-2 overall rating	Key strengths	Key weaknesses (mapped to AMSTAR-2 domains)
Narrative Review	Critically low	Clear narrative synthesis of AI applications	No protocol (1), non-systematic search (4), no dual screening, no risk-of-bias assessment (9), no publication bias analysis (15)
Narrative Review	Critically low	Broad overview of AI in diagnosis	No predefined protocol (1), search methods unclear (4), no risk-of-bias assessment (9)
Narrative Review	Critically low	Targeted exploration of neural networks	No protocol (1), unspecified search strategy (4), no RoB assessment (9), no justification for exclusions (7)
Systematic Review (partial)	Low	Multi-database search, dual investigators	No protocol registration (1), no detailed RoB assessment (9), no publication bias assessment (15)
Systematic Review	Low to Moderate	Multi-database search, screening procedure described	No reported protocol (1), unclear risk-of-bias assessment (9), no publication bias assessment (15)
Narrative Review	Critically low	Organized classification of AI applications	No protocol, no systematic search, no RoB (1,4,9)
Bibliometric Review	Critically low	Robust bibliometric tools used	AMSTAR-2 domains not applicable; no protocol, no RoB assessment
Narrative/ Technical Review	Critically low	Detailed technical evaluation of models	No protocol, non-systematic search, no RoB or publication bias analysis
Systematic Review	Moderate	Protocol-like procedures, dual screening, RoB *via* JBI checklist	Unclear protocol registration (1), limited reporting on publication bias (15), no meta-analysis (if needed)
Narrative Review	Critically low	Broad multi-specialty synthesis	No protocol, no systematic search, no RoB assessment
Narrative Review	Critically low	Detailed evaluation of endodontic applications	No protocol (1), search strategy unclear (4), no RoB assessment, no publication bias
Narrative Review	Critically low	Focus on diagnostic imaging accuracy	No systematic search, no protocol, no RoB evaluation

Table 5. Applications of AI in dentistry based on the included studies

Application	Description
Diagnostic imaging	AI algorithms can analyze dental images (X-rays, CT scans, etc.) to detect conditions such as cavities, periodontal disease, and tumors. By training on large datasets, these algorithms can improve accuracy and reduce the chance of human error
Treatment planning	AI can assist in developing personalized treatment plans by analyzing patient data, including dental history and imaging, to recommend the most effective interventions
Predictive analytics	By analyzing historical patient data, AI can predict future dental issues, allowing for preventive measures to be taken. This ensures better patient outcomes and can reduce long-term treatment costs

Contd. table 5.

Patient management	AI-powered chatbots and virtual assistants can help with scheduling appointments, answering frequently asked questions, and sending reminders for follow-up visits, thus improving patient engagement and practice efficiency
Tele-dentistry	AI can enhance teledentistry platforms by assisting in remote consultations and assessments. It enables practitioners to provide accurate diagnostics and treatment recommendations without requiring a physical visit
Orthodontics	AI is used in creating aligners and orthodontic plans. Predictive algorithms can analyze tooth movement and suggest optimal treatment paths for orthodontic patients
Digital dental records	AI can help in organizing and analyzing vast amounts of dental data, from patient history to treatment outcomes. This allows for better data management and insights into clinical practices
Robotics	Robotic systems integrated with AI are being developed to assist dentists during surgical procedures, such as implant placements. They can enhance precision and reduce the risk associated with manual interventions
Education and training	AI-driven simulations and virtual reality applications can aid in the training of dental students, providing them with a risk-free environment to practice their skills
Patient monitoring	AI tools can help monitor patients' oral health, using data from wearable devices or smart toothbrushes to provide feedback on hygiene habits and identify issues early on
Marketing and business intelligence	AI can analyze trends and patient data to help dental practices understand patient preferences and improve their marketing strategies, leading to better patient acquisition and retention
Endodontics	AI algorithms can assist in diagnosing and predicting outcomes for treatments like root canals by assessing clinical data and radiographs

through the analysis of radiographic, optical, and histopathological images. Diagnostic processes and treatment planning were enhanced by the integration of AI technologies such as deep learning, convolutional neural networks, and fuzzy logic. AI was found to reduce time-consuming tasks for dental professionals and enable personalized, predictive, proactive, and collaborative dental services. Decision support systems were advanced, improving clinical decision-making and patient management, while also facilitating disease detection, prognosis prediction, and treatment guidance.

In implantology, AI models demonstrated high accuracy in implant type detection and variable performance in predicting implant success, with additional applications in implant design optimization. In endodontics, AI showed notable effectiveness in analyzing root canal anatomy, detecting lesions, determining working lengths, and interpreting CBCT scans. AI also improved diagnostic accuracy for oral cancer and periodontal diseases and was indicated to potentially reduce the demand for dental specialists due to enhanced diagnostic reliability.

Despite these benefits, several barriers to AI adoption were identified. These included limited data availability and quality, lack of standardization and methodological rigor, computational limitations, ethical concerns, transparency issues, and class imbalances in datasets. The volume of publications on AI in dentistry has rapidly increased since 2019, with research focusing on medical devices and clinical decision support systems. Large datasets were efficiently processed by AI, supporting treatment planning and clinical workflows. However, challenges related to data management, algorithm interpretability, and ethical implications were consistently noted across studies.

Overall, AI technologies were suggested to improve diagnostic accuracy, clinical efficiency, and decision-making in dental practice, although practical implementation faced significant hurdles that should be addressed for broader integration.

Discussion

The purpose of this systematic overview was to highlight the essential applications of AI in dentistry, their potential benefits, and the challenges that dental professionals must overcome to effectively implement the aforementioned technologies. The studies included have demonstrated a dynamic landscape in which AI technologies, *e.g.,* image analysis and machine learning algorithms, offer a wide range of applications across various dental specialties; including diagnostic dentistry, orthodontics, periodontics and implant dentistry (21,25).

Artificial intelligence has emerged as a transformative force in many sectors, and dentistry is no exception. From predictive analytics that aid in early detection of oral disease to machine learning algorithms that improve imaging techniques, artificial intelligence is poised to significantly enhance the capabilities of dental professionals (31).

The applications of AI in dentistry can be generally categorized into diagnostic tools, treatment planning, administrative processes and patient management; each of which plays an important role in improving dental practices (32). Diagnostic tools use advanced image recognition algorithms to interpret dental radiographs, CBCT images and other diagnostic procedures. Seemingly, machine learning models are able to analyses the images to diagnose diseases; *e.g.,* caries, periodontal diseases and even oral cancers at a level of acceptable accuracy (33).

The included studies indicated that AI systems can achieve diagnostic accuracy comparable to that of experienced radiologists; potentially leading to earlier and even more accurate diagnosis of disease. Moreover, AI has facilitated personalized treatment plans through analyzing patients' dental history, genetics and unique preferences. In addition, by combining large amounts of data, AI can help dental professionals choose the most effective treatment options for various patients (34). In orthodontics, AI algorithms can simulate the progress and results of treatment(s), and enable better visualization/ communication with the patient; which promises the optimization of treatment outcomes as well as an increase in patient satisfaction and compliance (35). Furthermore, the integration of AI into orthodontics could facilitate the development of personalized treatment plans; potentially providing access to advanced care without necessitating extensive specialist training (36).

Additionally, the recent findings have confirmed the transformative potential of AI in endodontics as well as oral diagnosis. Recent research has demonstrated that AI technologies, *e.g.*, convolutional neural networks, have shown significant promise in the enhancement of root canal procedures as well as their accuracy and efficiency (37). The ability of AI to analyses complex root canal anatomy, detect periodical lesions and accurately determine working length represents a notable advancement in diagnostic and therapeutic approaches. The mentioned capabilities can help present clinical workflows and improve patient outcomes by enabling early detection and intervention (29).

Similarly, Dashti *et al* reported the broad applicability of AI across various dental subspecialties; including oral radiology and pathology. The potential of AI to analyze radiographic and histopathological images enhances diagnostic accuracy; allowing for the identification of conditions that may evade human detection. The aforesaid advancement is specifically critical in the context of diseases, *e.g.,* oral cancer and periodontal disease, where timely and accurate diagnosis is of utmost importance (30).

AI can assist the rearrangement of different administrative functions in other dental departments; *e.g.*, appointment scheduling, billing and patient follow-up. Besides, natural language processing could be used to automate communication with patients while predictive analytics may help manage practice operations by predicting patient influx and optimizing resource allocation (38). The above-mentioned improvements and alike can reduce the administrative limitations on the dental staff, and increase the overall efficiency of the practice (35).

Potential benefits of AI in dental practice

The integration of AI in dental setting has presented numerous benefits. Findings from Schwendicke *et al* and Ahmed *et al* have indicated that AI can rationalize workflows, reduce pitfalls on dental professionals and provide personalized treatments based on predictive analysis (18,21). Additionally, AI algorithms have shown to improve diagnostic

processes by enhancing accuracy and efficiency, which, in turn, facilitate timely patient management and decision-making (23,27). A study by Carrillo-Perez *et al* has demonstrated the ability of AI to predict clinical outcomes as a significant advantage and highlighted AI's potential to simulate treatment results; ultimately improving patient satisfaction and treatment effectiveness (11).

The ability to improve diagnostic accuracy is one of the most important advantages of the implementation of AI in dentistry. AI algorithms are capable of analyzing dental images; *e.g.,* X-rays and intraoral scans, with a level of accuracy that minimizes human error. AI techniques, *e.g.,* machine learning and deep learning, enable the detection of dental cavities, periodontal disease and other oral health issues at an earlier stage compared to traditional methods. Early diagnosis is very important in dentistry, as it allows for timely intervention and improved patient outcomes (39).

AI can help create personalized treatment plans based on individual patient data. By analyzing a patient's dental history, genetics and specific oral health conditions, AI systems can suggest appropriate treatment options that offer the best chance for success. The stated personalized approach can increase the effectiveness of treatments and promote patient satisfaction since people could feel their unique needs are being met. In addition, through advanced data analysis, AI can optimize patient management processes in dental offices with predicting no-show rates, adjusting scheduling, reducing wait times and increasing operational efficiency (40).

Additionally, AI can facilitate follow-up and patient engagement through automated reminders; helping to ensure adherence to treatment plans and improving overall patient compliance. Dentists are often faced with administrative difficulties that take time away from patient care. AI can automate routine administrative tasks; *e.g.,* invoicing, handling insurance claims and record keeping. Besides, dental practices can reduce overhead costs, minimize errors and devote more time to clinical activities. This administrative efficiency can translate into more productive operations and improved patient experiences. AI seems to have the potential to change dental education and training. Virtual/augmented reality technologies integrated with AI can create realistic simulations for dental students and professionals to practice their procedures and skills (41).

Challenges and barriers to AI adoption

Despite the evident advantages, the adoption of AI in routine dental practice faces considerable challenges. Schwendicke *et al* showed significant barriers; including limited data availability, a lack of methodological rigor in AI development and ethical concerns relating to the use of AI in patient care (21). Similar challenges were reported by Sha *et al* emphasizing concerns around algorithm transparency, data quality and the need for ethical frameworks to govern AI use (22). Moreover, technological limitations, *e.g.,* computational power and the complexity of integrating AI with existing clinical workflows, present further obstacles. Notably, the requirement for continuous human oversight is critical to ensure the responsible application of AI and to maintain the irreplaceable human element in patient care (28).

One of the main obstacles to the adoption of AI is the technical complexity of its systems. Organizations often struggle to integrate AI into their existing infrastructure; especially if they lack strong data management practices. The needed algorithms require large amounts of high-quality data for training and could be scarcely or poorly accessed in some organizations (42). In addition, the need for specialized talent to develop, implement, and maintain AI systems is a significant challenge. A shortage of skilled professionals, *e.g.,* data scientists and machine learning engineers, can impede progress and limit on the ability to invest in AI technologies (43). Moreover, organizational resistance to change is deliberated as another important obstacle. Many companies may have routines, processes, and cultures resistant to integrating AI technologies. Employees may be afraid of changing jobs or lack an adequate understanding of AI, leading to skepticism and reluctance. Change management strategies are essential to address such concerns and foster a culture of innovation. Successful adoption of AI requires technology investment and a thoughtful approach to managing human factors in organizations (44).

Ethical concerns surrounding AI technologies, *e.g.,* bias in algorithms, data privacy and accountability, creates additional barriers to adoption. Organizations should engage in the implications of deploying AI systems that could inadvertently preserve existing biases or compromise user privacy. Nonetheless, developing responsible AI frameworks is critical to ensuring the ethical use of AI. Companies should establish clear guidelines and appropriate structures to protect against potential abuse and build public trust in AI solutions (45).

The evolution and future of AI in dentistry

Recent studies have highlighted the evolution of AI tools from mere diagnostic aids to comprehensive systems, capable of supporting various aspects of dental procedures. For future advancements, a collaborative approach, which integrates AI with evidence-based dental practices, seems essential. This multidimensional integration will require dental professionals to develop digital literacy and adaptability to effectively utilize AI technologies (27,46).

The use of AI in dentistry covers a wide range of applications; *e.g.*, AI algorithms can analyze radiographs and other imaging methods to help the early detection of cavities, periodontal diseases and other dental problems, which can significantly improve diagnostic accuracy. What is more, AI systems, such as deep learning models, can evaluate patient images and identify conditions that even experienced doctors might miss. In addition, software tools based on AI can assist in treatment planning by suggesting evidence-based approaches tailored to the patient's individual need/profile. Patient management has also benefited from advances in artificial intelligence (47). Chatbots and virtual assistants simplify appointment scheduling, follow-up reminders and initial observations, allowing dental professionals to focus more on patient care. Additionally, AI can improve patient education by providing tailored information based on individual needs; improving understanding and engagement (48).

While AI has many benefits, it poses ethical and practical challenges. Issues, such as data privacy, informed consent, and the possibility of artificial intelligence bias, should be addressed to maintain trust in artificial intelligence-based systems. Additionally, the risk of over-reliance on AI could diminish the dentist's role as a decision-maker and lead to the erosion of critical thinking and clinical skills (49).

A trend towards more personalized and proactive care is likely to emerge; using predictive AI capabilities to intervene before conditions escalate. Integrating AI with other technologies, *e.g.,* augmented reality for surgical guidance has exceptional potential to enhance clinical outcomes and patient safety (50). Additionally, education and training for dental professionals should evolve alongside AI technologies. As AI tools become more common, curricula in dental schools may need to incorporate data analytics and AI literacy, preparing future clinicians to work effectively with AI systems. Ongoing professional development will be also necessary to keep current practitioners informed of these developments, and to ensure that they integrate AI into their practices responsibly and efficiently (51).

The evolution of AI in dentistry promises a new era of increased clinical workflow, improved patient outcomes, and a more efficient practice. However, it is important to carefully consider the ethical, educational, and practical challenges that accompany it. By addressing the mentioned issues, the dental community can benefit from the full potential of AI while maintaining the integrity of the profession, and safeguarding the well-being of patients. As the field continues to grow, the collaboration between dental professionals and AI technologies will likely redefine the future of oral health care; making dental practices more accurate and efficient.

AI adoption in dentistry raises serious concerns about algorithmic bias, especially due to the underrepresentation of darker skin tones, minority populations, and atypical anatomic variations in many training datasets. These biases may contribute to diagnostic disparities. Additionally, AI models often rely on large image repositories that may lack explicit patient consent, posing privacy challenges. Transparency and explainability remain limited, hindering clinicians' ability to interpret AI outputs.

Future perspective

Based on the results of this systematic review, the future perspective of AI applications in dentistry is

highly promising yet calls for targeted advancements to overcome current limitations. As AI continues to demonstrate substantial improvements in diagnostic accuracy, treatment planning, and surgical precision across multiple dental subfields—from radiographic analysis to implantology and endodontics—its integration into routine clinical practice is expected to expand significantly. Future developments should focus on enhancing the availability and quality of dental datasets, establishing standardized protocols, and improving algorithm transparency and interpretability to foster greater clinician trust and ethical compliance. Additionally, addressing computational constraints and refining AI models to manage class imbalances will be crucial for robust and reliable performance. Continued innovation in personalized and predictive AI-driven dental care can potentially transform patient management by enabling more proactive, collaborative, and efficient treatment strategies. Moreover, as AI reduces reliance on specialist intervention through improved diagnostic support, dental education and workforce dynamics may evolve accordingly. Ultimately, bridging the gap between research advancements and practical implementation will require multidisciplinary collaboration, regulatory guidance, and ongoing validation studies to ensure safe, effective, and equitable AI adoption across global dental healthcare systems.

Conclusion

The integration of AI into dentistry holds the transformative potential to significantly improve diagnostic accuracy, treatment planning and patient outcomes. The current review revealed that AI technologies can simplify procedures, provide predictive analytics and support dental professionals in managing complex clinical scenarios. However, the journey to widespread adoption of AI in routine dentistry is not without challenges; key barriers, including limited data availability, algorithm transparency issues, ethical considerations, and the need for methodological rigor, should be overcome to unlock the full potential of AI in dentistry. As AI continues to evolve, it is critical for dental education to adapt and equip future practitioners with the digital literacy necessary to effectively use these technologies. Emphasis on "explainable AI" and continuous human oversight will be critical in promoting trust and ensuring the ethical application of AI solutions. Furthermore, ongoing research and development should prioritize the robustness of AI systems, especially in overcoming challenges associated with data uniformity and computing power. Consequently, while the promise of AI in dentistry is significant, its successful implementation depends upon a collaborative approach that honors the essential human element in patient care. As the dental landscape follows such technological shift, using AI as a supportive tool, rather than a replacement, can ensure the advancement of dental practice, and protect the quality of care and essential patient-provider communication. The future of AI in dentistry is not just about increasing capabilities, but on enriching the dental practice itself for better healthcare outcomes.

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Ethical approval

This study was a review article and did not involve human participants, animals, clinical interventions, or the collection of identifiable personal data. Therefore, ethical approval and an ethics committee code were not required. No clinical trial was conducted; thus, an IRCT registration ID is not applicable.

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Conflict of Interest

Authors declare no conflict of Interest.

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