REVIEW ARTICLE

Artificial Intelligence (AI) Trends in Dentistry: A Literature Review

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Abstract

Global health systems face challenges due to various socio-political factors, and there's an increased demand for delivering health services efficiently with optimal resources while ensuring patient safety. AI methods support dental professionals in multiple aspects, including reducing chairside time, streamlining procedures, providing effective infection control, and delivering precise and accurate treatments. AI proves effective in-patient diagnosis, aiding clinical decision-making, and predicting dental issues, making it a dependable approach for future applications across different dental fields.

Keywords: *Artificial intelligence, dentistry, implication and risks, trends, health services, efficiently.*

INTRODUCTION

Global health systems face challenges due to various socio-political factors, and there's an increased demand for delivering health services efficiently with optimal resources while ensuring patient safety. The growing population especially elderly persons with multiple chronic illnesses, coupled with the rise in global healthcare spending, contributes to the challenges faced by healthcare systems. Primary health care can, to some extent, meet these needs at both the community and population levels. Primary health care (PHC) is evolving quickly, both in terms of health policies and technological advancements. The majority of PHC providers have adopted digitization and integrated health information systems into their services [1]. Advances in computational and informatics technologies have made it possible to incorporate Artificial Intelligence (AI) techniques, such as machine learning and deep learning, into these health information systems [2].

The term artificial intelligence (AI) was introduced by John McCarthy at a conference held at Dartmouth in 1956. Artificial intelligence is characterized as the capability of machines to mimic the human brain, enabling them to undertake tasks ranging from simple to complex, including problem recognition, decision-making, and problem-solving [3]. AI encompasses subfields such as machine learning, neural networks, and deep learning (**Fig. 1**). This technology function using neural network architecture modelled after the human brain. Common types of neural networks include artificial neural networks (ANN), convolutional neural networks (CNN), and recurrent neural networks (RNN). Deep learning, a subset of neural networks, enables computers to autonomously learn how to process data [2, 4].

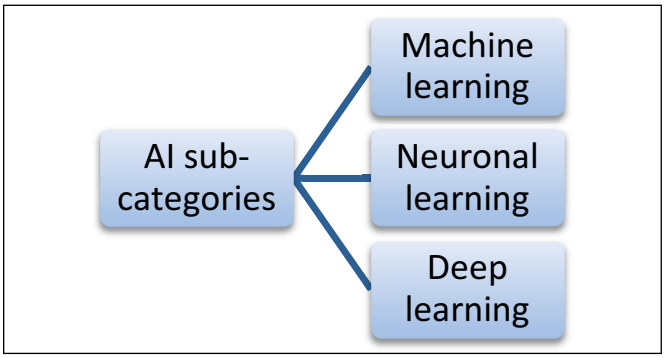

Fig. (1): Sub-categories of AI.

AI has significantly impacted our everyday lives across different realms, with substantial advancements in AI technology evident in search engines, chatbots, virtual assistants like Siri or Alexa, and facial recognition systems. This progress aids humans by reducing workload in various fields [5].

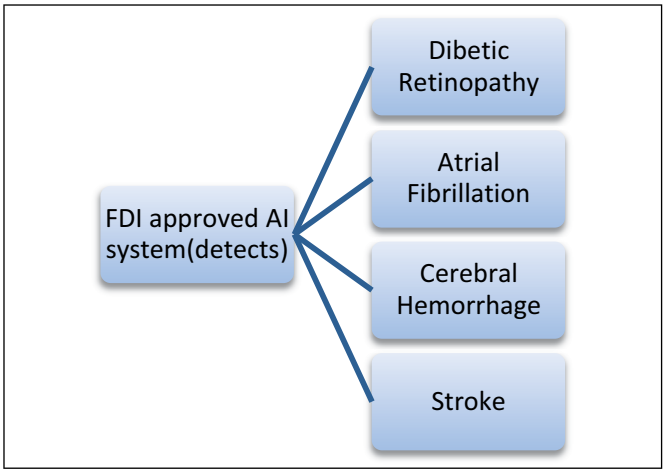

Fig. (2): FDI-approved AI detection system.

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AI IN THE FIELD OF MEDICINE

AI has become essential in the medical field, handling tasks ranging from basic functions to more complex ones like patient history and appointment scheduling to intricate responsibilities such as predicting disease risk factors, diagnosing various illnesses, detecting pathologies, planning effective treatment therapies, managing patients, prognosticating diseases, and engaging in preventive measures (**Fig. 2**) [1, 4, 6].

AI IN THE FIELD OF DENTISTRY

AI plays a role in clinical decision-making within dentistry, contributing to disease detection and pattern prediction based on existing datasets. It aids clinicians by rapidly analyzing extensive data sets to enhance workflow, recognize disease patterns, assess risks, and formulate personalized, patient-centred treatment plans. AI proves valuable in increasing office efficiency through tasks like scheduling, tracking, and updating patient records for improved data organization [7]. The widespread adoption of artificial intelligence in dentistry results from technological advancements and the digitization of dental practices. This technology operates on neural network architecture similar to the human brain, enabling it to provide a second dental opinion by mimicking human thinking abilities. This, in turn, streamlines the processes of diagnosis and treatment planning, making them more efficient and rapid. The study aims to present an overview of the overall use of AI in the healthcare system, with a focus on dentistry [4].

AI methods support dental professionals in various aspects, including reducing chairside time, streamlining procedures, ensuring effective infection control, and delivering precise and accurate treatments. AI proves effective in patient diagnosis, aiding clinical decision-making, and predicting dental issues, making it a dependable approach for future applications across different dental fields [2].

DIAGNOSIS

AI is a dependable technology for assessing the severity of dental caries, diagnosing apical lesions, determining working lengths, classifying dental arches, segmenting teeth, detecting TMJ osteoarthritis, and identifying early signs of osteoporosis in jaws through panoramic radiographs (**Fig. 3**) [8-10].

Rekow *et al.* [11] used machine learning to detect and classify dental restorations in panoramic images. Kuwada *et al.* [12] demonstrated the potential usefulness of "DetectNet and AlexNet" in identifying the impacted extra teeth in the upper front teeth area

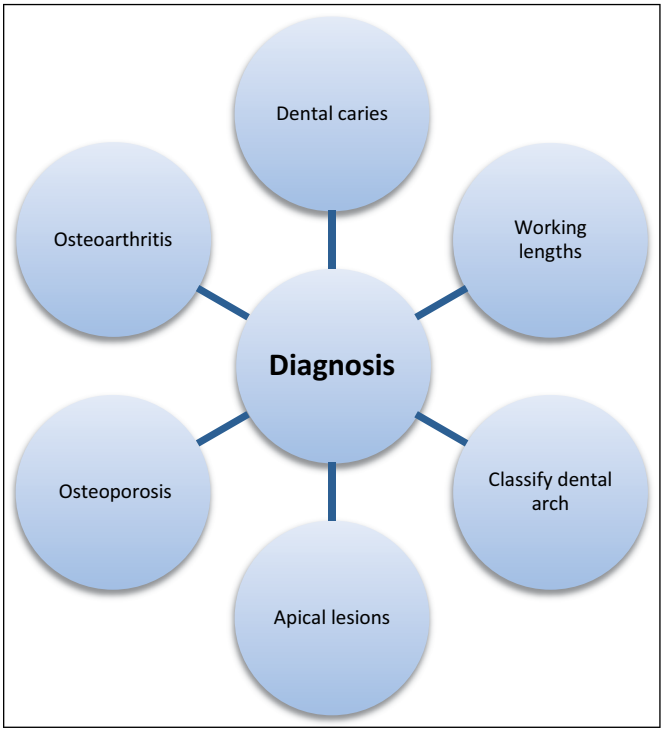

Fig. (3): Role of AI in diagnosis.

on panoramic X-rays. Drevenstedt *et al.* [13] employed voice commands for tasks such as recording patients' history, offering suggestions during dental procedures, scheduling appointments, sending reminders for routine checkups, and facilitating necessary dental consultations. Artificial neural network (ANN) models analyzed bitewing photos and reached 97.1% accuracy in detecting cavities, with 95.1% precision, 94.3% specificity, and sensitivity between 85% and 99.6% [14]. Sornam and Prabhakaran used a back-propagation neural network (BPNN) AI model to classify cavities with 85% to 100% accuracy [2].

PROSTHODONTICS

AI technologies in prosthodontics could offer new solutions, such as AI systems that design crown surfaces based on existing wear patterns in the mouth. It includes automated designs for setting up complete dentures, shaping implant emergence profiles, and designing frameworks for removable partial dentures [15]. AI also helps teach less experienced undergraduate students and supports their learning and growth [16]. A computer colour-matching system showed more accurate colour reproduction within the given colour space than traditional visual methods [17]. AI performs well in tasks like diagnosing and predicting issues with teeth affected by periodontal disease and identifying dental implant systems through radiographic images. While AI's role in (dental) medicine focuses on image data processing for caries and endodontic lesion detection,

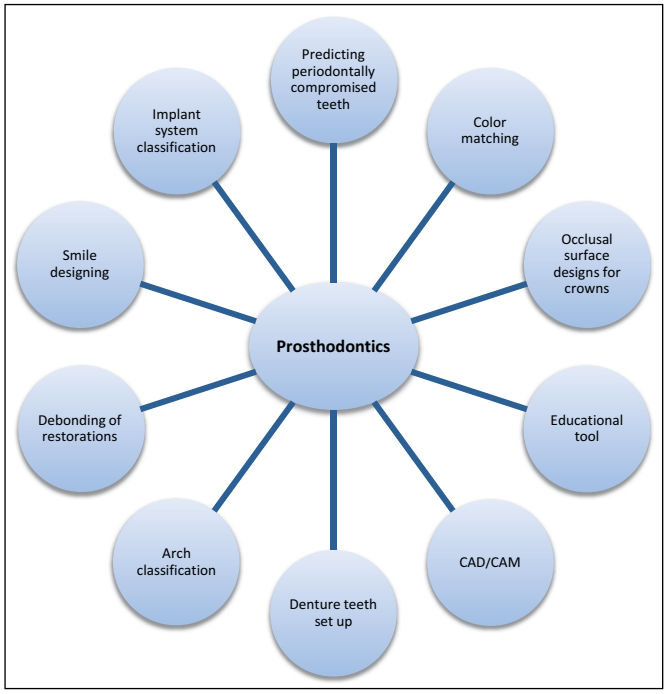

Fig. (4): Role of AI in prosthodontics.

and oral implant system classification, its presence in prosthodontics remains limited due to the complexity of diagnostics and personalized treatment protocols [18].

The introduction of artificial intelligence (AI) in prosthodontics has brought about a significant paradigm shift, manifesting itself in applications such as automated diagnostics, predictive measures, and classification or identification tools [18]. Digital dentistry now encompasses every facet of prosthodontics, with intraoral scanners replacing analogue impressions and AI playing a role in various stages of the workflow [19]. In fixed prosthodontics, AI helps with margin detection and supports the design and production of dental restorations using CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) technology. Machine learning in CAD/CAM software also plays a role in creating optimal crown designs [20]. Machine learning in CAD/CAM software contributes to optimal crown designs, and AI predicts the debonding of CAD/CAM restorations [21]. Convolutional neural networks (CNN) are utilized for dental arch classification in removable prosthodontics, and AI assists in setting up denture teeth, shade matching, and optimizing dental implant design [18].

Smile designing, a popular aspect of the digital workflow, benefits from AI-driven software that leverages 3D scanning and virtual fusion of data for treatment planning affecting the patient's smile [22]. Image datasets, including photographic and 3D scanning data, are employed in prosthodontic studies, utilizing AI for tasks such as recognizing mixture patterns, classifying specific features of teeth, predicting facial changes after denture placement, and decision models for removable partial denture designs [2]. Various AI architectures, including artificial neural networks (ANNs), support vector machines (SVM), case-based reasoning (CBR), and k-nearest neighbours (k-NN), are utilized in these studies, showcasing high accuracy, sensitivity, specificity, and evaluation criteria. The incorporation of AI in prosthodontics continues to advance across diverse applications, demonstrating its potential to transform traditional practices (**Fig. 4**) [23].

ORTHODONTICS

AI is essential for improving the precision and efficiency of orthodontic diagnoses and treatments. Utilizing 3D intraoral scanner imaging data and digital dental models enables quick and easy patient dental measurement and analysis [24]. AI aids in detecting anatomical landmarks on patient radiographs, assisting orthodontists in treatment planning by determining the patient's CVM stage using a lateral cephalogram [25]. Facial analysis, upper airway assessment, and hypertrophic adenoid detection are facilitated by AI, supporting orthodontic diagnosis and treatment planning. AI also assists in predicting tooth extraction plans and the potential for surgical intervention [26].

Digital technology has made it much easier to use 3D intraoral scanner images and digital dental models in clinical practice [27]. Some companies have successfully used these technologies for automated measurement and analysis, but automated facial

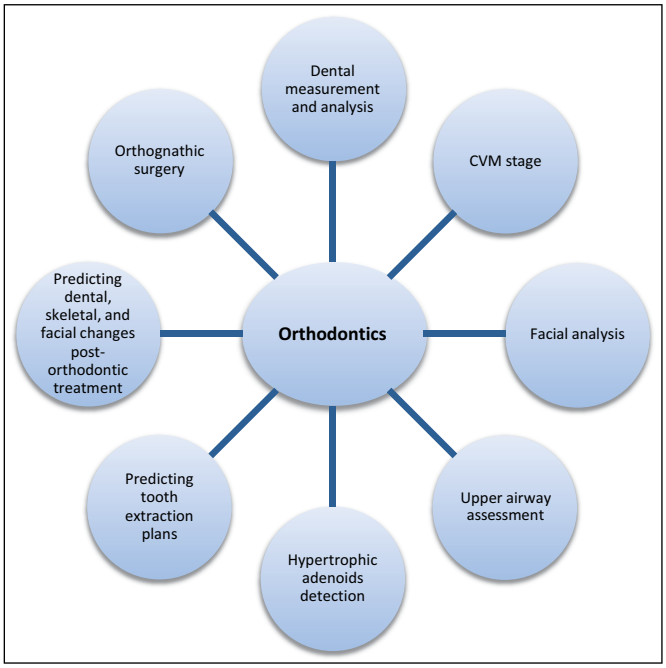

Fig. (5): Role of AI in orthodontics.

analysis is still in its early stages and needs more research to improve [28]. AI is expected to continue assisting orthodontists by providing diagnostic accuracy information for orthodontic treatments, particularly in predicting dental, skeletal, and facial changes post-orthodontic treatment [27]. AI has advanced in decision-making for orthognathic surgery using lateral cephalograms, posteroanterior cephalograms, and 3D facial images, but further improvement is still needed. AI cannot completely replace human experts at present but acts as a valuable tool for ensuring quality in clinical routines (**Fig. 5**) [28].

ENDODONTICS

AI exhibited high accuracy and precision in detecting, determining, and predicting diseases within the field of endodontics. Its potential contribution to enhancing diagnosis and treatment could lead to improved success rates in endodontic treatment outcomes [29]. It is crucial to carefully evaluate the reliability, relevance, and cost-efficiency of AI models before adopting them for regular use in clinical practice [30].

Nagendrababu *et al.* [30] discussed AI models tailored for use in endodontics, encompassing tasks like analyzing root canal anatomy, identifying and diagnosing periapical lesions and root fractures, and establishing the working length for strategic root canal treatment planning (**Fig. 6**). The authors emphasized that these AI models offer valuable support to clinicians, enhancing the accuracy of diagnosis and treatment planning and ultimately leading to improved treatment outcomes. The authors highlighted that these AI models provide significant support to clinicians by improving diagnostic accuracy and treatment planning, ultimately resulting in better patient outcomes [31]. Similarly, Umer *et al.* [32] presented AI models specifically crafted for endodontic diagnosis and treatment planning.

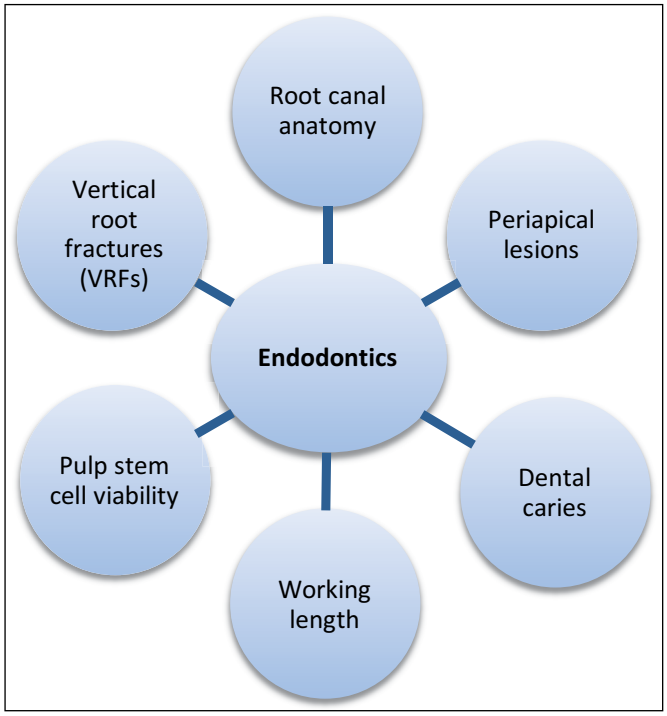

Fig. (6): Role of AI in endodontics.

The goal of endodontic treatment is to provide excellent care focused on maintaining the tooth's function and avoiding future complications [29, 33]. AI models have demonstrated a wide range of applications in endodontics, including analyzing root canal system anatomy, detecting periapical lesions and root fractures, measuring working length, predicting the viability of dental pulp stem cells, and forecasting the success of retreatment procedures [30]. Computer-aided diagnosis (CAD) is primarily aimed at developing artificial intelligence to evaluate periapical lesions using digital periapical radiographs, panoramic radiographs, and CBCT imaging. AI-based models prove highly effective in identifying non-specialists in clinical settings. AI technology plays a crucial role in diagnosing periapical pathologies, particularly in radiographic detection and CBCT images, demonstrating satisfactory results with high sensitivity and moderate specificity [10, 33]. The early identification of vertical root fractures (VRFs) is crucial for protecting supporting structures, and AI technologies demonstrate significant effectiveness in diagnosing VRFs using CBCT images compared to periapical radiographs [34].

In the realm of conservative dentistry, including endodontics, most studies focus on detecting lesions in X-ray images, such as dental caries [35-37], vertical root fractures, [38] and apical lesions [10]. Al Haidan *et al.* [39] proposed a mathematical model predicting tooth abrasion or erosion based on input data like teeth brushing frequency, dietary information, and tooth clenching habits. Additionally, Ekert *et al.* [10], Araki *et al.* [35], and Devito *et al.* [36] compared AI-generated results with human diagnoses.

ORAL AND MAXILLOFACIAL SURGERY

Artificial intelligence is primarily utilized in oral surgery through radiography, with successful clinical applications in image-guided cranial procedures such as oral implant surgery, tumour and foreign body removal, biopsy, and TMJ surgery [40]. Comparative studies in oral implant surgery show that AI-assisted techniques achieve significantly higher accuracy than manual freehand methods, even when performed by skilled surgeons. Interestingly, no substantial difference in accuracy is observed between experienced surgeons and trainees (**Fig. 7**). This method typically leads to reduced

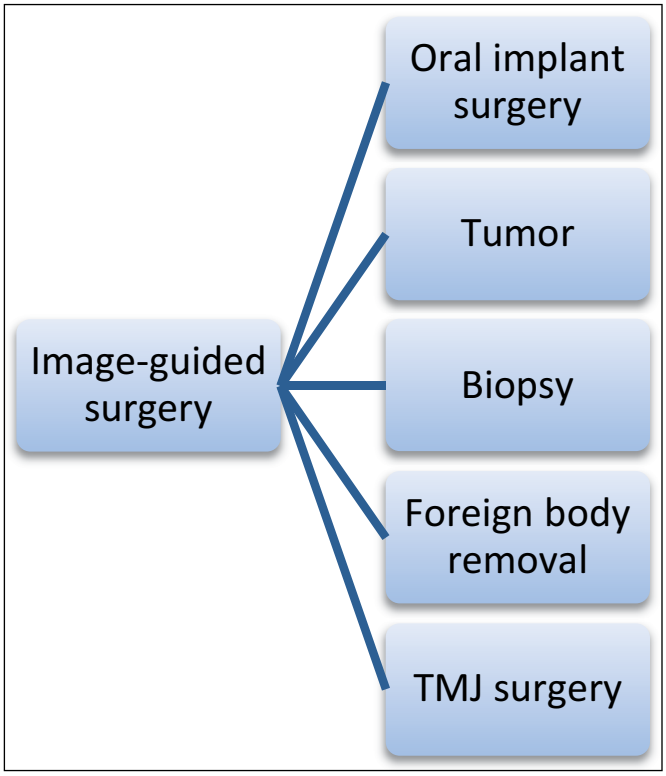

Fig. (7): Role of AI in image-guided surgeries.

operation times, safer handling near sensitive structures and greater accuracy during surgery [41]. Image guidance enables more precise surgical resections, which may help minimize the need for follow-up procedures [42].

In the realm of oral surgery, AI is useful in analyzing radiological images for detecting pathological changes such as cysts and bone tumours [43]. Moreover, AI holds promise in implantology, where AI-driven treatment planning in CAD/CAM implant dentistry could streamline virtual 3D treatment planning [44].

AI, when combined with human expertise, proves to be an essential tool in the daily practice of oral and maxillofacial surgery, much like advanced medical imaging technologies such as computed tomography (CT), cone-beam computed tomography (CBCT), and magnetic resonance imaging (MRI) [45]. AI algorithms are already aiding in diagnosis, therapeutic decision-making, preoperative planning, and outcome prediction and assessment. By utilizing advanced capabilities in classification, learning, prediction, and detection, AI enhances human skills while reducing errors and inaccuracies [46]. Multiple studies suggest a preference for AI in detecting head and neck tumours through various image data sources, including radiographic, microscopic, and ultrasonographic images [23, 40, 46, 47].

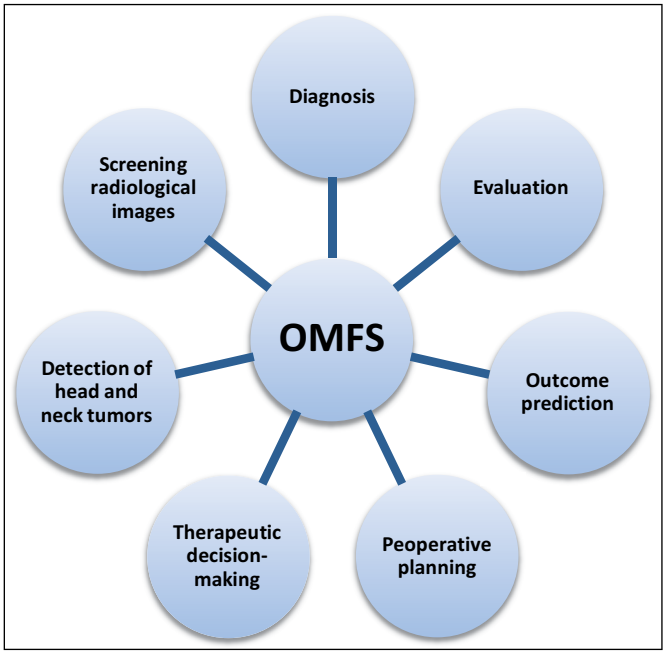

Fig. (8): Role of AI in Oral and maxillofacial surgery.

In oral and maxillofacial surgery, the majority of studies concentrate on tumour detection through image data, such as radiographic, microscopic, and ultrasonographic images [48-50]. Input data from medical records, medication consumption, and exosome spectra obtained from saliva are also utilized for detecting oral cancers, tumours, osteoporosis, cystic lesions, and maxillary sinusitis [49]. Most studies utilize artificial neural networks (ANNs), convolutional neural networks (CNNs), support vector machines (SVM), decision trees (DT), and random forests (RF), often comparing multiple architectures. Studies show accuracy, sensitivity, specificity, and AUC values ranging from 83.0% to 98.9%, 81.8% to 100.0%, 76.7% to 98.4%, and 0.88, respectively [23]. Finally, Tanaka *et al.* [48] reported the successful development of a computer-assisted diagnosis by an inexperienced clinician using an expert system (ExS) (**Fig. 8**).

RISKS AND IMPLICATIONS OF AI

Faulty AI decisions can be risky, like when a neural network wrongly labelled pneumonia patients with asthma as lower risk of death than others [51]. A dentist's mistake affects one patient, but a faulty algorithm could harm many. That's why AI decisions must be clear, reliable, and easy to understand and verify [52].

Dental AI research is still in its early stages, and more large clinical trials are needed. AI systems are not expected to affect dental practice soon. The success of AI in medicine shows great potential for its use in dentistry. A big goal for personalized dental care is to create AI systems that combine information from a

patient's medical and dental records, images, genetic data, and social, economic, and behavioural factors. AI could improve patient outcomes by helping dentists make better decisions and making dental practices more efficient. However, there isn't enough evidence to show how effective AI is with big data in dentistry [3].

AI is not expected to replace dentists because it might miss the human aspects important for patient care. Also, dental treatment depends a lot on patient factors, and skills like connecting with patients and guiding them to change their behaviour can't be replaced by AI. Dentists and AI systems can collaborate to improve patient care. However, more research in dental AI and ways to overcome challenges in using AI is important right now.

CONCLUSION

The studies show that AI is a useful tool for making dental care more efficient, saving time, and reducing costs for practitioners. AI helps dentists meet patient needs, provide quality treatment, improve oral health, and ensure accuracy.

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None.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Declared none.

AUTHORS' CONTRIBUTION

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Data Collection: Syed Ibn E Ali, Shaher Yar Khattak
Formal Analysis: Syeda Sana Faiq
Writing-Original draft: Syeda Kiran Faiq
Writing-Review & Editing: Syeda Kiran Faiq, Syed Muhammad Ali Shah

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