REVIEW ARTICLE OPEN ACCESS

Role Of Artificial Intelligence in The Dental Practice -A Narrative Review

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ABSTRACT

AI has helped dental care professionals in different aspects which directly influence the increase in quality of service provided by dentists and improving patient personalized experience. AI can detect carious lesions, and gingival health, interpret X-rays and CBCT, record impressions of flabby tissues, and predict patient experience with accuracy and precision of more than 85%. AI-based robots can mimic patient expressions and reactions in dental treatment helping dental students at the undergraduate level. AI-based robotics can play an important role in different dental procedures because of the lack of tiredness as compared to manual instrumentation. Machine learning can play a vital role in detecting cancer markers, histological features of oral tissues, and forensic odontology. AI software used to interpret CBCT, and X-rays is useful to dental surgeons since it can measure bone height and width and help clinicians plan treatment accordingly. Patient data records are easily accessible to researchers and clinicians when data is digitalized with the help of AI software. AI has its limitations mainly because of ethical considerations, In the future dentists should make comprehensive AI-based clinics that would record patient pre-treatment records, medical history, and dental history and make treatment plans accordingly.

Keywords: Artificial Intelligence, Artificial neural network, Dentistry, Machine learning.

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INTRODUCTION

Artificial intelligence (AI) is predominant in many aspects of human life. In today's world, AI algorithms are commonplace in technology[1]. The concept of AI was given by James McCarthy in 1956. Artificial neural networks (ANN) are inspired by the biological brain, and are used by healthcare workers, especially dentists, for precision and efficiency in diagnosis and treatment planning [2].

AI is rapidly making its presence felt in dental practices worldwide [3]. The integration of machine learning (ML) and AI has the potential to fundamentally alter how dentists diagnose and treat patients, ultimately leading to a new era of personalized and optimized oral healthcare.

A subfield of ML called deep learning (DL) is particularly good at interpreting high-dimensional data, like text and images[4]. Convoluted neural networks (CNNs) are a type of deep learning, that has been used for the detection of dental lesions (Fig 1)[5].

This comprehensive scoping review explores the

multi-faceted applications of AI across various dental specialties, examining its impact on diagnostic accuracy, treatment planning, and overall clinical decision-making. By exploring the advancements in AI-powered diagnostics, treatment planning and robotic surgery, tele dentistry, and patient education this review aims to shed light on the immense potential of AI in shaping the future of oral healthcare.

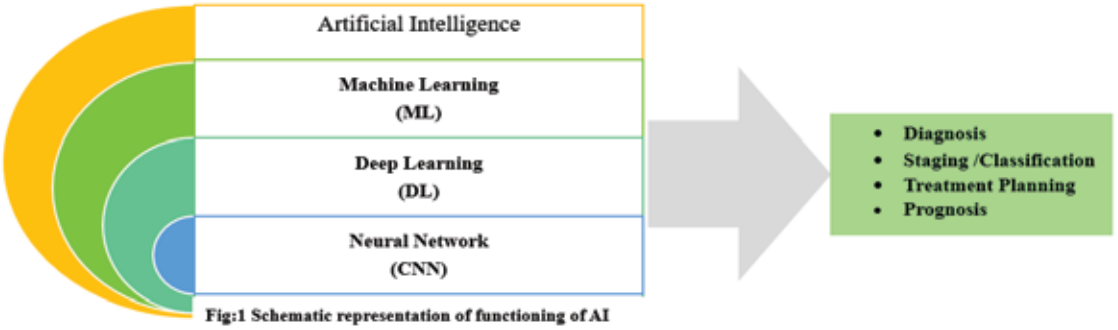


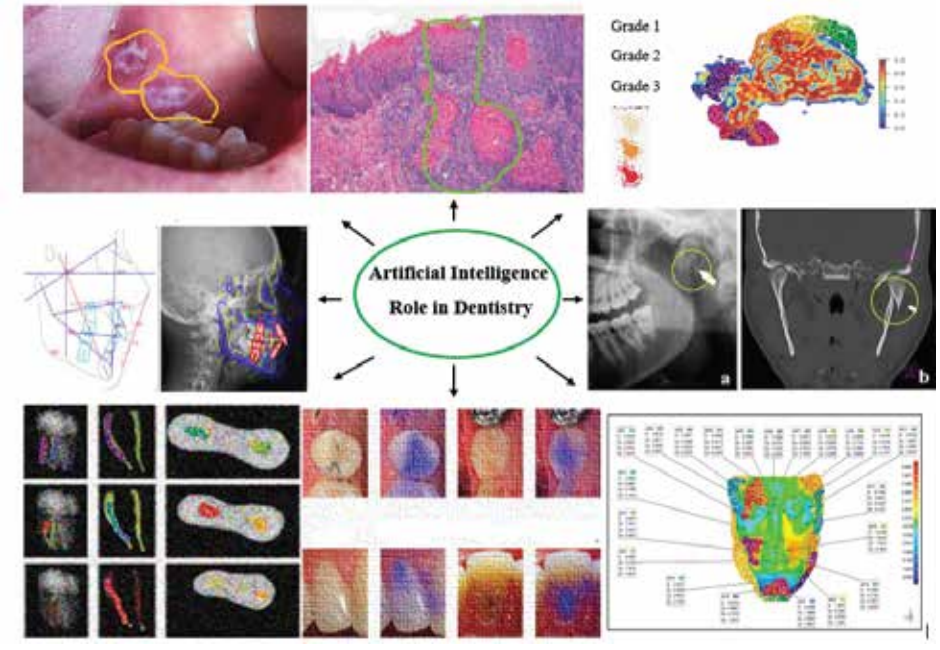
Fig:1 Schematic Representation of Functioning of AI

METHODS

A systematic search was conducted across prominent electronic databases like PubMed, Scopus, and Cochrane Library. The search strategy employed relevant keywords such as "artificial intelligence," "dentistry," "diagnosis," "treatment planning," "oral health," "machine learning," and "deep learning." Studies published in English within the last decade (2014-2024) were included for review. Additionally, the reference lists of retrieved articles were screened to identify further relevant publications.

EMERGING ROLE OF ARTIFICIAL INTELLIGENCE

The search yielded a substantial volume of research investigating the multifaceted applications of AI in various dental disciplines. The key findings highlight the transformative potential of AI in dentistry (Fig 2).



(Figures adapted From Saba et al 2023, Kühnisch et al 2022, Abdou DA 2024 & Google image)

Fig:2 Role of Artificial Intelligence in Diagnosis and Treatment Planning of Dental Disease

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i) Enhanced Diagnostic Accuracy

AI algorithms have emerged as powerful tools for achieving superior diagnostic accuracy in various dental pathologies. Studies have demonstrated the efficacy of AI detecting in common dental diseases such as dental caries. The DL algorithms can analyse intraoral and extraoral images with high accuracy, exceeding the performance of human examiners in identifying carious lesions [5,6]. CNN-based algorithms were able to correctly classify caries in 92.5% of the images when all the included images were considered. For caries-related cavitation detection, 93.3% of all tooth surfaces could be correctly classified5. AI-powered systems have been devised that use near-infrared light transillumination for caries detection[4].

Many endodontists use AI-automated 3D CBCT to diagnose periapical lesions because of its accuracy as compared to 2D radiographs [7]. Twenty CBCT volumes with 61 roots with and without periapical lesions were subjected to a deep learning system by Setzer et al. This deep learning system was able to 93% accuracy detecting lesion with a specificity of 88% [7]. AI-assisted machine learning model can predict the prognosis of endodontic treatment with 80% accuracy [8].

Similarly, ML has revolutionized the diagnostic accuracy of periodontal diseases. AI-powered imaging software has made the detection and classification of various stages of periodontal diseases, including gingivitis, periodontitis, and apical periodontitis, using panoramic radiographs and periapical images very easy and efficient. Deep CNN Model detected bone loss with an accuracy of 73% and classified the severity of bone loss with an accuracy of 59% from a dataset comprising 1724 intraoral periapical images of upper and lower anterior from 1610 adults [9]. Home-based AI tools for monitoring periodontal health in smartphones have effective results in individuals who have the non-surgical periodontal treatment and had human counseling, improving their overall periodontal health status [10]. In one of the studies, a multi-task learning CNN model screened gingivitis, dental calculus, and soft deposits from a sample of 625 patients with an accuracy of 87.11 %, 80.11%, and 78.57 % respectively [11]. Deep learning-assisted model detected periodontal bone loss with tooth numbering from 12179 panoramic dental radiographs with 75% validity while dental clinicians had 69 % validity [12]. The automatic diagnosis of periodontal bone loss and the staging of periodontitis, the innovative hybrid framework that combined deep learning architecture with the traditional CAD approach showed great accuracy and excellent reliability [13].

The staging of oral cancers has always relied on manual detection of dysplasia in biopsy samples. However, ongoing research in AI-based analysis of histological and histopathological images demonstrates promising results in identifying oral squamous cell carcinoma, a potentially life-threatening malignancy [14,15]. Using machine learning in combination with conductive polymer spray mass spectrometry (CPSI-MS), premalignant lesions and Oral squamous cell carcinoma may be individually and accurately identified in real time from normal physical conditions with an accuracy of 86.7% [16]. Machine learning has also been used for the detection of cancer markers such as AUNIP (Aurora Kinase A and Ninein Interacting Protein)[17].

AI algorithms are being explored for the detection of vertical root fractures, assessment of root canal morphology, and identification of landmarks for maxillofacial surgery [7,18,19]. In cases of third molar impaction, the use of AI-automated 3D CBCT improves our understanding of the anatomic relationship between the mandibular third molar, the inferior alveolar canal, and anatomic structures located in its surroundings [20,21]. Automatic detection and segmentation of mucosal thickness and mucosal retention cysts MRCs in the maxillary sinus from low-dose CBCT images, a novel three-step algorithm based on CNN and SVR (support vector regression) method produced favorable segmentation performance that was non-inferior to that obtained from full-dose CBCTs, as well as high diagnostic accuracy. In comparison to manual measurement, the suggested algorithm can automatically measure the volume of the detected MT/MRCs and the ratio of MT/MRCs to the sinus and achieve high measurement accuracy (Table 1)[22].

ii) Revolutionizing Treatment Planning

AI is transforming the treatment planning process by providing valuable insights to dentists. Software based on DL algorithms can analyze orthodontic images with high accuracy, assisting orthodontists in treatment planning and potentially reducing chair time [23,24] AI can also predict the need for extraction and can even predict patient experience during treatment (pain, discomfort, and effect on quality of life). AI-based automated 3D CBCT can analyze palatal thickness and segmentation with high accuracy assisting orthodontists in determining the available sites and designing surgical guides for palatal orthodontic mini-implants [25].

During endodontic AI algorithms have been used to accurately diagnose peri-apical lesions and predict endodontic treatment outcomes [7,8]. While designing prostheses AI-powered software can help in designing removable dentures and analyzing the dental arches with exceptional accuracy, aiding prosthodontists in advanced treatment planning [26,27].

A novel protocol has been designed that uses

augmented reality (AR) and AI to accurately plan dental implants in three dimensions (3D). The system showed promising results in cases of static-guided implant surgery in partially edentulous patients and proved to be efficacious and time-efficient. Using real-world 3D modeling, the physician can plan the implants without the need for radiological-guided surgery software [28]. Deep CNN can detect bone thickness and height, missing teeth, sinuses, fossa, and canals more accurately as compared to manual measurement which would aid dental clinicians in dental implant treatment planning (Table 1)[29].

iii) AI-powered Robotics for Improved Precision

Robotics integrated with AI offers a new frontier in dentistry. The advantage of having robotics in dentistry is because of its accuracy and precision in doing work without the factor of tiredness and ease in instrumentation when compared with the freehand technique (Table 1).

During oral and maxillofacial surgical procedures AI-powered robots provide improved dexterity and precision [30]. Similarly, Endo Micro Robots were developed to improve the accuracy and efficacy of endodontic treatment and to deliver superior root canal therapy. With the help of state-of-the-art computer-assisted endodontic technology, the robot completed autonomous root canal drilling, cleaning, shaping, and three-dimensional filling through online supervision and an intelligent system [30]. The robotic dental drill, which is one of the new developments, immobilizes the jaw of the patient and consists of pins that penetrate the gums and locate the position of bone which is then transmitted wirelessly to a PC and arranged with CT scan data which gives guidance about the drill, also assists in dental Implant placement [30].

For teaching undergraduate dental students AI robots that mimic patient responses, including involuntary movements and discomforts, can provide a realistic training environment for dental students (Table 1)[31].

iv) Applications of AI in Forensic Dentistry

While the focus of this review has primarily been on AI applications in clinical dentistry, it is important to acknowledge the growing role of AI in forensic odontology – a specialized field that utilizes dental evidence for human identification[32]. Forensic odontology focuses on age estimation[33], bitemark analysis, face reconstruction, sex determination and database management[33].

Traditionally, bite mark analysis relies on the expertise of trained forensic odontologists to compare bite marks on objects with dental records of suspects. AI algorithms are being developed to analyze digital images of bite marks and potentially identify unique dental characteristics that can aid in suspect identification [34]. While still under development, AI has the potential to streamline the bitemark analysis process and increase objectivity.

Features like tooth eruption patterns, root development and wear patterns can provide valuable clues about an individual's age and sex. AI algorithms are being trained on large datasets and associated age and sex information. These algorithms can then analyze dental x-rays or photographs from unidentified remains and estimate the age and sex of the deceased with greater accuracy than traditional methods [35].

AI in conjunction with 3-D printing technologies is also under development to create more accurate facial reconstructions from dental remains. Software to manage large databases based on specific dental characteristics can significantly reduce the time required to identify potential matches for unknown remains (Table 1)[36].

v) AI in Promoting Oral Health Awareness

AI-driven mobile apps can provide patients with customized oral hygiene education based on their individual needs and risk factors. These apps can offer interactive coaching, motivational reminders and personalized feedback to encourage healthy oral habits and disease prevention [37,38]. Oral self-care apps developed by periodontologists evaluate the behavioral patterns of individuals, make interventional designs based on behavioral models, and assess their effectiveness. The dental calendar applications were developed by dentists, computer scientists, and service scientists to remind patients of their scheduled dental appointments and help them take pictures of their oral cavity (Table 1) [39].

Table 1: Summary of Enhanced Diagnostic Accuracy and Treatment Planning Based on AI Tools

Disease/Application	AI Model Used	Diagnostic Accuracy & Treatment Accuracy
1.Endodontics		
Early Childhood Caries	AI Caries (App)	Early intervention
Caries Detection	Deep Learning (DL), CNN-based algorithms	92.5% classification, 93.3% caries cavitation detection Higher than traditional methods [4,5,6]
Periapical Lesions	Deep Learning, AI-automated 3D CBCT	93%diagnostic and 80% prognosis prediction[7,8]
Root Canal Morphology	AI Algorithms	High
Vertical Root Fractures	AI Algorithms	High
2.Periodontology		
Gingivitis, Dental Calculus	Multi-task Learning CNN	Gingivitis: 87.11%, Calculus: 80.11%, Soft deposits: 78.57%
Periodontal Disease	Deep CNN	73% bone loss detection, 59% severity classification
Bone Loss (Periodontitis)	Deep CNN, Hybrid Framework (CAD + DL)	75% (AI), 69% (human examiners)
Gingivitis	Multi-task Learning CNN	87.11%
Periodontal Health Monitoring	AI in Smartphone-based Tools	Effective with non-surgical treatment [9-13]
3.Oral and maxillofacial surgery		
Oral Cancer (OSCC)	ML with CPSI-MS	86.7%
Third Molar Impaction	AI-automated 3D CBCT	High
Dental Implants	Deep CNN, AI-assisted AR for 3D planning	High Improved precision
Maxillofacial Surgery	AI Robots	High precision and efficacy [14-17]
4. Prosthodontics		
Removable Dentures Design	AI-powered software	High
Dental Arch Analysis	AI-powered software	High
5. Forensic Dentistry		
Age and Sex Estimation	AI with large datasets, ML Algorithms	Greater accuracy than traditional methods[32-35]
Bite Mark Analysis and Face Reconstruction	AI Algorithms 3D printing	Under development
6. Oral Health Awareness		
Oral Hygiene Monitoring	AI-driven mobile apps	Personalized education and intervention
Dental Appointment Management	AI-assisted calendar apps	Improved appointment adherence [37-39]

vi) Tele-dentistry Empowered by AI

Tele-dentistry is an emerging field that provides door-to-door dental services mainly through telecommunication and mobile dental care vans. AI algorithms can analyze images captured during teledentistry consultations, allowing dentists to make preliminary diagnoses of dental problems and recommend appropriate treatment options [40]. This can improve access to care for patients in remote areas or those with limited mobility.

Recent advancements in AI technology, such as CNN offer advantages over traditional methods. These new algorithms require less computational power while achieving even higher accuracy in caries detection during remote consultations [41]. AI Caries, a teledentistry app helps parents to take their children's oral cavity pictures to diagnose early childhood caries that would help the dentist to start treatment early in the reversible stage (Fig:3)[42].

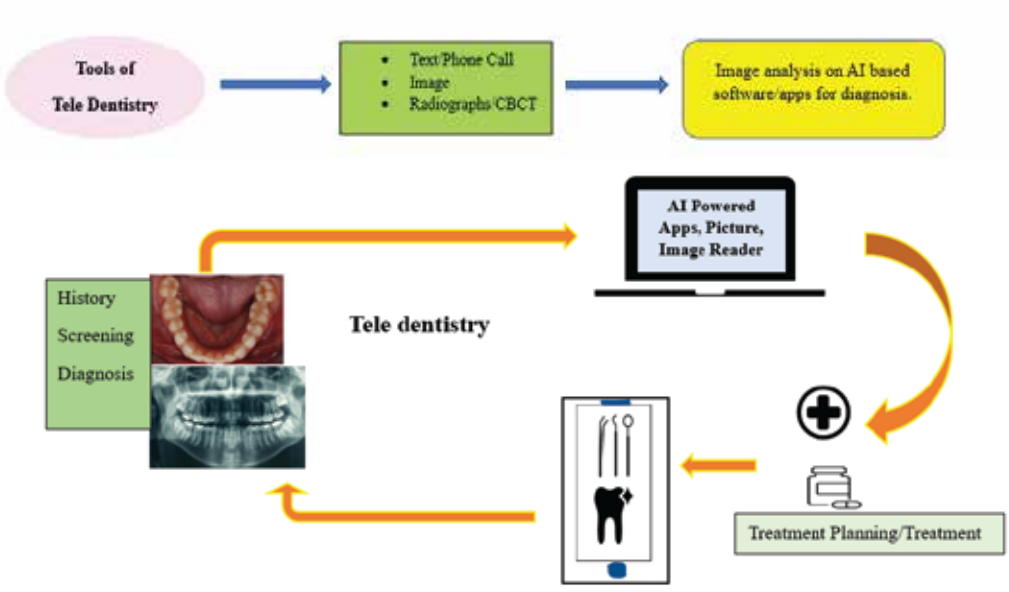

Fig:3 Schematic presentation of AI-based Tele Dentistry

LIMITATIONS OF ARTIFICIAL INTELLIGENCE

Although Artificial intelligence has made the decision-making of healthcare workers more accurate and precise, it also has its limitations. AI needs expert supervision to correct the software in case of error. DL software needs high accuracy in image acquisition to correctly interpret it. It is highly dependent on the comprehensiveness of the algorithm which can cause potential bias and may misdiagnose the disease which may have deleterious effects on people's health and lives [43]. Lack of technical resources and training in using AI at undergraduate and postgraduate levels are barriers [44]. Another issue with using AI is protecting medical data records privacy of patients as healthcare workers should be equipped with knowledge about AI's regulatory and ethical considerations, such as patient privacy, biases, and accountability. However, there are no regulatory body or laws governing the use of data collected from healthcare systems or used in AI algorithms[45]. When efforts are made to apply normative ethical principles to AI or consciousness uploads (the transformation of the human brain into inorganic computers that can mimic the original brain personhood), ethical issues arise [46].

FUTURE PERSPECTIVE

Artificial intelligence will play a major role in dentistry because of its precision and accuracy helping researchers in understanding multifactorial diseases in a much-improved way because of machine learning software which is currently not fully understood. In the future clinics may establish AI Comprehensive health care which will evaluate the patient's pretreatment record, patient complete history and make a diagnosis according to clinician reference point. AI-assisted CAD/CAM technology may help the dentist to record impressions with more accuracy and precision[45]. AI might eventually be able to read a CBCT scan, which could notify the doctor of any potential apical pathosis areas as well as any other odontogenic or non-odontogenic lesions that might be visible. This can be very beneficial, especially in places with limited access to oral radiologists and adequate radiology training 8. There are many ethical concerns when it comes to the potential creation of thinking machines. As of right now, we don't have any appropriate guidelines or recommendations for handling these kinds of problems that could arise during research. These concerns concern the moral standing of the machines themselves as well as making sure that they do not damage people or other morally significant beings. When artificial intelligence (AI) is developed, care must be taken to ensure that the technology is applied for good rather than evil [46].

CONCLUSION

This comprehensive review has unveiled the transformative potential of AI in dentistry. From revolutionizing diagnostic accuracy to optimizing treatment planning and empowering patients with personalized oral health tools, AI is poised to usher in a new era of personalized and efficient oral healthcare. The advancements in AI-powered diagnostics offer the exciting possibility of earlier and more accurate detection of dental diseases, leading to improved treatment outcomes and potentially reducing the burden of oral health problems on individuals and healthcare systems. While challenges like limited awareness, algorithmic bias, and data security concerns need to be addressed. As AI continues to evolve and integrate seamlessly into dental prac-

tice, the future of oral healthcare appears bright, promising a future of personalized care, improved treatment outcomes, and empowered patients. This review serves as a steppingstone for further exploration and implementation of AI in dentistry, paving the way for a healthier and more informed future for all.

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
ANN	Artificial neural network
CNNs	Convoluted neural networks
ML	Machine learning
DL	Deep Learning
CAD	Computer-aided diagnosis
CPSI-MS	Conductive polymer spray mass spectrometry
AUNIP	Aurora Kinase A and Ninein Interacting Protein
MT	Mucosal thickness
MRCs	Mucosal retention cysts
SVR	Support vector regression
AR	Augmented Reality
PC	Personalized Computer
CT Scan	Computed tomography scan
CAD/CAM	Computer-aided design/ computer-aided manufacturing
CBCT	Cone beam computed tomography

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CONFLICT OF INTEREST
The authors declared no conflict of interest.

AUTHORS CONTRIBUTION
MAK designed and wrote the manuscript, **ASA** designed the concept, drafted, and critically reviewed the article, and is the corresponding author, **MA** finalized and proofread the article.

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