



ARTIFICIAL INTELLIGENCE IN DENTISTRY

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ABSTRACT

Artificial intelligence (AI) has a transformative role in the field of dentistry. As technology continues to evolve, AI applications are increasingly integrated into various aspects of dental practice, ranging from diagnosis and treatment planning to patient management. This review highlights key AI-driven innovations such as image analysis for radiographic interpretation, predictive analytics for disease risk assessment, and intelligent systems aiding in treatment customization. The potential impact of AI on enhancing precision, efficiency, and overall quality of dental care is discussed. This article aims to provide a concise overview of the current landscape of AI in dentistry, emphasizing its potential to reshape and optimize dental healthcare practices.

KEYWORDS :**INTRODUCTION**

Humanity, recognizing the importance of intellectual abilities to its existence and sense of self, has adopted the scientific name *Homo sapiens*, meaning "man the wise." The human brain is a unique structure made up of networks of connected neurons that send information throughout the body. Since ancient times, scientists and researchers have been curious about the human brain's unexplained nature.¹

What once appeared like science fiction is now a reality in the healthcare industry. A rapidly emerging technology called artificial intelligence (AI) enables machines to carry out tasks that are only capable of being completed by humans. The field of healthcare is booming as traditional dentistry develops and becomes more replaced by digital dentistry. It could transform healthcare and greatly increase the accuracy of diagnoses.²

Over the past ten years, technology has also completely changed the medical and dental fields, including online appointment scheduling, online check-ins at medical facilities, the digitization of medical records, reminder calls for follow-up appointments and child and pregnant woman immunization dates, drug dosage algorithms, adverse effect warnings when prescribing multidrug combinations, and much more.¹

Although AI research began in 1943, John McCarthy coined the phrase "artificial intelligence" in 1956 during a meeting in Dartmouth.³ As an illustration, Amazon Alexa, a virtual assistant, was introduced and has the capacity to identify and comprehend various dialects and voices. With the ability to add "skills," it began assisting people in doing their everyday responsibilities. Deep learning was used in the programming of AlphaGo (Google DeepMind), which defeated multiple Go champions. The Apple A13 Bionic chip, found in the iPhone (Apple), was designed to manage the software requirements of machine learning procedures, including the quick rectification of dimly lit images. Another AI product that was unveiled included IBM Watson (IBM), which has cognitive computing capabilities. This self-learning system was created

to handle issues in a variety of professional domains without the need for human intervention.⁴

Artificial intelligence (AI) is defined as 'a field of science and engineering concerned with the computational comprehension of what's commonly called intelligent behavior, and with the creation of artifacts that show such behavior'. It's basically a zone of computer science that emphasizes the production of intelligent machines that work and respond like humans. The human brain is a matchless structure composed of networks of interlinked neurons which transmit signals all through the body. Since the beginning of time, scientists and researchers have been intrigued by the unique characteristics of the human brain.^{5,6}

History

Alan Turing, a British mathematician, was a key visionary and theorist who demonstrated in 1936 that a universal calculator, or Turing machine, was feasible. Turing's main realization is that any problem that can be stated and addressed by an algorithm may be solved by such a machine. Newell and Simon's 1955 creation of "The Logic Theorist" is regarded as the first artificial intelligence software that signifies the advent of contemporary AI. In 1965, John McCarthy first used the term "artificial intelligence."⁶

The field of artificial intelligence (AI) expanded rapidly between 1957 and 1974 due to advancements in computer power, accessibility, and AI algorithms. ELIZA, a computer program that could decipher spoken language and use text to solve problems, is one example. Due to a lack of useful applications and a decrease in research funding in the middle of the 1970s and late 1980s, there were two "AI Winters" after the initial wave of advancement. Though there were not many advancements between the two eras, AI did make a breakthrough. It evolved via two avenues in the 1980s: expert systems and machine learning (ML).⁷

Concept Of AI

Two types of AI are available for general health care delivery: physical and virtual. Automated robotic arms or complex

robots are examples of physical applications. Clinical decision-making is supported by virtual components, which are algorithms of the software type.⁸

1. Artificial Neural Networks

The structure of the biological or human brain served as the basis for the development of artificial neural networks (ANNs), which are capable of managing data, learning, and pattern recognition. The primary benefit of artificial neural networks (ANNs) is their ability to handle issues that are too difficult for traditional methods or that lack an algorithmic answer. They are used in many different areas of medicine, including image analysis, medication development, biomedical analogies, and diagnostics or diagnostic systems.⁹

2. Machine Learning

ML is a branch of AI that combines concepts from statistics, engineering, neurobiology, and psychology. Without prior knowledge or manually created rules, systems are able to learn how to carry out intelligent acts. Rather, the algorithms work independently of humans to find patterns in samples drawn from a huge dataset. To do this, set a target and maximize the system's adjustable functions to achieve it. A machine learning algorithm learns during this procedure, called training, by being exposed to random examples and gradually adjusting the "tunables" in order to get the right answer. Consequently, the system finds patterns that it may use to analyze fresh photos.

This method is similar to an adult showing a child multiple cat picture. Eventually, the child picks up on the patterns needed to distinguish between a real cat and one in a new image.¹⁰ Datasets are divided into training and test datasets in machine learning research; the former is used to train the model and the latter is used to assess its performance on unobserved data. In dentistry, the idea of using training datasets to assess and enhance performance is not new. A fuzzy logic algorithm for pattern recognition and signal processing was utilized to create ultrasonic scalers that can differentiate between cementum and subgingival calculus using a learning dataset. Different sets of datasets have been used to assess how well electronic caries performs.

Patient histories, periodontal and restorative charts, lab and diagnostic test results, radiographs, and extraoral and intraoral images are just a few of the many diverse types of datasets that are used in dentistry. These datasets can be used as inputs into machine learning models to produce results like diagnosis, picture interpretation, suggested treatments, and predictions of future diseases. The kind and caliber of the data that an ML system is trained to learn from greatly influences the precision of analytics and predictive modeling produced by ML. For example, radiographs with multiple overlaps or cone cuts within an area of interest or incomplete, missing, or inaccurate information in an electronic health record (EHR) will produce unreliable results.¹¹

3. Deep Learning

The field of deep learning (DL), a branch of machine learning (ML), has seen a rise in interest recently due to its potential to enable increasingly sophisticated and autonomous machine intelligence mimicking. Multiple layers of non-linear units are used by DL to analyze and extract meaningful information from massive amounts of data. The most advanced prediction results are then generated using the knowledge that has been extracted. The neural network architectures utilized in deep learning offer the capacity to carry out precise and automated identification in the medical field. According to the study, DL has enormous potential to bring truly transformative applications to the field of dentistry.¹²

Application Of AI In Dentistry

1. AI in Community Health Sector

"Denta Mitra" is a smartphone app that tracks oral health

using artificial intelligence (AI). Through the app's AI-based scanner, users can keep an eye on their dental health. It also periodically reminds users to practice good oral hygiene, connects them with a nearby dentist, allows them to schedule appointments, and allows them to virtually consult with dentists. AI is also capable of demonstrating its prowess in any pandemic or crisis. In light of the current global health crisis, the medical community is searching for innovative technologies to track and manage the COVID-19 pandemic. It is helpful in real-time infection control, easily monitors the virus's spread, and identifies patients who are at high risk.^{6,13}

While artificial intelligence has been successfully applied to academic research and inference jobs within the wider economic system, its application to the fundamental public health roles of population protection and promotion has been far less successful. Thus far, vision statements for the future of public health have focused more on the technical potential of AI than on the potential influence of social variables on the results that could be obtained through its use. The performance and efficacy of procedures throughout a broader public health system can be improved using artificial intelligence.¹

2. AI In Patient Management

Virtual dental assistants powered by artificial intelligence are capable of carrying out a variety of tasks in dental clinics with more accuracy, fewer mistakes, and less labor than human assistants. It can help with clinical diagnosis or treatment planning, scheduling appointments, insurance management, and paperwork management. Informing the dentist about a patient's medical history and lifestyle choices, such as smoking and alcoholism, is highly helpful. Does the patient have the option of using emergency teleassistance in dental emergencies, particularly in cases where the dentist is not available? As a result, it is possible to build a comprehensive virtual database about the patient, which will help to ensure that they receive the best possible care.¹⁴

3. AI In Endodontics

Artificial intelligence is becoming increasingly significant in endodontics, particularly in treatment planning and disease diagnosis. AI-based networks can detect even the smallest changes, down to a single pixel, that might go unnoticed by the human eye.

Periapical Lesions detection

Determining a diagnosis and treatment plan for teeth with periapical lesions and related symptoms can be complex for clinicians. Convolutional neural networks (CNNs) have shown promise in addressing this challenge. In a study using CBCT images, a CNN detected 142 out of 153 periapical lesions with a high accuracy of 92.8%, closely matching the diagnostic performance of an experienced dental practitioner. CNNs, a specialized type of artificial neural network, are particularly effective in image analysis, as they use convolutional operations to extract intricate features from images, making them invaluable for identifying subtle abnormalities in medical and dental imaging.³

Root Fractures Detection

According to Fukuda et al.¹⁵, CNNs may serve as a valuable tool for detecting vertical root fractures (VRFs) on panoramic radiographs. Another study utilized periapical radiographs and CBCT images to develop a neural network capable of identifying VRFs in both intact and root-filled teeth. The findings revealed that CBCT images outperformed 2D radiographs in detecting root fractures, offering superior specificity, accuracy, and sensitivity. Similarly, Shah et al.¹⁶ generated fractures in second molars and analyzed them using wavelets on synthetic data. These mathematical operations, used in machine learning, help recover weak signals from noisy environments. Despite the small sample

size, steerable wavelets successfully identified fractures in high-resolution CBCT images.

Determination of Working Length

According to an author the accuracy of working length assessment can be improved by employing ANNs as a second opinion to locate the radiographic apical foramen. In a different research, author used a model of a human cadaver to replicate a clinical setting and examined the accuracy of WL assessment by an artificial neural network. When comparing an artificial neural network with the real measurement after extraction, they discovered no change in the root length measurements. Additionally, they noted that when utilizing periapical radiographs to determine minor anatomic constriction, the ANN (96%) outperformed an endodontist (76%) by a wide margin. As a result, an ANN may be thought of as an accurate approach for determining WL.¹⁷

4. AI In Periodontics

In periodontics, artificial intelligence has been employed to diagnose periodontitis and categorize potential types of periodontal disease. One study utilized convolutional neural networks (CNNs) to detect periodontal bone loss (PBL) on panoramic radiographs. Another study assessed the effectiveness and accuracy of a proposed CNN algorithm for automatically identifying periodontally compromised teeth. Additionally, the researchers claimed that their CNN algorithm, developed using systemic health-related data, could evaluate periodontal conditions with significant potential.⁷

5. AI In Orthodontics

Artificial intelligence is becoming increasingly prevalent in orthodontics, with commonly used algorithms including artificial neural networks (ANNs), convolutional neural networks (CNNs), support vector machines, and regression algorithms. Studies have employed ANNs to predict whether extractions are necessary in treatment planning, considering anchorage patterns. The accuracy of these networks was 94.0% for predicting the need for extractions and 92.8% for forecasting the use of maximum anchorage, demonstrating the potential of ANNs to enhance precision in orthodontic treatment planning.

Researchers have also developed ANN-based systems to predict treatment outcomes for Class II and Class III patients. These systems can analyze craniofacial growth, identify auxological anomalies, and pinpoint reactive sites for therapeutic interventions to address malocclusion. Furthermore, ANNs have shown promise in determining growth and development periods. Using cephalometric and hand-wrist radiographs from patients aged 8 to 17 years, ANNs analyzed cervical vertebrae to determine growth stages and gender, achieving an accuracy of 94.27%. These findings highlight the utility of ANNs in enhancing orthodontic diagnostics and treatment planning.³

6. AI In Pediatric Dentistry

AI has the potential to transform behavioral pediatric practice, paving the way for innovative advancements in the field. In restorative dentistry, AI-enabled computer-aided design and manufacturing systems are set to become a significant asset, offering improved efficiency and aesthetic outcomes in pediatric restorations. During the mixed dentition period, artificial neural networks (ANNs) can accurately predict the sizes of unerupted premolars and canines. Additionally, AI-driven pain control devices provide a smarter, injection-free alternative for pediatric dental procedures. Tools such as 4D goggles, animated movies, and virtual reality-based games serve as effective behavior modification aids for young patients, enhancing their overall experience.⁶

7. AI In Radiology

Convolutional neural networks (CNNs) have demonstrated

remarkable potential in detecting and identifying anatomical structures in dentistry. For instance, some CNN models have been trained to recognize and label teeth from periapical radiographs, achieving a precision rate of 95.8–99.45%, which is comparable to clinical experts who achieve a precision rate of 99.98%. CNNs have also been applied to the detection and diagnosis of dental caries. In a study involving 3,000 periapical radiographs of posterior teeth, a deep CNN algorithm identified carious lesions with an accuracy of 75.5–93.3% and sensitivity ranging from 74.5–97.1%. This performance significantly surpasses the sensitivity of clinicians diagnosing caries from radiographs, which ranges from 19% to 94%. The high sensitivity and rapid processing capabilities of deep CNNs position them as highly effective tools for enhancing the accuracy and efficiency of dental caries diagnosis.¹⁰

Abdalla aslam et al developed a machine-learning algorithm or automatic detection and classification of dental restorations on panoramic radiographs as an initial step to enable the detection of dental and maxillofacial abnormalities, such as caries, periodontal diseases, and other bone lesions.¹⁸

Bilgiri et al concluded that a deep CNN was proposed for tooth detection and numbering. The model demonstrated high precision and sensitivity, highlighting the utility of AI in tooth identification and numbering. This AI system can be used to support clinicians in detecting and numbering teeth on panoramic radiographs and may eventually replace evaluation by human observers and improve performance in the future.¹⁹

8. AI In Oral Pathology

In dental practice, early diagnosis and detection of oral lesions are essential because they greatly improve prognosis. Accurate diagnosis and appropriate treatment are crucial because some oral lesions may be cancerous or precancerous. CNN has shown to be an effective diagnostic tool for lesions associated with head and neck cancer. It holds great promise for the identification of tumors in tissue samples or radiographs. In addition to its potential applications in treatment planning, the Artificial Neural Network (ANN) has the potential to identify and classify patients who are precancerous or at high risk of oral cancer.²

9. AI In Prosthodontics

Rapid, an advanced assistant designed for denture applications, integrates anthropological calculations, facial measurements, ethnicity, and patient preferences to deliver the most aesthetically pleasing prosthesis. Efficiently integrate databases, data systems, and computer-aided design using logic-based representations as a unifying framework. Advancements in neural networks have enabled laboratories to leverage artificial intelligence to independently design innovative dental restorations, ensuring exceptional standards of fit, function, and aesthetics. This is useful for dentistry, but it also greatly affects oral-facial and craniofacial prostheses.²⁰

Computer-aided design/computer-aided manufacturing (CAD/CAM) is gaining acceptance in prosthetic dentistry. The integration of AI with CAD/CAM enhances its effectiveness in chair-side applications. ANNs based on panoramic radiographs, periapical radiographs, micro-computed tomography images, and 3-dimensional scanning of dental surfaces have been explored for tooth segmentation and classification. With >90% accuracy, such automatic classification is instrumental for bridging the gap between data acquisition and manufacturing n CAD/CAM technology.⁸

10. AI In Forensic Odontology

AI is a scientific development that has been extensively

applied in forensic medicine. It has shown to be quite effective in determining the biological age and gender of the healthy and ill. Additionally, it is employed for analyzing bite marks and predicting mandibular morphology. One of the most creative uses of AI is in the field of "bioprinting," which allows living tissue and even organs to be created in successive thin layers of cells and may one day be used to reconstruct oral hard and soft tissues that have been lost due to pathological or unintentional causes.¹⁷

Challenges

Managing and sharing clinical data pose significant challenges to implementing AI systems in healthcare. Patient data are vital for the initial training of AI algorithms and their ongoing training, validation, and improvement. Additionally, AI development requires data sharing across institutions and, in some cases, across national borders. To ensure seamless integration of AI into clinical workflows, systems must be designed to protect patient confidentiality and privacy. AI systems also bring safety concerns, necessitating robust mechanisms to maintain algorithm quality. Transparency in AI algorithms and their data is a key issue, as the accuracy of predictions relies heavily on the quality of dataset annotations and labeling. Poorly labeled or inconsistent clinic-generated datasets can compromise AI performance, limiting its efficacy and reliability.¹⁰

CONCLUSION

AI has the potential to revolutionize oral healthcare by addressing the shortcomings often criticized in traditional dental care. It has already enhanced clinical diagnosis and decision-making across various dental tasks. However, its ultimate impact on dental practice, including advancements in disease detection and treatment, will depend on how effectively AI applications evolve alongside a healthcare system facing significant financial challenges while adapting to rapid progress in molecular and genomic science.

In conclusion, artificial intelligence stands at the forefront of technological innovation, offering unprecedented possibilities for enhancing efficiency, solving complex problems, and revolutionizing various industries. As we navigate this era of AI, it is crucial to prioritize ethical considerations, ensuring responsible development and deployment. The future holds exciting prospects, but success hinges on a thoughtful and collaborative approach that balances technological advancement with ethical responsibility, ensuring that AI contributes positively to society's well-being and progress.

REFERENCES

1. Tariq S, Gupta N, Gupta P, Sharma A. Artificial Intelligence in Public Health Dentistry. *Int Health Res J*. 2021;5(9):RV1-RV5.
2. Mitra R, Tarnach G. Artificial intelligence - A boon for dentistry. *International Dental Journal of Student's Research* 2022;10(2):37-42.
3. Ossowska, A.; Kusiak, A.; S wietlik, D. Artificial Intelligence in Dentistry—Narrative Review. *Int. J. Environ. Res. Public Health* 2022, 19, 3449.
4. Chen YW, Stanley K, Att W. Artificial intelligence in dentistry: current applications and future perspectives. *Quintessence Int*. 2020;51(3):248-257. doi: 10.3290/j.qi.a43952. Erratum in: *Quintessence Int*. 2020;51(5):430. PMID: 32020135.
5. Artificial Intelligence; Mutating Dentistry. *IJRAR*; 6(1), February (2019).
6. Rashmi J Kurup., et al. "Dentistry and Artificial Intelligence". *Acta Scientifica Dental Sciences* 4.10 (2020): 26-32.
7. Ding H, Wu J, Zhao W, Matinlinna JP Burrow MF and Tsoi JKH (2023) Artificial intelligence in dentistry—A review. *Front. Dent. Med* 4:1085251.
8. Shan T, Tay FR, Gu L. Application of Artificial Intelligence in Dentistry. *J Dent Res*. 2021 Mar;100(3):232-244. doi: 10.1177/0022034520969115. Epub 2020 Oct 29. PMID: 33118431.
9. Bindushree V, Sameen RJ, Vasudevan V, Shrihari TG, Devaraju D, Mathew NS. Artificial intelligence: In modern dentistry. *J Dent Res Rev* 2020;7:27-31.
10. Nguyen TT, Larrivé N, Lee A, Bilaniuk O, Durand R. Use of Artificial Intelligence in Dentistry: Current Clinical Trends and Research Advances. *J Can Dent Assoc*. 2021 May;87:17. PMID: 34343070.
11. Pethani F. Promises and perils of artificial intelligence in dentistry. *Aust Dent J*. 2021 Jun;66(2):124-135. doi: 10.1111/adj.12812. Epub 2021 Jan 17. PMID: 33340123.
12. Fatima, A.; Shafi, I.; Afzal, H.; Diez, I.D.L.T.; Lourdes, D.R.-S.M.; Breñosa, J.; Espinosa, J.C.M.; Ashraf, I. Advancements in Dentistry with Artificial Intelligence: Current Clinical Applications and Future Perspectives.

- Healthcare 2022, 10, 2188.
13. Vaishya Raju., et al. "Artificial Intelligence (AI) applications for COVID-19 pandemic". *Diabetes and Metabolic syndrome : Clinical Research And Reviews* (2020)
14. Bijo Alexander And Sunil John. (2018); *Artificial Intelligence In Dentistry: Current Concepts And A Peep Into The Future. Int. J. Of Adv. Res.* 6 (Dec). 1105-1108
15. Fukuda M, Inamoto K, Shibata N, et al.: Evaluation of an artificial intelligence system for detecting vertical root fracture on panoramic radiography. *Oral Radiol*. 2020, 36:337-43. doi: 10.1007/s11282-019-00409-x
16. Shah H, Hernandez P, Budin F, et al.: Automatic quantification framework to detect cracks in teeth . *Proc SPIE Int Soc Opt Eng*. 2018, 10578:10.1117/12.2293603
17. Agrawal P, Nikhade P (July 28, 2022) *Artificial Intelligence in Dentistry: Past, Present, and Future. Cureus* 14(7): e27405.
18. Abdalla-Aslan R, Yeshua T, Kabla D, Leichter I, Nadler C. An artificial intelligence system using machine-learning for automatic detection and classification of dental restorations in panoramic radiography. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2020 Nov;130(5):593-602. doi: 10.1016/j.oooo.2020.05.012. Epub 2020 Jun 3. PMID: 32646672.
19. Bilgir E et al. An artificial intelligence approach to automatic tooth detection and numbering in panoramic radiographs. *BMC Med Imaging*. 2021 Aug 13;21(1):124. doi: 10.1186/s12880-021-00656-7. PMID: 34388975; PMCID: PMC8361658.
19. Dr Farzeen Tanwir et al. *Artificial Intelligence In Dentistry: A Glance To The Future*. March, 2023, vol 19(03), 1074-1083