Artificial Intelligence In Periodontics: A Review

Dalvi Priyanka Ashok[1], **Dixit Mala Baburaj**[1]

[1]*Department of Periodontology, Nair Hospital Dental College, Dr A.L Nair Road, Opp Maratha Mandir, Mumbai Central.*

Corresponding Author
Dalvi Priyanka Ashok
E-mail ID: dalvipriyanka3@gmail.com

Submission: 24.09.2024 Acceptance: 24.10.2024 Publication: 31.12.2024

Abstract:

Periodontitis is the most common disease globally, affecting supporting tissues of teeth. Artificial intelligence (AI) is the development of computer models and system that imitate human intelligence. It is gradually used as a supportive tool in helping clinicians with diagnosis and treatment of diseases. This review explores the use of AI in diagnosing the disease, its various application in periodontics

Keywords: Artificial intelligence, Periodontics, Diagnosis, Radiography

Introduction:

In the world of healthcare, the integration of technology has played an instrumental role in enhancing diagnostics, treatments and patient care across various medical fields. One such ground breaking evolution is the utilization of artificial intelligence (AI) in dentistry, especially in field of periodontology.[1]

Periodontal disease including gingivitis and periodontitis, is the sixth most prevalent health conditions globally, affecting millions of people worldwide. Periodontitis presents as diagnostic challenge as complex relationship exist between predisposing factors that are difficult for clinicians to fully comprehend. Despite various advances, periodontal diagnosis and its treatment, risk assessment and management of disease remain challenging.[2,3]

Artificial intelligence (AI) offers new opportunities to address these challenges by using machine learning algorithms, deep learning and neural networks to improve the decision-making process in periodontics[3].Before delving into the intersection of artificial intelligence (AI) and periodontics, its crucial to understand what is periodontics and artificial intelligence.

Understanding Periodontics:

Periodontitis is a chronic inflammatory disease of the periodontal structure consisting of gingiva, periodontal ligament, cementum and alveolar bone. Accumulation of biofilm on the tooth surface is considered to be primary etiological factors for developing gingivitis and periodontitis.[4]

Gingivitis is characterized by red swollen gingival margins and bleeding on probing which is reversible if appropriate intervention is performed. It can progress to periodontitis leading to gingival recession, bone loss, and potentially resulting into tooth loss, if it is left untreated.[4]

Artificial Intelligence (AI):

It is defined as "The branch of science and engineering associated with computational knowledge which is commonly referred to as intelligent behaviour, as well as the development of systems exhibiting similar behaviour". It refers to the simulation of human intelligence in machines that are programmed to perform task mimicking human intelligence, ideally with a shorter time and high accuracy.[4,5]

History And Evolution Of Artificial Intelligence:

In the 1950s, Alan Turning, an English mathematician, one of the pioneers of AI established the concept of the "Turning test", originally called "Imitation Game". It tested the capability of a machine to imitate and show intelligent behaviour almost identical to human.[6] In 1955, Allen Newell and Herbert Simon designed "The Logic Theorist" the first ever AI program. In 1956 Dartmouth Conference, John McCarthy coined the term "Artificial Intelligence". This conference is considered as the birth of AI. In 1959, Arthur Samuel introduced the term "Machine Learning".[6,7]

From 1970-1980, AI was subjected to critique and financial difficulties. Therefore, this period came to known as "First AI Winter". The period from 1980-1987 saw the boom with the rise of the "Expert System". The late 1980's to early 1990's again faced many financial setbacks and came to be known as the "Second AI winter".[8]

Subdivisions Of Artificial Intelligence:

1) Machine Learning:

It is part of AI which depends on algorithms to predict the outcome based on dataset. It enables computers to pick up new information and adapt on their own, without the aid of a human.[7,9]

2) Deep Learning:

It is the component of machine learning that mimics the way human brain works by learning from the structure of data rather than from an algorithm that is programmed to perform a certain task. The purpose of deep learning is to construct a neural network that automatically identifies patterns to improve feature detection.[7,9]

3) Neural Networks:

They are a set of algorithms that compute signals via artificial neurons. The purpose of neural networks is to form neural networks that function just like the human brain.[7]

Working Of Artificial Intelligence:

AI works in two phases:

1) Training phase.

2) Testing phase.

In training phase, the characteristics, associations and the pattern in data and algorithm are taught to the AI. The objective of training phase is to teach the model to make correct decisions and prediction.

In testing phase, the trained AI model makes decision and predictions for fresh data that were not given during training phase.[10]

Applications Of Artificial Intelligence In Periodontics:

Several studies have researched the use of AI for the automated detection of periodontal disease from clinical images such as intraoral photographs and radiographs. The various research on the use of AI models in periodontics has been growing constantly, which has shown that in upcoming years, AI will transform periodontology with its various technique and applications.[5]

1.Haptics Based Virtual Reality Periodontal Training Stimulator:

It was first developed by Luciano et al exclusively for periodontics. It helps students to develop necessary skills required to diagnose and treat periodontal disease. It consists of haptic device along with 3D images of upper and lower arches along with gingiva. It can be felt by touch. It replicates the clinical feel of the operator hand while using dental instruments. In 2007, Steinberg et al incorporated recording and playback features of trainee performances. This stimulator helps to shorten the lesson time, improve the learning curve and allow unlimited practice to the trainee.[11]

2. Ultrasonography Periodontal Probe:

In 1998, Companion et al, first published the results of an ultrasonographic periodontal probe at NASA Langley.[12] It consists of a hollow conical tip that is filled with water for coupling of the ultrasonic beam into the tissues. It uses high frequency (10-15 MHz) to determine the depth of periodontal pocket non-invasively. An ultrasonic transducer projects high frequency ultrasonic energy between the tooth and the gingiva and it detects echoes of the returning waves.[13]

In 2009, Kevin Rudd et al used the 3D parallel acoustic finite integration technique (3DPAFIT) that simulates ultrasound propagation in the tip and the complex geometries of the periodontal tissues. A software then creates the 2D and 3D geometry of the tip and the structures of periodontal tissue. It performs simulations which can produce realistic data which echoes corresponding to the periodontal pocket depths.[12]

3. Artificial Olfaction For Detection Of Halitosis:

Organoleptic assessment is most commonly used to detect halitosis. The major drawbacks of assessment of organoleptic alone is:

A. Absence of VSC does not mean absence of bad breath.

B. It only assess Volatile sulfur compounds (VSC).

C. Non sulfur volatile compounds, biomarkers of systemic disease, also causes halitosis in 15% cases which are ignored.

Barash et al, Haick et al, Nakhleh, Broza et al, 2014 invented Artificial olfaction. Artificial Olfaction, is a non-invasive technique that assesses the full spectrum of exhaled volatile compounds. It is also called an “Electronic Nose” as it is a combination of mammalian olfaction and AI. It identifies a specific pattern of smell and is used as a reference for future identification.

It consists of array of non-selective sensors mainly made of nanomaterials which semi selectively and/or collectively assess the composition of the exhaled breath. It consists of two subsets, the lower panel has a higher affinity towards volatile sulphur compounds (VSC) and the top panel has a higher affinity towards non sulphuric volatile organic compounds.

On exposure, the sensors react simultaneously and assesses the composition of exhaled breath using analysis software and a database of breath patterns and then it is processed toward a pattern-recognition application. The software compares the pattern obtained from different sensors with the database of the previously obtained patterns during preclinical training phase.

A decision tree-based classifier determines whether the subject suffers from oral or extra oral halitosis. which are caused by various systemic conditions. In case of extra oral halitosis, it will also classify the volatolomic pattern based on various systemic disease.[14,15,16]

4. Classification Of Periodontal Disease:

AI models have been used to differentiate between chronic and aggressive periodontitis, and differentiate between healthy and inflamed gingiva.

In 2017 Feres et al successfully differentiated between Generalised Aggressive Periodontitis in younger adults and Generalised Chronic Periodontitis using bacterial species of the subgingival microbial complexes and a linear Support Vector Machine (SVM)[17]

In 2017 Rana, Yauney et al introduced a machine learning classifier that could distinguish between inflamed and healthy gums. After irradiating the mouth with light of 405-450 nm wavelength, the corresponding fluorescence due to the biomarker porphyrin was recorded using an oral imaging device. Plaque was displayed in shades of yellow and orange whereas inflamed gums was displayed in shades of magenta and red. The classifier then gives a pixel-by-pixel segmentation of regions suspected to have gingivitis.[18]

5. Assessment Of Periodontal Bone Loss:

In 2019, Krois et al used AI to discover periodontal bone loss on panoramic dental radiographs. AI algorithm was created to automatically identify and calculate the radiographic bone loss (RBL) and the probability of tooth loss and periodontal disease. Since the calculation of radiographic bone loss (RBL) can be complicated, time consuming and subjective to the clinicians.[19]

Various studies have been carried out to review the potential of AI model to detect RBL to diagnose the periodontal diseases. The radiographs used in these studies include panoramic radiographs, periapical radiographs and cone beam computed tomography (CBCT). However, these studies conclude that the AI models which detect RBL and periodontal disease require further refinement but they might provide as a powerful diagnostic tool.[20,21,22]

6. In Implantology:

Implant dentistry has undergone exemplar shift with the use of AI. AI algorithms reduce risks, optimize aesthetics and improves the accuracy of implant placement. It also improves success rate of implants by providing patient specific treatment plans.

I. Treatment Planning:

CBCT are the choice of radiographs for planning dental implants globally. AI can be helpful for those clinicians who face difficulties to interpret CBCT scans for implant planning. It helps to determine the optimal location for implant placement, reduces the risk of complications during surgery and improves the success rate of implants. AI assist in the decision-making process and can be an asset in implant planning.[23]

II. Optimization Of Implant Design:

AI algorithms have been used in combination with finite element analysis (FEA) to optimize implant design. It helps to optimize the implant design, length and diameter. It also helps to determine the elastic modulus of implant bone interface. Studies have stated that AI models can be used to reduce stress by 36.6% at the implant bone interface.[24]

Advantages Of Artificial Intelligence:

1) Accuracy in diagnosis.

2) Standardization of treatment procedure.

3) It enables more systemic and structured collection of patient data.

4) Reduces human error.

5) Saves time and resources by means of automating essential procedure.

6) Assist in automated tasks like scheduling patient appointment, obtaining clinical data and guiding the treatment plan for patients.[25]

Challenges And Limitations Of Artificial Intelligence:

Despite the immense potential benefits of AI in periodontics, several challenges and limitations exist and needed to be addressed. These includes:

1) Need for large-scale, high-quality datasets for training AI algorithms.

2) Concern regarding data privacy and security related to patient data.

3) Lack of regulatory guidelines and the need for continuous validation and improvement of AI models.

4) Need human surveillance as AI operates with logical reasoning and lacks empathy and emotions.

5) High setup costs [26]

Conclusion:

The integration of AI in periodontics represents a new era and a pivotal moment in oral healthcare. AI has become a ground breaking force, reshaping the picture of periodontal diagnostics. Despite the challenges and limitations, AI holds immense promise for revolutionizing the field of periodontics by enhancing disease detection, treatment planning and patient management.

Conflict of Interest: Nil

Source of Support: Nil

References:

1. Abdelaziz SK, Glasgow FR. The Role of Artificial Intelligence in Periodontics.

2. Scott J, Biancardi AM, Jones O, Andrew D. Artificial intelligence in periodontology: a scoping review. Dentistry journal. 2023 Feb 8;11(2):43.
3. Parihar AS, Narang S, Tyagi S, Narang A, Dwivedi S, Katoch V, Laddha R. Artificial Intelligence in Periodontics: A Comprehensive Review. Journal of Pharmacy and Bioallied Sciences.:10-4103.
4. Pitchika V, Büttner M, Schwendicke F. Artificial intelligence and personalized diagnostics in periodontology: A narrative review. Periodontology 2000. 2024.
5. Khan SF, Siddique A, Khan AM, Shetty B, Fazal I. Artificial intelligence in periodontology and implantology—a narrative review. Journal of Medical Artificial Intelligence. 2024 Mar 30;7.
6. Park WJ, Park JB. History and application of artificial neural networks in dentistry. European journal of dentistry. 2018 Oct;12(04):594-601.
7. Sachdeva S, Mani A, Vora H, Saluja H, Mani S, Manka N. Artificial intelligence in periodontics: A dip in the future. Journal of cellular biotechnology. 2021 Jan 1;7(2):119-24.
8. Ramani S, Vijayalakshmi R, Mahendra J, Burnice Nalin Kumari C, Ravi N. Artificial intelligence in periodontics-An overview. IP Int J Periodontol Implantol. 2023;8(2):71-4.
9. Cholan P, Ramachandran L, Umesh SG, Sucharitha P, Tadepalli A. The impetus of artificial intelligence on periodontal diagnosis: a brief synopsis. Cureus. 2023 Aug;15(8).
10. Altalhi AM, Alharbi FS, Alhodaithy MA, Almarshedy BS, Al-Saaib MY, Aljohani AS, Alshareef AH, Muhayya M, AL-harbi NH. The Impact of Artificial Intelligence on Dental Implantology: A Narrative Review. Cureus. 2023 Oct;15(10).
11. Luciano C, Banerjee P, DeFanti T. Haptics-based virtual reality periodontal training simulator. Virtual reality. 2009 Jun;13:69-85.
12. Rudd K, Bertoncini C, Hinders M. Simulations of ultrasonographic periodontal probe using the finite integration technique. The Open Acoustics Journal. 2009 Jan 30;2(1).
13. Bertoncini CA, Hinders MK. An ultrasonographic periodontal probe. InAIP Conference Proceedings 2010 Feb 22 (Vol. 1211, No. 1, pp. 1566-1573). American Institute of Physics.
14. Nakhleh MK, Quatredeniers M, Haick H. Detection of halitosis in breath: Between the past, present, and future. Oral diseases. 2018 Jul;24(5):685-95.
15. Nakhleh MK, Amal H, Jeries R, Broza YY, Aboud M, Gharra A, Ivgi H, Khatib S, Badarneh S, Har-Shai L, Glass-Marmor L. Diagnosis and classification of 17 diseases from 1404 subjects via pattern analysis of exhaled molecules. ACS nano. 2017 Jan 24;11(1): 112-25.
16. Mathur A, Mehta V, Obulareddy VT, Kumar P. Narrative review on artificially intelligent olfaction in halitosis. Journal of Oral and Maxillofacial Pathology. 2024 Apr 1;28(2):275-83.
17. Feres M, Louzoun Y, Haber S, Faveri M, Figueiredo LC, Levin L. Support vector machine-based differentiation between aggressive and chronic periodontitis using microbial profiles. International dental journal. 2018 Feb 1;68(1):39-46.
18. Rana A, Yauney G, Wong LC, Gupta O, Muftu A, Shah P. Automated segmentation of gingival diseases from oral images. In2017 IEEE Healthcare Innovations and Point of Care Technologies (HI-POCT) 2017 Nov 6 (pp. 144-147). IEEE.
19. Krois J, Ekert T, Meinhold L, Golla T, Kharbot B, Wittemeier A, Dörfer C, Schwendicke F. Deep learning for the radiographic detection of periodontal bone loss. Scientific reports. 2019 Jun 11;9(1):8495.
20. Miller A, Huang C, Brody ER, Siqueira R. CE Credit. Artificial Intelligence Applications for the Radiographic Detection of Periodontal Disease: A Scoping Review. Journal of the California Dental Association. 2023 Dec 31;51(1):2206301.
21. Revilla-León M, Gómez-Polo M, Barmak AB, Inam W, Kan JY, Kois JC, Akal O. Artificial intelligence models for diagnosing gingivitis and periodontal disease: A systematic review. The Journal of Prosthetic Dentistry. 2023 Dec 1;130(6):816-24.
22. Patil S, Joda T, Soffe B, Awan KH, Fageeh HN, Tovani-Palone MR, Licari FW. Efficacy of artificial intelligence in the detection of periodontal bone loss and classification of periodontal diseases: A systematic review. The Journal of the American Dental Association. 2023 Jul 14.
23. Shirmohammadi A, Oskouei SG. The growing footprint of artificial intelligence in periodontology & implant dentistry. Journal of Advanced Periodontology & Implant Dentistry. 2023;15(1):1.

24. Revilla-León M, Gómez-Polo M, Vyas S, Barmak BA, Galluci GO, Att W, Krishnamurthy VR. Artificial intelligence applications in implant dentistry: A systematic review. The Journal of prosthetic dentistry. 2023 Feb 1;129(2):293-300.

25. Pros & cons of artificial intelligence in medicine. 2021. Accessed: December 7, 2023. Available online: https://drexel.edu/cci/stories/artificial-intelligence-in-medicine-pros-and-cons/

26. Schwendicke FA, Samek W, Krois J. Artificial intelligence in dentistry: chances and challenges. Journal of dental research. 2020 Jul;99(7):769-74.