

Artificial Intelligence in Periodontics - An Overview

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Abstract

Artificial intelligence (AI) is the development of computer systems whereby machines can mimic human actions. Artificial intelligence (AI) is changing each of the healthcare fields, including periodontology, through the improvement of every diagnosis, treatment plan, and the handling of all patients. This is increasingly used as an assistive tool to help clinicians diagnose and treat diseases. (AI) in dentistry is a fast-expanding field that primarily aims to help dentists provide excellent care to patients by streamlining procedures and saving time. AI is revolutionizing dentistry by enabling more precision, reduced errors, and a reduction in staffing needs. This review discusses key applications of AI in periodontology and its potential to improve clinical outcomes.

Keywords: Artificial Intelligence, Periodontal Diseases, Machine Learning.

Introduction

The Glossary of Periodontal Terms defines periodontitis as “the inflammation of the supporting tissues of the teeth, usually a progressively destructive change leading to loss of bone and periodontal ligament.¹ Periodontology, the branch of dentistry concerned with the study of supporting structures of the teeth and the diseases and conditions that affect them, plays a critical role in oral health. Periodontal diseases, particularly gingivitis and periodontitis, are highly prevalent worldwide, often leading to tooth loss if left untreated (Pihlstrom et al., 2005).² Traditional diagnostic methods and treatment approaches are limited by human error and subjective interpretation. However, the advent of Artificial Intelligence (AI) in healthcare has opened up new possibilities for enhancing the precision and efficiency of periodontal care. AI technologies, such as machine learning (ML), deep learning, and neural networks, have the potential to transform

periodontal practices by improving diagnostic accuracy, optimizing treatment plans, and enhancing patient outcomes (Jiang et al., 2021).³

Implications of AI in Periodontology

1. Early Detection of Periodontal Diseases

One of the most significant contributions of AI to periodontology is its ability to aid in the early detection of periodontal diseases. Traditional diagnostic methods often rely on subjective evaluation of clinical signs and symptoms, which may result in delayed diagnoses.

- **AI in Radiographs:** Deep learning algorithms can analyze dental radiographs to detect subtle signs of periodontal disease, such as bone loss, alveolar defects, or changes in the periodontal ligament. A study by Lee et al. (2018) demonstrated that AI models could achieve diagnostic accuracy comparable to experienced periodontists in detecting radiographic signs of periodontitis.⁴
- **Clinical Imaging:** AI-driven systems are also used to assess intraoral images, identifying signs of gingivitis, plaque accumulation, and bleeding gums (Ravindran et al., 2020). These systems can provide a more consistent and objective evaluation than human clinicians.⁵

2. Diagnosis and Risk Assessment

AI's ability to evaluate large volumes of patient data makes it an invaluable tool for diagnosis and risk assessment. Periodontal disease risk is multifactorial, influenced by factors such as genetics, smoking, diabetes, and oral hygiene. AI models can integrate these variables to assess an individual's susceptibility to periodontal disease more accurately.

- **Predictive Analytics:** By analyzing historical patient data, machine learning algorithms can predict the likelihood of disease progression and help periodontists identify high-risk patients who may benefit from preventive measures (Yuan et al., 2019).⁶

3. Treatment Planning and Personalization

AI can assist periodontists in developing personalized treatment plans based on individual patient data. Traditional treatment protocols are often generalized, but AI allows for a more customized approach by analyzing the outcomes of similar cases and recommending the most effective treatment options.

- **Machine Learning Algorithms:** AI tools can process data from clinical examinations, patient medical history, and previous treatment outcomes to suggest optimal interventions. For example, if a patient is diagnosed with periodontitis, AI can recommend whether non-surgical therapies like scaling and root planing are sufficient or if surgical options such as regenerative procedures are necessary (Kuo et al., 2020).⁷
- **Treatment Optimization:** AI can also help optimize the timing of interventions, such as choosing the best moment for periodontal surgery or identifying the need for adjunctive treatments like antimicrobial agents or lasers (Liu et al., 2020).⁸

4. Robotic Surgery and Automation

AI is playing an increasing role in periodontal surgeries, particularly in robotic systems that assist with precision tasks. Robotics combined with AI allows for more accurate procedures and reduces the margin for human error.

- **Robotic-Assisted Surgeries:** AI-powered robotic systems assist in procedures such as dental implant placement, soft tissue grafting, and guided tissue regeneration. These systems provide real-time feedback to the surgeon, improving the accuracy of implant positioning and reducing recovery times (Mastrolonardo et al., 2019).⁹
- **Minimizing Errors:** AI-based robots can perform repetitive tasks with high precision, such as bone contouring or suturing, allowing clinicians to focus on more complex decision-making aspects of the surgery (Park et al., 2020)¹⁰.

5. AI in Periodontal Education and Research

Beyond clinical applications, AI is transforming periodontal education and research. Machine learning algorithms can quickly process and analyze large datasets, leading to new insights into the etiology and progression of periodontal diseases.

- **Virtual Simulators:** AI-powered simulations provide dental students with realistic virtual patients for training purposes. These simulations can mimic a wide variety of periodontal conditions, offering a risk-free environment for students to practice diagnosis and treatment (Wu S in 2024).¹¹
- **Research and Data Mining:** AI enhances the ability to analyze epidemiological data and clinical trials. By recognizing patterns in patient outcomes, AI can help identify novel biomarkers for periodontal disease and predict treatment responses (Zhou et al., 2021).¹²

Challenges and Limitations

Despite the numerous benefits of AI in periodontology, its implementation is not without challenges. One of the major obstacles is the need for high-quality, large-scale datasets to train AI models effectively. In many regions, especially in low-resource settings, access to comprehensive dental data may be limited (Elangovan et al., 2021).¹³

Moreover, AI algorithms are only as reliable as the data they are trained on. If the data contains biases or inaccuracies, these can be propagated into the AI system, potentially leading to flawed diagnoses or treatment recommendations (Wang et al., 2020).¹⁴ Additionally, AI should be viewed as an adjunct to, rather than a replacement for, human expertise. Periodontists must remain involved in the decision-making process, using AI tools to support, rather than supplant, their clinical judgment.

Recent Advancements in Artificial Intelligence In Periodontology

1. AI-Driven Diagnostic Imaging

Recent developments have seen the implementation of AI systems that combine object detection and semantic segmentation techniques to assess dental findings from panoramic radiographs. A multinational study analyzed 6,669 images from datasets across the Netherlands, Brazil, and Taiwan, demonstrating high sensitivity and specificity in identifying various dental conditions, including periodontal bone loss.

Additionally, advanced AI models like DeNTNet 2.0 have been developed to enhance the identification of subtle periodontal changes in cone-beam computed tomography (CBCT) scans, facilitating early disease detection.¹⁵

2. Natural Language Processing in Clinical Documentation

The integration of natural language processing (NLP) into periodontology has streamlined the extraction of diagnostic data from unstructured clinical notes. A 2024 study utilized advanced AI and NLP methods, including GPT-4-generated

synthetic notes, to fine-tune a RoBERTa model. This approach significantly improved the model's ability to understand medical and dental language, achieving high accuracy in diagnosing periodontal status, stage, and grade.¹⁶

3. Predictive Modeling for Disease Progression

Artificial neural networks (ANNs) have been employed to predict periodontitis progression using parameters such as age, sex, smoking status, plaque levels, bleeding on probing, probing depth, and clinical attachment loss. These models have demonstrated high accuracy, sensitivity, and specificity, facilitating early intervention and tailored treatment strategies.¹⁷

4. AI in Dental Education

AI language models have shown promise in dental education. A 2024 study evaluated the performance of ChatGPT-4o, Claude 3 Opus, and Gemini Advanced on the American Academy of Periodontology in-service examination. The AI models significantly outperformed second-year periodontics residents, with ChatGPT-4o achieving an accuracy rate of 92.7%, highlighting the potential of AI as a supplementary educational tool.¹⁸

5. Quantitative Ultrasound for Periodontal Soft Tissue Characterization

A novel application of quantitative ultrasound (QUS) has been explored for noninvasive characterization of periodontal soft tissues. In an in vivo animal study, QUS analysis of oral soft tissues demonstrated promising results, suggesting its potential as a diagnostic tool in periodontology.¹⁹

Conclusion

Artificial Intelligence holds significant promise for the future of periodontology. From enhancing diagnostic accuracy to personalizing treatment plans and improving surgical precision, AI is poised to revolutionize the way periodontal care is delivered. However, its widespread adoption will require overcoming data-related challenges and ensuring that AI systems are transparent, accurate, and used as tools to complement clinical expertise.

So, it is recommended to be updated by the recent trends in machine learning and artificial intelligence as AI technology continues to evolve, it is likely to become an indispensable tool in periodontics, contributing to improved patient outcomes and advancing the field as a whole.

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