

Artificial Intelligence in Periodontal Disease Prediction: A New Frontier in Dental Diagnostics

Priya Vadhana

MSc, Freelancing Microbiologist, Chennai, India.

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Abstract: Periodontal disease, a chronic inflammatory condition affecting the supporting structures of the teeth, is a leading cause of tooth loss and is closely associated with systemic conditions such as diabetes and cardiovascular disease. Early diagnosis and accurate prediction of disease progression are critical for effective treatment and prevention. In recent years, artificial intelligence (AI) has emerged as a powerful tool in healthcare, demonstrating potential in enhancing diagnostic precision and predictive capabilities in periodontal care. This article provides a comprehensive overview of AI applications in predicting periodontal disease, focusing on machine learning (ML), deep learning (DL), and neural networks. It explores various datasets, clinical parameters, and imaging modalities used to train AI models, such as radiographs, periodontal probing depths, and microbial profiles. The article also reviews recent advancements in AI-based prediction models, their performance metrics (accuracy, sensitivity, specificity), and clinical applicability. Furthermore, it discusses challenges including data standardization, ethical considerations, model interpretability, and integration into existing dental practice workflows. The findings suggest that AI, when properly validated and integrated, can significantly improve early detection, risk assessment, and personalized treatment planning in periodontal care, ultimately leading to better patient outcomes and resource optimization.

Keywords: Artificial Intelligence (AI), Periodontal Disease, Machine Learning, Deep Learning, Predictive Modeling, Dental Radiographs, Oral Health, Risk Assessment, Neural Networks, Clinical Decision Support Systems

I. Introduction

Periodontal disease, a chronic inflammatory condition affecting the supporting structures of the teeth, is a major cause of tooth loss in adults and is linked to systemic diseases such as diabetes and cardiovascular disorders. Accurate and early diagnosis is vital for effective treatment. Traditional diagnostic tools—clinical probing, radiographic evaluation, and microbial assessments—are time-consuming, subject to human error, and often detect the disease only after significant progression. In this context, Artificial Intelligence (AI) has emerged as a promising tool in predicting and diagnosing periodontal disease with enhanced speed, consistency, and accuracy¹.

Early detection and accurate prediction of periodontal disease progression are critical for effective intervention and management. In recent years, artificial intelligence (AI) has emerged as a transformative tool in healthcare, offering new opportunities for enhancing diagnostic precision and personalized treatment planning. By leveraging vast datasets, machine learning algorithms, and advanced image analysis techniques, AI systems can identify subtle patterns and risk factors that may be imperceptible to the human eye. This article explores the role of AI in the prediction of periodontal disease, highlighting its potential to revolutionize periodontal diagnostics, improve patient outcomes, and contribute to the evolution of precision dentistry³.

AI Technologies in Periodontology

AI encompasses a range of techniques, including machine learning (ML), deep learning (DL), and natural language processing (NLP), which can be applied to large datasets to recognize patterns, classify outcomes, and make predictions. These technologies are being increasingly integrated into dental research and clinical practice³.

Machine Learning in Periodontal Prediction

Machine learning algorithms have been trained on large datasets of clinical, radiographic, and microbial parameters to identify patterns indicative of periodontal disease. For example, supervised learning models such as support vector machines (SVM), random forests, and logistic regression have demonstrated high accuracy in distinguishing between healthy and diseased sites⁴.

A study by Lee et al. (2020) used ML models to analyze periodontal data from the National Health and Nutrition Examination Survey (NHANES) and successfully predicted periodontitis with over 80% accuracy. Similarly, interproximal bone loss and pocket depth data fed into ML algorithms have achieved comparable predictive performance⁴.

Deep Learning and Image Analysis

Deep learning, especially convolutional neural networks (CNNs), excels in image recognition tasks. This makes it highly suitable for interpreting dental radiographs. CNNs can identify early bone loss and anatomical changes associated with periodontitis more reliably than conventional techniques⁵.

In a landmark study, Krois et al. (2019) trained a CNN to detect periodontal bone loss on panoramic radiographs. The system reached diagnostic performance levels comparable to expert clinicians, highlighting the potential of AI-assisted imaging in dental diagnostics⁵.

Integration with Electronic Health Records (EHRs)

AI can also synthesize information from EHRs, integrating demographic data, medical history, lifestyle factors, and clinical findings to create risk prediction models. These systems can be especially beneficial in identifying patients at risk before clinical symptoms appear, facilitating preventive strategies⁶.

Advantages of AI in Periodontal Disease Prediction

Artificial intelligence (AI) has emerged as a transformative tool in the field of dentistry, especially in the prediction and early diagnosis of periodontal diseases. These diseases, including gingivitis and periodontitis, are among the most prevalent oral health issues worldwide and can lead to tooth loss and systemic health complications if not diagnosed and treated promptly. AI offers the potential to revolutionize periodontal care by enabling more accurate, efficient, and personalized treatment approaches. However, its implementation also presents several challenges⁷.

Early and Accurate Diagnosis

AI algorithms, particularly machine learning (ML) and deep learning (DL) models, can analyze complex patterns in clinical, radiographic, and genetic data that are often missed by human clinicians. These tools can detect early signs of periodontal disease, even before clinical symptoms become apparent⁸.

Example: Convolutional neural networks (CNNs) can assess radiographs to identify subtle bone loss indicative of early periodontitis.

Outcome: Early intervention can prevent disease progression and reduce the need for invasive treatments.

Integration of Multimodal Data

AI systems can integrate various types of patient data—clinical parameters (e.g., probing depth, bleeding on probing), imaging (e.g., panoramic X-rays, CBCT), microbiome analysis, and genetic predispositions—to offer a comprehensive risk assessment⁹.

Benefit: Enables a more holistic understanding of disease risk and progression.

Personalized Treatment Plans

AI can stratify patients based on risk profiles and disease severity, aiding in the creation of customized treatment plans¹⁰.

Impact: Improves patient outcomes and optimizes resource allocation in clinical practice.

Efficiency and Workflow Enhancement

AI tools can automate repetitive tasks such as image annotation, data entry, and diagnostic reporting.

Benefit: Saves time for dental professionals and reduces human error.

Example: Automated segmentation of periodontal structures on radiographs.

Predictive Analytics¹¹

AI models can predict future disease progression or treatment outcomes by learning from historical patient data.

Use case: Predicting the likelihood of tooth loss due to periodontitis in a given time frame.

Continuous Learning and Improvement

AI models can be trained on vast datasets and continuously improve as more data becomes available.

Outcome: Leads to increasingly accurate and robust prediction systems over time.

Challenges of Artificial Intelligence in Periodontal Disease Prediction¹²

Data Quality and Availability

AI models require large volumes of high-quality, labeled data for training. In periodontal research, such datasets may be limited or fragmented¹³.

Issue: Inconsistent data from different clinics, missing information, or variability in annotation standards can impair model performance.

Bias and Generalizability

AI models trained on data from a specific population or setting may not perform well across different demographic or geographic groups.

Consequence: Can lead to biased predictions and health disparities.

Example: An algorithm trained on data from a single ethnicity may not accurately predict disease risk in other populations.

Interpretability and Transparency

Many AI models, especially deep learning systems, operate as “black boxes” with limited interpretability¹³.

Challenge: Clinicians may be hesitant to trust or adopt AI recommendations without clear reasoning behind them.

Solution: Explainable AI (XAI) approaches are being developed to address this.

Ethical and Legal Concerns

Issues around patient consent, data privacy, and liability for AI-driven decisions pose significant challenges¹⁴.

Example: If an AI system fails to diagnose a patient’s disease correctly, who is responsible—the clinician, the AI developer, or the healthcare institution?

Integration with Clinical Workflow

Incorporating AI tools into existing dental practice management systems can be technically complex and costly.

Barriers: Interoperability with electronic health records (EHRs), staff training, and maintenance.

Regulatory and Validation Hurdles

Before clinical deployment, AI models must be validated and approved by regulatory bodies, which is a time-consuming and rigorous process.

Concern: Ensuring that models meet clinical standards and are safe and effective for patient use.

Resistance to Adoption

Some clinicians may be skeptical about adopting AI due to fears of job displacement or lack of familiarity with the technology.

Mitigation: Education and demonstration of AI as a supportive tool rather than a replacement for human judgment.

Artificial intelligence holds significant promise in enhancing periodontal disease prediction by enabling early diagnosis, personalized care, and efficient clinical workflows. However, its successful implementation hinges on addressing key challenges such as data quality, model interpretability, ethical concerns, and integration into clinical practice. A collaborative approach involving dental professionals, data scientists, regulatory authorities, and technology developers is essential to unlock the full potential of AI in periodontology. As the field advances, ongoing research and validation will be critical to ensure AI tools are accurate, equitable, and beneficial for all patients¹⁵.

To summarize:

Advantages of AI in Periodontal Disease Prediction¹⁶

Early Detection: AI models can identify subtle changes or patterns not apparent to the human eye.

Consistency: AI reduces diagnostic variability among clinicians.

Efficiency: Automated image and data analysis saves time in busy clinical settings.

Personalized Care: AI allows for the development of individualized treatment and monitoring plans based on patient-specific risk profiles.

Challenges and Limitations

Despite its promise, AI in periodontology faces several challenges:

Data Quality and Quantity: High-quality, annotated datasets are essential but often limited.

Ethical and Legal Concerns: Issues of patient privacy and algorithm transparency must be addressed.

Integration into Clinical Workflow: Seamless integration into dental software systems and training for clinicians are required.

II. Conclusion

AI holds substantial promise in enhancing the prediction and early diagnosis of periodontal disease¹⁷. As research progresses and technology becomes more accessible, AI-driven tools are likely to become integral components of periodontal care, offering improved outcomes for patients through timely and tailored interventions. Ongoing advancements in AI models, including federated learning and explainable AI, could address current limitations. Additionally, combining genomics, salivary biomarkers, and AI could further refine risk prediction models, ushering in an era of precision periodontics¹⁸.

References

1. Tonetti MS, Jepsen S, Jin L, Otomo-Corgel J. Impact of the global burden of periodontal diseases on health, nutrition, and wellbeing of mankind: a call for global action. *J Clin Periodontol.* (2017) 44(5):456–62. doi: 10.1111/jcpe.12732
2. Yadalam PK, Thirukkumaran PV, Natarajan PM and Ardila CM (2024) Light gradient boost tree classifier predictions on appendicitis with periodontal disease from biochemical and clinical parameters. *Front. Oral. Health* 5:1462873. doi: 10.3389/froh.2024.1462873
3. Schwendicke F, Krois J, Gomez J. Artificial intelligence in dentistry: chances and challenges. *J Dent Res.* (2020) 99(7):769–74. doi: 10.1177/0022034520915714
4. Lee, J.H., Kim, D.H., Jeong, S.N., Choi, S.H. (2020). Predicting periodontitis through machine learning analysis of risk factors. *Scientific Reports*, 10, 5930.
5. Krois, J., Ekert, T., Meinhold, L., Golla, T., Kharbot, B., Wiegand, T., & Schwendicke, F. (2019). Deep learning for the radiographic detection of periodontal bone loss. *Scientific Reports*, 9, 8495.
6. Wang J, Zhang Y, Liu H, Xu W, Li K, Chen J, et al. Hybrid CNN-decision tree for automatic detection of periodontal disease. *Dentomaxillofac Radiol.* (2019) 48(6):20180055.
7. Yadalam PK, Sharma S, Natarajan PM, Ardila CM. Gradient boosting-based classification of interactome hub genes in periimplantitis with periodontitis - an integrated bioinformatic approach. *Front Oral Health.* 2024 Nov 26;5:1462845. doi: 10.3389/froh.2024.1462845. PMID: 39659491; PMCID: PMC11628506.
8. Yadalam PK, Natarajan PM, Shetty N, Marrapodi MM, Uzunçubuk H, Russo D, Cicciù M, Minervini G. Analyzing and exploring Graph Attention Networks and protein-based language models for predicting *Porphyromonas gingivalis* resistant efflux protein sequences. *Dent Med Probl.* 2025 Mar-Apr;62(2):265-273. doi: 10.17219/dmp/186143. PMID: 40372388.
9. Ganesan A, Gautham Kumar N, Natarajan PM, Gauthaman J. Automated classification of elongated styloid processes using deep learning models-an artificial intelligence diagnostics. *Front Oral Health.* 2025 Jan 20;5:1424840. doi: 10.3389/froh.2024.1424840. PMID: 39902080; PMCID: PMC11788325.
10. Krois J, Ekert T, Meinhold L, Golla T, Kharbot B, Wittemeier A, et al. Deep learning for the radiographic detection of periodontal bone loss. *Sci Rep.* (2019) 9:8495. doi: 10.1038/s41598-019-44839-3
11. Yadalam PK, Barbosa FT, Natarajan PM, Ardila CM. Graph Neural Networks-Based Prediction of Drug Gene Interactions of RTK-VEGF4 Receptor Family in Periodontal Regeneration. *J Clin Exp Dent.* 2024 Dec 1;16(12):e1454-e1458. doi: 10.4317/jced.61880. PMID: 39822781; PMCID: PMC11733889.
12. Umaphathy, V.R.; Natarajan, P.M.; Swamikannu, B. Regenerative Strategies in Dentistry: Harnessing Stem Cells, Biomaterials and Bioactive Materials for Tissue Repair. *Biomolecules* 2025, 15, 546. <https://doi.org/10.3390/biom15040546>
13. Yadalam, P.K., Arumuganainar, D., Natarajan, P.M. et al. Artificial intelligence-powered prediction of AIM-2 inflammasome sequences using transformers and graph attention networks in periodontal inflammation. *Sci Rep* 15, 8733 (2025).
14. Lee JH, Kim DH, Jeong SN, Choi SH. Diagnosis and prediction of periodontally compromised teeth using a deep learning-based convolutional neural network algorithm. *J Periodontal Implant Sci.* (2018) 48(2):114–23. doi: 10.5051/jpis.2018.48.2.114
15. Yadalam PK, Chatterjee S, Natarajan PM and Ardila CM (2025) Comparison of light gradient boosting and logistic regression for interactome hub genes in *Porphyromonas gingivalis* and *Fusobacterium nucleatum*-induced periodontitis with Alzheimer's disease. *Front. Oral Health* 6:1463458. doi: 10.3389/froh.2025.1463458
16. Yadalam, P.K., Natarajan, P.M. & Ardila, C.M. Variational graph autoencoder for reconstructed transcriptomic data associated with NLRP3 mediated pyroptosis in periodontitis. *Sci Rep* 15, 1962 (2025).
17. Tonetti MS, Greenwell H, Kornman KS. Staging and grading of periodontitis: framework and proposal of a new classification and case definition. *J Periodontol.* (2018) 89:S159–72. doi: 10.1002/JPER.18-0006
18. Vidhyarekha U, Prabhu Manickam Natarajan, S. Bhuminathan, Jaganathan Sabarinathan, Rajinikanth Suba, Peryasamy Vijayalakshmi. Role of artificial intelligence in Oral Cancer. *Advances in Public Health.* 2024. 3664408, 16, 2024.