



Changing Periodontitis Treatment Through the Use of AI, Biomarkers, and Regenerative Technology

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Abstract

Recent advances in digital technologies are transforming the diagnosis and management of periodontal diseases by enabling more precise, efficient, and patient-centered care. This editorial provides an overview of selected emerging technologies and their applications in periodontology, with particular emphasis on artificial intelligence (AI) based tools. These innovations include AI-assisted radiographic analysis, the integration of salivary biomarkers into point-of-care testing, and advances in regenerative periodontal therapies. Collectively, these approaches facilitate more accurate diagnosis, improved risk assessment, and individualized treatment strategies. However, the successful translation of these technologies into routine clinical practice requires interdisciplinary collaboration, standardization protocols, and a sustained commitment to patient-centered care.

Keywords:

salivary biomarkers; regenerative technology; radiographic diagnosis; artificial intelligence; periodontitis

1. Introduction

Periodontitis is one of the most prevalent chronic inflammatory diseases, affecting more than 40% of the adult population and contributing to systemic morbidity, reduced quality of life, and increased healthcare costs [1,2]. The diagnosis and management of periodontal disease continue to rely on traditional diagnostic and therapeutic approaches, including clinical probing, radiographic interpretation, and conventional treatment modalities, which may involve subjectivity and can contribute to late-stage disease detection [3]. With advances in artificial intelligence (AI), molecular diagnostics, and regenerative bioengineering, periodontology has entered a new era of transformative innovation. These innovations represent a paradigm shift from a reactive, damage-control approach to periodontal care toward a more predictive, preventive, and personalized model of healthcare [4–6].

This editorial provides an overview of artificial intelligence-based applications and other emerging diagnostic technologies used in the diagnosis and management of periodontal diseases.

2. AI and Radiographic Diagnosis

AI-driven deep learning systems such as convolutional neural networks (CNNs) are rapidly transforming the radiographic diagnosis of periodontal disease. AI has demonstrated promising accuracy in detecting and staging alveolar bone loss on radiographic images used for periodontal diagnosis and, in some studies, has shown performance comparable to or exceeding that of human clinicians [7–9].

To stage periodontitis using panoramic radiographs, researchers developed an integrated deep learning model that identifies alveolar bone loss, cemento-enamel junction boundaries, and tooth number and length. The model

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achieved high diagnostic accuracy of 0.929 compared with clinical periodontal assessments, suggesting its potential to support more consistent diagnosis and staging of periodontitis [10].

In another study, a Faster R-CNN model was trained on digital panoramic radiographs from periodontally compromised patients using a pretrained ResNet architecture. The model demonstrated satisfactory performance in detecting periodontally compromised teeth, with the potential to reduce diagnostic time [11].

Beyond detecting dental conditions, AI has been proposed as an effective tool for screening in general dental practice, risk prediction, and personalized medicine [5,6]. Nevertheless, the majority of studies have been based on retrospective data, highlighting the need for prospective, real-world validation and integration into routine clinical workflows [4].

3. Salivary Biomarkers and Point of Care Testing

The emergence of salivary biomarkers, including active-matrix metalloproteinase-8 (aMMP-8), interleukin-1 β (IL-1 β), and tumor necrosis factor- α (TNF- α), represents an important advancement toward near-real-time periodontal disease monitoring. Compared with conventional clinical parameters, active MMP-8 provides a dynamic assessment of current disease activity by reflecting the status of ongoing collagen degradation [12,13]. In addition, when integrated with chairside point-of-care testing platforms, these biomarkers enable a rapid, simple, and noninvasive method of assessment, facilitating early disease detection and accurate monitoring of treatment outcomes [12,13].

However, several challenges remain in the implementation of these novel biomarker-based diagnostic approaches, including variable diagnostic thresholds across different assays, confounding patient-related factors (e.g., smoking and uncontrolled type 2 diabetes), and the lack of standardized integration into existing periodontal risk assessment models [12,14]. Longitudinal studies are required to establish the consistent applicability of these tests in routine clinical diagnosis.

4. Progress in Regenerative Periodontal Treatment

A significant shift in periodontal therapy is occurring as regenerative approaches evolve beyond traditional guided tissue regeneration through the integration of advanced biotechnology and digital imaging technologies. Current advances in 3-D bioprinting have enabled the development of patient-specific, multiphasic regenerative scaffold

that mimic the distinct tissue compartments of the periodontium, including cementum, the periodontal ligament, and alveolar bone [15]. Preclinical studies have demonstrated advances in multiphasic scaffold design; however, these developments require further evaluation in large animal models and, ultimately, in clinical trials.

Digital imaging and 3D reconstruction using cone-beam computed tomography (CBCT) have facilitated more precise defect characterization and surgical planning for minimally invasive regenerative procedures [16]. There is insufficient clinical evidence on the effectiveness of innovative scaffolds when compared with existing regenerative therapies; only a few randomized controlled trials have been conducted.

5. Moving to Precision Practice in Periodontics

AI, multi-omics profiling technologies, and salivary diagnostics may create opportunities for developing systems-based approaches that support precision periodontal therapy. Early evidence suggests that integrating host genetic data, microbiome profiles, and biomarker assessments may facilitate early disease detection, improve risk assessment, and predict treatment outcomes [17,18]. A systems-based approach aligns well with the broader trend toward personalized medicine and offers opportunities for timely intervention and the development of tailored therapeutic strategies.

6. Future Directions

Despite these significant advancements, several barriers must be addressed before these technologies can be fully integrated into routine clinical practice. These barriers include algorithm reliability, data security, and ethical concerns associated with AI-based personalized diagnostic tools, underscoring the need for transparency, multidisciplinary collaboration, and patient involvement [4,19]. These challenges are further compounded by the need for standardized protocols, well-defined regulatory approval pathways, cost-effectiveness analyses, and adequate clinician training. Importantly, prospective clinical trials are essential to validate the real-world impact of these innovations on clinical outcomes and patient care [20,21].

7. Conclusions

Periodontology is undergoing a significant transformation driven by rapid technological advances. Artificial intelligence is emerging as a valuable support tool for the

detection, monitoring, and management of periodontal disease by streamlining clinical workflows and supporting clinical decision-making. Moving forward, the successful translation of these advances into routine clinical practice will depend on interdisciplinary collaboration, standardized protocols, and a sustained commitment to patient-centered care. The future of periodontology extends beyond reacting to existing disease; it is likely to become increasingly predictive, personalized, and regenerative.

List of Abbreviations

AI	Artificial Intelligence
CBCT	Cone Beam Computed Tomography
CNNs	Convolutional Neural Networks
MMP-8	Matrix Metalloproteinase-8

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AI Declaration

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