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

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Abstract:

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

Keywords: digital technologies in periodontitis; regenerative technology; diagnosis of periodontal diseases; management of periodontal diseases; AI and radiographic diagnosis

Introduction

Periodontitis is one of the most common chronic inflammatory diseases, affecting more than 40% of the adult population and contributing to substantial systemic suffering, reduced quality of life, and higher healthcare expenses [1,2]. The diagnosis and management of the disease continue to employ more traditional forms of diagnosis and treatments (clinical probing, radiographic interpretation, and standard treatment) with a high degree of subjectivity and late-stage disease identification [3]. With the innovations of Artificial Intelligence (AI), molecular diagnostics, and regenerative bioengineering, periodontology has entered into a time of tremendous transformation. These innovations represent a shift from a reactive, damage-control model of periodontal healthcare to one that is more predictive, preventive, and personalized [4-6].

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

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 achieved high degrees of accuracy in detecting and staging bone loss in the radiographic diagnosis of periodontal disease and in some studies has achieved higher accuracy levels than human providers [7-9].

In the development of periodontitis staging from panoramic radiographs, researchers developed an integrated deep learning model to stage periodontitis by identifying bone loss, cemento-enamel junction boundaries, as well as the number and lengths of teeth, with a high degree of accuracy (0.929) relative to dental assessments suggesting the ability of this tool to substantially reduce the potential for human error in the diagnosis for periodontitis patients [10].

In another study, a faster regional CNN model was trained by utilizing the digital panoramic images of periodontally compromised patients through the pretrained ResNet architecture. This model was able to demonstrate satisfactory results in the detection of periodontally compromised teeth, potentially reducing the diagnosis time [11].

Apart from the detection of dental conditions, AI is proposed to provide effective screening tools in general dental practice, risk prediction, and personalized medicine [5,6]. Nevertheless, the majority of the studies have been based on retrospective data, highlighting the need for prospective, real-world validation and integration into clinical workflows [4].

Salivary Biomarkers and Point of Care Testing

With the emergence of salivary biomarkers that have been confirmed as bio-indicator for the detection of various disease processes (such as; active Matrix Metalloproteinase-8 (MMP-8), Interleukin-1 beta and Tumor Necrosis Factor-alpha), they represent a major step toward real-time disease monitoring. Compared to classical clinical parameters, the use of active MMP-8 provides a dynamical estimation of present disease activity by reflecting ongoing collagen degradation status [12,13]. In addition, when used in connection with a chairside point of care testing platform, they enable a rapid, easy, noninvasive method of evaluation to assist with early disease detection and accurate monitoring of treatment results [12,13].

However, there remain numerous concerns when using these new diagnostic biomarker-testing approaches, including variable diagnostic thresholds between the tests, confounding patient determinants (i.e., smoking, uncontrolled type 2 diabetes), and lack of standardization in integration into existing periodontal risk assessment models [12,14]. Longitudinal studies must continue to be performed to ensure these tests are consistently applicable for use with routine diagnosis.

Progress in Regenerative Periodontal Treatment

A significant shift in periodontal therapy is occurring as regenerative approaches evolve via advanced biotech and digital imaging technologies from traditional guided tissue regeneration. Current advances in 3-D bioprinting techniques have allowed for the development of 3-D patient-specific, multiphasic regenerative scaffold structures that mimic the different tissue compartments of the periodontium (cementum, periodontal ligaments, and alveolar bone) [15]. Preclinical studies showed advances in multiphasic scaffold design, but these advances need to be tested in large animal models and eventually in clinical trials.

To date, digitized imaging and 3D image reconstruction using cone beam computed tomography (CBCT) facilitate precision in defect characterization and surgical planning for use with 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.

Moving to Precision Practice in Periodontics

AI, multi-omics profiling technologies, and salivary diagnostics will create opportunities for developing systems-based approaches that support precision periodontal therapy. Early evidence supports that integrating genetic data from the host, microbiome data, and biomarker evaluation may assist in early disease detection, assessing risk, and predicting treatment outcome [17,18]. A systems-based approach is well aligned with the larger trend in the development of personalized medicine and will provide opportunities for providing timely intervention and developing tailored therapeutics.

Future Directions

Despite the outstanding advancements, a number of barriers must be addressed before these technologies can be fully incorporated into routine practice. These barriers include challenges related to algorithm reliability, data security, and ethical considerations in adopting AI-based personalized diagnostic tools, emphasizing the importance of transparency, multidisciplinary collaboration, and patient involvement [4, 19]. These are further compounded by the need for standardized protocols, clear 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 patient outcomes [20,21].

Conclusion

Periodontology is currently undergoing significant changes in response to the rapid advances in technology. Artificial intelligence is valuable support tool by redefining how periodontal disease is detected, monitored, and treated; facilitating clinician's workflow and strengthening decision making process. Moving forward, the successful translation of these advances into clinical practice will depend on interdisciplinary collaboration, standardization and a commitment to patient-centered care. The future of periodontology is not just about reacting to the present. The future of the specialty is predictive, personalized, and regenerative.

List of Abbreviations:

AI: Artificial Intelligence,

CNNs: Convolutional Neural Networks,

MMP-8: Matrix Metalloproteinase-8,

CBCT: Cone Beam Computed Tomography

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