CLINICAL, RADIOGRAPHIC, AND MOLECULAR METHODS FOR EARLY DIAGNOSIS OF PERI-IMPLANTITIS

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Abstract: Peri-implantitis is a chronic inflammatory disease of peri-implant tissues, characterized by progressive marginal bone loss and the risk of implant failure. Early and accurate diagnosis is essential to ensure timely intervention and improve treatment outcomes. Conventional clinical methods, including probing depth, bleeding on probing, and suppuration, as well as radiographic assessment of bone levels, remain the cornerstone of diagnosis [1,3]. However, recent advances in the analysis of peri-implant crevicular fluid (PICF) biomarkers and molecular technologies enable the detection of pathological processes before clinical manifestations become evident [2,5,6]. Integration of clinical, radiographic, and molecular approaches enhances diagnostic accuracy and facilitates prediction of disease progression.

Keywords: peri-implantitis; early diagnosis; clinical indicators; radiography; biomarkers; peri-implant crevicular fluid; molecular approaches

Introduction. Peri-implantitis develops due to interactions between bacterial biofilm and host immune responses, leading to inflammation of the soft tissues and progressive bone loss around dental implants [1,3]. Accurate and early detection is critical because isolated diagnostic methods may fail to identify subclinical pathology.

Key clinical indicators include:

- Probing pocket depth (PPD) — increased depth reflects soft tissue compromise;
- Bleeding on probing (BoP) — indicates active inflammation;
- Suppuration on probing (SoP) — reflects pronounced inflammatory activity;
- Alterations in peri-implant soft tissues, such as peri-implant recession, signaling disruption of gingival homeostasis [1,3].

Radiographic Evaluation. Radiographic methods, including periapical radiographs and, when indicated, cone-beam computed tomography (CBCT), provide essential assessment of marginal bone levels. Comparison with baseline images taken after implant placement allows monitoring of bone loss over time [1,3].

Although clinical and radiographic assessments are fundamental, they often detect changes after substantial tissue damage, limiting sensitivity at early stages.

Molecular and Biomarker-Based Approaches. Recent studies emphasize peri-implant crevicular fluid (PICF) biomarkers for early detection. Systematic reviews have identified proteins and metabolites, including collagenases, alkaline phosphatase, and regulatory miRNAs, which correlate with bone loss and may serve as early predictive indicators [5,6].

Meta-analyses indicate that pro-inflammatory cytokines (IL-1β, IL-6, TNF-α), osteoclastogenic factors (RANKL), and the RANKL/OPG ratio possess moderate prognostic value in peri-implantitis [7].

Further research has demonstrated that concentrations of APRIL and RANKL in PICF are significantly higher in peri-implantitis compared to healthy tissues and peri-implant mucositis. Incorporating these biomarkers with clinical parameters into diagnostic models achieves high accuracy (ROC-AUC ~95%) [2,4]. These findings highlight the importance of combining molecular markers with traditional diagnostic methods for early disease stratification.

Conclusion. Integrating PICF biomarker analysis with standardized clinical and radiographic assessments creates a multi-level, sensitive diagnostic approach, enabling early detection of peri-implant pathology and more accurate prediction of disease progression. Adoption of such comprehensive protocols may improve long-term implant survival and patient outcomes.

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