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Editorial

Biomarkers in endodontics and conservative dentistry: An editorial overview with latest literature and future perspectives

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1. Introduction

Accurate diagnosis in endodontics and conservative dentistry is essential—from identifying reversible pulpitis to determining optimal therapy for apical periodontitis. Conventional tools like thermal/electric pulp testing or radiographs provide limited insight into the inflammatory status, often leading to misdiagnosis or unnecessary treatments. This clinical need has catalyzed interest in biomarkers: measurable molecules that reflect biological processes, offering objective evidence of disease activity and healing potential.

1.1. What are biomarkers?

A biomarker is a biological molecule—protein, enzyme, metabolite, or nucleic acid—found in tissues or fluids, whose presence or level changes with disease states. In dentistry, these can be sampled from pulpal blood or exudate, gingival crevicular fluid (GCF), serum or saliva. They reveal not only inflammation (e.g., pulpitis or periapical pathology) but also recovery or regenerative processes. The increasing use of biomarkers supports a movement toward evidence-based, personalized care. [1]

2. Current Literature: Indicators & Evidence

2.1. Inflammatory cytokines in pulpitis

Recent systematic reviews and studies highlight several key inflammatory biomarkers:

IL-8, TNF-α, MMP-9, and RAGE are significantly up regulated in irreversible pulpitis, IL-1α and IL-8 in pulpal blood are positively correlated with higher pain scores and severity of inflammation. TNF-α plays an early and critical role in inflammation and is being studied as a potential threshold marker for vital pulp therapy decisions. Meta-analyses confirm that MMP-8, MMP-9, IL-1β, and TNF-α are reliable indicators for irreversible pulpitis.[2]

2.2. Systemic biomarkers in apical periodontitis

Research also shows that endodontic infections influence systemic inflammation:

Successful root canal therapy significantly reduces high-sensitivity CRP (hs-CRP) and IL-1β levels at 6 and 12 months, respectively. Studies also reported serum changes in sCD14 and IL-10 depending on the type of endodontic sealer used.

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2.3. Metabolomic biomarkers

Metabolomic studies have discovered that: Pulpitis is associated with decreased levels of ascorbic acid, inosine, allopurinol riboside, and L-asparagine. These findings may enable future diagnostics based on small-molecule signatures.

2.4. Biomarkers in regenerative endodontics

Stem-cell-based regenerative dentistry relies on biological cues: Biomarkers like TGF-β, BMPs, and inflammatory modulators in dental pulp stem cells (DPSCs) are essential in predicting regenerative potential. Transcriptomic analysis is being used to classify DPSC subtypes for specific clinical applications.[3]

3. Non-Invasive Sampling: A Clinical Advantage

Sampling from GCF, pulpal exudate, or even saliva allows for non-invasive biomarker analysis:

Cytokines such as IL-6, IL-8, MMP-9, and Substance P are detectable in GCF and reflect pulpal status. The pilot CRP study showed how biomarkers can be reliably analysed chair side with minimal effort. Future diagnostic kits could include multiple biomarkers for greater accuracy, paving the way for multiplex testing in dental clinics.[4]

4. Clinical Implications: Diagnosis, Prognosis and Personalization

4.1. Early diagnosis

Pulpal and periapical pathosis can be detected earlier using specific inflammatory biomarkers (e.g., IL-6, TNF-α, MMPs). These markers help differentiate between reversible and irreversible pulpitis, guiding clinicians toward more conservative treatment decisions.

Example: Elevated levels of IL-8 and MMP-9 in gingival crevicular fluid (GCF) or pulp blood suggest irreversible pulpitis.

4.2. Treatment monitoring

Biomarkers allow for monitoring healing and treatment response. Levels of pro-inflammatory cytokines post-RCT or pulp capping procedures can show whether inflammation is resolving or persisting.

Example: A decrease in CRP or IL-6 post-treatment can confirm the success of regenerative procedures.

4.3. Prognostic indicators

Certain biomarkers can predict outcomes and help in risk stratification. A high level of TIMP-1/TIMP-2 is associated with better regenerative potential and tissue stability.[5]

4.4. Differential diagnosis

Differentiating between periapical granulomas and cysts is often challenging radiographically. Biomarker analysis (e.g., VEGF, IL-1β) in aspirated fluid or periapical tissue can guide appropriate treatment (surgical vs. non-surgical).

4.5. Material evaluation

Biomarkers help in evaluating the biocompatibility and bioactivity of pulp capping materials like: MTA, Biodentine, Calcium hydroxide and CEM cement

Example: MTA and Biodentine upregulate TGF-β1 and VEGF, promoting pulp healing.

4.6. Regenerative endodontics

Biomarkers like TGF-β, BMPs, and VEGF are crucial for designing and monitoring regenerative procedures such as revascularization or pulp-dentin regeneration.[6,7]

4.7. Caries risk assessment

Salivary biomarkers like amylase, mucins, and antimicrobial peptides can help assess an individual's caries susceptibility, promoting personalized preventive strategies.

4.8. Systemic disease link

Biomarkers in the oral cavity can also reflect systemic conditions. For instance, increased IL-6 or hs-CRP in periodontal tissues may indicate underlying systemic inflammation (e.g., diabetes, cardiovascular diseases).[8]

4.9. Point-of-care (PoC) applications

New technologies like lab-on-a-chip allow real-time analysis of biomarkers at the chair side. Clinicians can make immediate evidence-based decisions without sending samples to a lab.

4.10. Personalized dental care

Biomarkers help shift dentistry from a "one-size-fits-all" approach to precision dentistry, where treatment protocols are customized based on genetic, molecular, and clinical profiles.

4.11. Therapeutic targets

Biomarkers like RANKL and OPG are being explored as targets for pharmacologic modulation, especially in inflammatory bone resorption and periodontitis.[9]

5. Future Perspectives

5.1. Standardization

Challenges such as variability in outcomes and the need for standardized clinical protocols remain in the application of regenerative biomaterials and biomarker-based diagnostics.

5.2. Multiplex diagnostic platforms

Emerging point-of-care (PoC) platforms offer multiplexing capabilities for simultaneous detection of salivary cytokines, CRP, and metabolic markers enhancing rapid chair side diagnostics in oral and systemic diseases.

5.3. Integration with AI

Biomarker data can enhance AI-assisted CBCT imaging and decision-making.

5.4. Regenerative advances

Biomarker profiling can optimize stem-cell based treatments and scaffold compositions.

6. Conclusion

Biomarkers offer a new dimension in conservative and endodontic dentistry: Enhance diagnostic accuracy, Improve monitoring and prognosis, Enable personalized treatment plans, the future lies in integrating biomarker diagnostics with chair side tools, AI and regenerative approaches.

7. Conflict of Interest

None.

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