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Review Article

Assessment of the microbiota in persistent periapical lesions and its clinical implications

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ABSTRACT

Persistent periapical lesions are chronic inflammatory conditions characterized by microbial colonization, immune responses and progressive tissue destruction. These lesions, often resistant to conventional endodontic therapy, are associated with diverse microbial communities, including anaerobic bacteria, fungi and viruses. Advanced diagnostic tools such as cone-beam computed tomography (CBCT) and next-generation sequencing have significantly improved lesion detection and microbial profiling, enabling precise treatment planning. CBCT provides detailed imaging of lesion size and bone loss, while molecular diagnostics reveal complex microbial compositions, including unculturable species and resistance genes. The therapeutic management of persistent lesions involves mechanical debridement, antimicrobial agents and emerging adjuncts. Sodium hypochlorite, chlorhexidine and bioceramic sealers are effective in disrupting biofilms and enhancing sealing properties. Advanced modalities such as antimicrobial photodynamic therapy and probiotics offer innovative approaches to combat resistant pathogens and restore microbial balance. Regenerative strategies, including stem cell therapies and platelet-rich fibrin, show promise for restoring periapical tissue structure and function. Prognostic evaluation relies on lesion size, microbial diversity and systemic health factors. Larger lesions and those linked to systemic conditions like diabetes exhibit lower healing rates, emphasizing the need for comprehensive care. Chronic inflammation from periapical lesions has broader systemic implications, including associations with cardiovascular disease and diabetes, necessitating interdisciplinary collaboration. Future directions in managing persistent periapical lesions include artificial intelligence-driven diagnostics and personalized treatment strategies. Artificial intelligence can enhance predictive analytics, while regenerative approaches aim to repair biological tissues rather than replace them mechanically. Together, these advancements highlight the need for integrated, evidence-based approaches to improve outcomes in the diagnosis, treatment and prognosis of persistent periapical lesions. This integrated understanding bridges the gap between clinical management and the broader systemic implications of chronic oral infections.

Keywords: Antimicrobial therapies, CBCT diagnostics, Microbial diversity, Persistent periapical lesions, Regenerative endodontics

INTRODUCTION

The human oral cavity hosts a complex microbiome that interacts dynamically with the host immune system to maintain oral health. However, dysbiosis within this ecosystem can result in various pathological conditions, including periapical lesions. Persistent periapical lesions, also known as peri-radicular or apical periodontitis, are characterized by chronic inflammation of the periapical tissues caused by bacterial infections that invade the root canal system. Despite advancements in endodontic therapies, some cases remain resistant to treatment, leading to persistent or recurrent lesions.

These lesions are primarily microbial in origin, with a diverse range of bacteria, fungi and viruses implicated in their pathogenesis. Studies utilizing advanced molecular techniques, such as 16S rRNA gene sequencing and metagenomics, have expanded our understanding of the microbial communities in these lesions. Such studies reveal a shift from a predominantly Gram-positive microbiota in primary infections to a more diverse and resistant microbial population in persistent infections.[1,2] This shift highlights the role of ecological succession in shaping the microbiome within the endodontic environment and underscores the need to understand the unique microbial profiles of persistent periapical lesions. Persistent periapical lesions are often polymicrobial, with anaerobic bacteria such as Fusobacterium, Prevotella and Treponema frequently detected.

Additionally, novel uncultivable bacteria have been identified, suggesting that traditional culture-based methods underestimate the microbial diversity.[3] These microbes not only evade host immune responses but also produce biofilms and express virulence factors that enhance their pathogenic potential. Moreover, persistent lesions are associated with the presence of opportunistic pathogens, including fungi such as *Candida albicans*, which further complicates their management.

Clinically, the persistence of periapical lesions poses significant challenges, as they are often asymptomatic and may remain undetected until significant bone destruction occurs. Radiographic and microbiological assessments are essential for diagnosis, but limitations in these diagnostic tools can hinder the identification of the full microbial spectrum. Understanding the microbial etiology of persistent periapical lesions is critical for developing targeted therapeutic strategies, including the use of antimicrobial agents, probiotics and innovative biomaterials.

Moreover, emerging evidence suggests that systemic conditions such as diabetes and cardiovascular diseases may be exacerbated by these chronic infections, underlining their broader health implications.[4] This review aims to explore the microbial diversity of persistent periapical lesions, their pathogenic mechanisms and their clinical implications, providing insights into potential diagnostic and therapeutic advancements.

REVIEW

Persistent periapical lesions present a unique microbiological and clinical challenge due to their complex microbial communities and ability to resist conventional endodontic therapies. Unlike primary infections, persistent lesions are characterized by a more diverse and resistant microbiota, including anaerobic and facultative anaerobic bacteria, fungi and viruses. This microbial diversity, coupled with the biofilm formation within the root canal system, contributes to their chronic nature and resistance to treatment.[5]

The ability of microorganisms such as *Enterococcus faecalis* to survive harsh conditions, including high pH and limited nutrient availability, highlights their role in persistent infections. Additionally, opportunistic pathogens such as *Candida albicans* and *Fusobacterium nucleatum* further complicate the microbiological landscape of these lesions. These pathogens not only evade host immune responses but also produce virulence factors that promote tissue destruction and inflammation, perpetuating the disease process.[6]

Clinically, the persistence of these lesions underscores the limitations of current diagnostic and therapeutic strategies. Advanced molecular tools, such as next-generation sequencing, provide deeper insights into the microbial profiles of persistent lesions, enabling more targeted approaches. Incorporating these technologies into clinical practice may improve diagnostic accuracy and guide antimicrobial therapies, ultimately enhancing treatment outcomes for persistent periapical lesions.

Diversity and composition of microbiota in persistent periapical lesions

Persistent periapical lesions represent a complex microbial environment shaped by unique ecological and pathological dynamics. These lesions typically house polymicrobial communities, with distinct differences in microbial composition compared to primary infections. Research utilizing next-generation sequencing techniques has significantly expanded our understanding of these microbial ecosystems, revealing a highly diverse range of bacterial, fungal and viral species.[7]

Studies highlight that the microbial diversity within persistent lesions is marked by a predominance of anaerobic bacteria, such as Porphyromonas, Prevotella and Fusobacterium. These taxa are often accompanied by facultative anaerobes like Streptococcus and *Enterococcus faecalis*, which demonstrate a remarkable capacity to survive under the extreme conditions of treated root canals. The coexistence of these organisms in biofilms allows for synergistic interactions that enhance

pathogenicity, with some species contributing to immune evasion while others drive tissue destruction.[8]

The spatial distribution of microbial communities within periapical lesions reveals intriguing insights. Bacteria form structured biofilms within the root canal and spread into the periapical tissues, with deeper regions exhibiting lower oxygen availability and higher bacterial loads of obligate anaerobes. This stratification influences the overall metabolic activity of the microbiota, promoting persistence and chronic inflammation.

Treponema species, for example, are frequently detected in deeper zones and have been linked to the degradation of extracellular matrix components, exacerbating lesion severity.[9] Fungal species, though less common, are an important component of persistent lesions. *Candida albicans* is the most frequently identified fungus and is known for its resilience in biofilms and ability to persist under antimicrobial treatment. Its presence often correlates with the failure of conventional therapies, likely due to its biofilm-mediated resistance mechanisms and ability to adapt to host defenses. The co-occurrence of fungi with certain bacterial species further complicates the microbial landscape, as these interactions can potentiate pathogenicity.[10]

Emerging evidence also points to the involvement of viral components in periapical lesions. Viruses such as bacteriophages influence the structure and behavior of bacterial communities by modulating bacterial gene expression and horizontal gene transfer. This phenomenon may contribute to the emergence of antibiotic-resistant strains within persistent infections. Additionally, the presence of human herpesviruses, particularly Epstein-Barr virus, has been linked to exacerbated inflammatory responses, suggesting a multifaceted role for viral pathogens in lesion progression.[11]

Clinical studies examining microbial dynamics in treated root canals emphasize the adaptive capabilities of these communities. Persistent lesions often harbor microorganisms that have undergone selective pressure from antimicrobial agents, resulting in resistant phenotypes. This selection process not only reshapes the microbial composition but also enhances virulence. For instance, strains of *Enterococcus faecalis* isolated from persistent lesions exhibit increased expression of adhesion molecules and enzymes, facilitating tissue invasion and biofilm stability.[12]

Advancements in molecular diagnostics have uncovered numerous previously undetected species, many of which remain uncultivable by traditional microbiological methods. High-throughput sequencing has revealed the presence of unculturable taxa such as Dialister and Filifactor, whose roles in pathogenesis are still being elucidated. These discoveries underscore the limitations of earlier diagnostic techniques and highlight the potential of genomic approaches in identifying keystone taxa that drive disease progression.[13] The diversity and composition of microbiota in persistent periapical lesions reflect an intricate interplay of microbial, environmental and host factors. Understanding these interactions at a molecular level provides critical insights into the mechanisms underlying disease chronicity and resistance to treatment.

Pathogenic mechanisms and virulence factors of identified microorganisms

The pathogenicity of microorganisms in persistent periapical lesions arises from a complex interplay of virulence factors that enable them to establish chronic infections, evade host immune responses and cause tissue destruction. These microorganisms rely on biofilm formation, metabolic adaptability and the production of various enzymes and toxins to persist and proliferate within the hostile environment of the root canal system.[13]

Biofilm dynamics and antibiotic resistance

Biofilm formation is a hallmark of microorganisms involved in persistent periapical lesions. These structured communities provide protection against antimicrobial agents and host immune responses. *E. faecalis*, a frequently isolated species, forms robust biofilms that are highly resistant to treatment. The extracellular polymeric substance matrix of these biofilms encases bacterial cells, creating a diffusion barrier that limits the penetration of antimicrobial agents. Studies have shown that biofilms of *E. faecalis* can withstand calcium hydroxide, a commonly used intracanal medicament, rendering conventional therapies less effective.[14]

Enzymatic degradation of host tissues

The secretion of enzymes such as collagenases, hyaluronidases and proteases play a crucial role in the pathogenesis of these lesions. For instance, *Porphyromonas gingivalis*, a keystone pathogen in polymicrobial communities, produces gingipains, which are cysteine proteases capable of degrading extracellular matrix proteins and disrupting host tissue integrity. Gingipains also modulate the immune response by cleaving cytokines and immune receptors, leading to impaired microbial clearance.[15]

Virulence factors of gram-positive and gram-negative bacteria

Gram-positive bacteria, including *E. faecalis*, produce extracellular vesicles that facilitate intercellular communication and enhance virulence. These vesicles carry enzymes, toxins and DNA fragments that contribute to bacterial survival and immune evasion. On the other hand, gram-negative bacteria such as *Fusobacterium nucleatum* are known for their ability to aggregate with other bacterial species, forming mixed-species biofilms

that amplify pathogenicity. The lipopolysaccharides in the outer membrane of gram-negative bacteria act as endotoxins, triggering inflammation and bone resorption in the periapical tissues.[16]

Immune modulation by fungi

Fungi, particularly *Candida albicans*, contribute to the persistence of periapical lesions through their ability to modulate immune responses. *C. albicans* forms biofilms with bacterial species, enhancing their collective resistance to antimicrobial treatments. The production of hydrolytic enzymes such as secreted aspartyl proteinases allows *C. albicans* to invade host tissues and establish persistent infections. Additionally, fungal pathogens alter the local immune environment by inducing the production of anti-inflammatory cytokines, which hinder effective immune clearance.[17]

Horizontal gene transfer and resistance development

Horizontal gene transfer among bacteria within the root canal microbiota facilitates the dissemination of antibiotic resistance genes and virulence traits. Plasmids, transposons and bacteriophages play a pivotal role in transferring genes that encode resistance to commonly used antibiotics such as amoxicillin and tetracyclines. The presence of bacteriophages in periapical biofilms not only affects microbial diversity but also promotes the evolution of pathogenic strains capable of evading therapeutic interventions.[18]

Role of host-pathogen interactions

Host-pathogen interactions are central to the pathogenesis of periapical lesions. Pathogens secrete molecules that interfere with host cell signaling pathways, leading to apoptosis or necrosis of periapical tissue cells. For example, *Treponema denticola* produces dentilisin, a protease that degrades immunoglobulins and complement proteins, impairing the host's ability to mount an effective immune response. Additionally, pathogens such as *Prevotella intermedia* exploit host iron stores by producing siderophores, enhancing their growth and virulence in the nutrient-limited environment of the root canal system.[19] Understanding the pathogenic mechanisms and virulence factors of these microorganisms is critical for developing targeted diagnostic tools and therapeutic strategies that address the complexity of persistent periapical lesions.

Clinical relevance: diagnostic, therapeutic and prognostic implications

Persistent periapical lesions pose significant clinical challenges due to their complex etiology, variable microbial composition and often asymptomatic nature. Understanding their diagnostic, therapeutic and prognostic dimensions is essential for effective management. The emergence of novel diagnostic tools, advanced treatment modalities and prognostic markers is redefining the way these lesions are approached in clinical practice.[20]

Diagnostic tools and their impact

Diagnostic advancements have made it possible to distinguish between types of periapical lesions with unprecedented accuracy. Cone-beam computed tomography (CBCT) has become a cornerstone in endodontics, enabling three-dimensional visualization of periapical structures. Compared to traditional radiographs, CBCT offers enhanced sensitivity in detecting early bone loss, cystic formations and subtle anatomical variations. Studies show that the ability to differentiate granulomas from cysts with CBCT can directly influence treatment planning, particularly when considering surgical options.[21]

Beyond imaging, molecular diagnostics such as polymerase chain reaction and next-generation sequencing have transformed microbial identification. These methods allow for the detection of uncultivable microorganisms, uncovering a broader range of bacterial species implicated in persistent lesions. Such precision is crucial for targeting antimicrobial therapies and predicting the microbial resistance profile, ultimately improving treatment outcomes.

Advances in therapeutic approaches

The treatment of persistent periapical lesions requires a combination of conventional techniques and innovative adjuncts. Root canal therapy remains the primary modality, with mechanical debridement playing a critical role in eliminating biofilms and necrotic tissue. However, persistent lesions often house resistant bacterial species embedded in biofilms, necessitating supplementary strategies to eradicate these pathogens.

Irrigation protocols have evolved to include combinations of sodium hypochlorite, chlorhexidine and ethylenediaminetetraacetic acid (EDTA). Each plays a specific role—sodium hypochlorite dissolves organic matter, chlorhexidine provides antimicrobial activity and EDTA removes inorganic smear layers. The use of ultrasonic or laser-assisted irrigation enhances penetration into complex anatomical structures, increasing the efficacy of these solutions.[22]

Bioceramic materials have revolutionized the sealing and repair of periapical tissues. Bioceramic sealers exhibit superior biocompatibility, antimicrobial properties and sealing capabilities, significantly reducing the risk of reinfection. Furthermore, regenerative approaches, such as the application of platelet-rich fibrin and stem cell-based therapies, are showing promise in restoring periapical health by promoting tissue regeneration rather than mere healing. Adjunctive treatments such as antimicrobial photodynamic therapy and probiotics are

gaining traction. Antimicrobial photodynamic therapy uses light-activated agents to target microbial cells selectively, minimizing collateral damage to host tissues. Probiotics, on the other hand, aim to restore microbial homeostasis by introducing beneficial bacteria, reducing the dominance of pathogenic species. Both approaches hold potential for improving outcomes in refractory cases.[23]

Prognostic indicators

The prognosis of persistent periapical lesions depends on a combination of clinical, radiographic and systemic factors. Lesion size and radiodensity are often predictive of treatment success, with larger lesions and those with diffuse radiolucency showing poorer healing rates. Patient-specific factors, such as age, immune status and systemic conditions like diabetes, also play a significant role. Chronic systemic inflammation from conditions such as diabetes or cardiovascular disease can impede tissue repair, necessitating a multidisciplinary approach to care.[24]

Long-term studies suggest that preoperative microbial diversity can serve as a prognostic marker. Lesions dominated by resistant or virulent species such as *Enterococcus faecalis* and *Candida albicans* are less likely to respond to conventional treatments. Identifying these pathogens early allows for tailored interventions, improving the chances of resolution. Additionally, advancements in artificial intelligence are enabling predictive analytics in endodontics. Artificial intelligence algorithms can analyze imaging data to assess healing potential, guiding clinicians toward more effective treatment strategies.

Systemic and interdisciplinary implications

Persistent periapical lesions are increasingly linked to systemic health concerns, highlighting the need for interdisciplinary collaboration. Chronic inflammation from these lesions has been implicated in systemic conditions such as atherosclerosis and adverse pregnancy outcomes. For example, bacterial endotoxins from oral pathogens can enter the bloodstream, exacerbating systemic inflammatory responses. Close coordination between dental and medical teams is essential to manage patients with comorbidities effectively.[25] Emerging evidence also suggests that managing systemic inflammation may improve periapical healing. Anti-inflammatory medications and lifestyle interventions targeting overall health can complement endodontic treatments, offering a holistic approach to patient care.

Future directions

Regenerative endodontics, leveraging stem cell technology and growth factors, represents the future of treatment for persistent periapical lesions. By focusing on biological repair rather than mechanical intervention, these approaches aim to restore the natural architecture and function of periapical tissues. Moreover, AI-driven diagnostics and real-time monitoring technologies promise to revolutionize the management of these lesions, ensuring personalized care that adapts to each patient's unique needs.[26]

CONCLUSION

Persistent periapical lesions are a complex interplay of microbial, host and environmental factors, requiring advanced diagnostic, therapeutic and prognostic approaches. Innovations such as CBCT, molecular diagnostics and regenerative therapies are transforming their management. Addressing systemic links highlights the need for interdisciplinary care to optimize outcomes. Future advancements in AI and regenerative endodontics promise to enhance personalized treatment strategies, improving patient care significantly.

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REFERENCES

1. Handal T, Caugant DA, Olsen I, Sunde PT. Bacterial diversity in persistent periapical lesions on root-filled teeth. J Oral Microbiol. 2009;1(1):1946.
2. Pereira R, Rodrigues VAA, Furtado W, Gueiros S, Pereira G, Avila-Campos MJ. Microbial analysis of root canal and periradicular lesion associated to teeth with endodontic failure. Anaerobe. 2017;48:12-8.
3. Siqueira Jr JF, Rôças IN. Clinical implications and microbiology of bacterial persistence after treatment procedures. J Endo. 2008;34(11):1291-301.
4. Tzanetakis GN, Azcarate-Peril MA, Zachaki S. Comparison of bacterial community composition of primary and persistent endodontic infections using pyrosequencing. Journal of Endo. 2015;41(8):1226-33.
5. Subramanian K, Mickel AK. Molecular analysis of persistent periradicular lesions and root ends reveals a diverse microbial profile. J of Endodontics. 2009;35(7):950-7.
6. Cavalla F, Letra A, Silva RM, Garlet G. Determinants of periodontal/periapical lesion stability and progression. J of Dental Research. 2021;100(1):29-36.
7. Arias-Moliz MT, Pérez-Carrasco V, Uroz-Torres D, Santana Ramos JD, García-Salcedo JA, Soriano M. Identification of keystone taxa in root canals and periapical lesions of post-treatment endodontic infections: Next generation microbiome research. Inter Endodon J. 2024;5:78-9.
8. Gan G, Luo Y, Zeng Y. Gut microbiota dysbiosis links chronic apical periodontitis to liver fibrosis in nonalcoholic fatty liver disease: Insights from a mouse model. Int Endo J. 2024;57(11):1608-22.

9. Wang W, Qu Y, Chen H, Huang L, Gu L. The microbial co-infection interaction network in apical periodontitis with sinus tracts. J Dent. 2025;153:105496.
10. Lin B, Wang J, Zhang Y. Bacterial dynamics in the progression of caries to apical periodontitis in primary teeth of children with severe early childhood caries. Frontiers in Microbiol. 2024;15:1418261.
11. Gan G, Zhang R, Zeng Y. Fecal microbiota transplantation validates the importance of gut microbiota in an ApoE−/− mouse model of chronic apical periodontitis-induced atherosclerosis. BMC Oral Health. 2024;24(1):1455.
12. Mehta RJ. The interplay between gut dysbiosis and diabetic nephropathy: implications for treatment and management. Clin Diabetol. 2024;13(4):189-92.
13. Ma R, Deng Z, Du Q. *Enterococcus faecalis* extracellular vesicles promote apical periodontitis. J Dental Res. 2024;103(6):672-82.
14. Colaco AS. Extreme resistance of *Enterococcus faecalis* and its role in endodontic treatment failure. Prog Med Sci. 2018;2(1):9-13.
15. Sato Y, Kishi J, Suzuki K, Nakamura H, Hayakawa T. Sonic extracts from a bacterium related to periapical disease activate gelatinase A and inactivate tissue inhibitor of metalloproteinases TIMP-1 and TIMP-2. Int Endod J. 2009;42(12):1104-11.
16. Bronzato JD, Davidian M, de Castro M. Bacteria and virulence factors in periapical lesions associated with teeth following primary and secondary root canal treatment. Int Endo J. 2021;54(5):660-671.
17. Kumar J, Sharma R, Sharma M, Prabhavathi V, Paul J, Chowdary CD. Presence of Candida albicans in root canals of teeth with apical periodontitis and evaluation of their possible role in failure of endodontic treatment. J Int Oral Health: JIOH. 2015;7(2):42.
18. Jain H, Mulay S, Mullany P. Persistence of endodontic infection and Enterococcus faecalis: Role of horizontal gene transfer. Gene reports. 2016;5:112-6.
19. Yoshida S, Nakazawa M, Kawasaki M, Ambrosini YM. Bacterial attachment and junctional transport function in induced apical-out polarized and differentiated canine intestinal organoids. Frontiers in Veterinary Science. 2024;11:1483421.
20. Karamifar K, Tondari A, Saghiri MA. Endodontic periapical lesion: an overview on the etiology, diagnosis and current treatment modalities. European Endod J. 2020;5(2):54.
21. Kruse C, Spin-Neto R, Reibel J, Wenzel A, Kirkevang L-L. Diagnostic validity of periapical radiography and CBCT for assessing periapical lesions that persist after endodontic surgery. Dentomaxillofacial Radiol. 2017;46(7):87-9.
22. Çalışkan M, Kaval M, Tekin U, Ünal T. Radiographic and histological evaluation of persistent periapical lesions associated with endodontic failures after apical microsurgery. Int Endo J. 2016;49(11):1011-9.
23. Abbott PV. Classification, diagnosis and clinical manifestations of apical periodontitis. Endodontic topics. 2004;8(1):36-54.
24. Segura-Egea JJ, Martín-González J, Cabanillas-Balsera D, Fouad AF, Velasco-Ortega E, López-López J. Association between diabetes and the prevalence of radiolucent periapical lesions in root-filled teeth: systematic review and meta-analysis. Clinical oral investigations. 2016;20:1133-41.
25. Restrepo-Restrepo F, Cañas-Jiménez S, Romero-Albarracín R, Villa-Machado P, Pérez-Cano M, Tobón-Arroyave S. Prognosis of root canal treatment in teeth with preoperative apical periodontitis: a study with cone-beam computed tomography and digital periapical radiography. International endodontic journal. 2019;52(11):1533-46.
26. Rotstein I, Simon JH. The endo-perio lesion: a critical appraisal of the disease condition. Endodontic Topics. 2006;13(1):34-56.

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