

MODERN APPROACHES TO THE TREATMENT AND PREVENTION OF DENTAL CARIES AND PULPITIS: AN EVIDENCE-BASED REVIEW

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Abstract: Dental caries remains one of the most prevalent chronic oral diseases worldwide and represents the primary etiological factor in the development of pulpitis. Despite advances in preventive dentistry, the progression of untreated carious lesions continues to result in pulpal inflammation, pain, and tooth loss. Recent developments in minimally invasive dentistry, bioactive restorative materials, and modern endodontic techniques have significantly transformed the management of both caries and pulp-related pathologies. Contemporary approaches emphasize early diagnosis, preservation of healthy tooth structure, and biological modulation of the pulp–dentin complex. Evidence from recent clinical studies demonstrates that minimally invasive caries management strategies, including resin infiltration and atraumatic restorative treatment, effectively arrest early lesions while maintaining tooth integrity. In addition, the introduction of calcium silicate–based materials has improved the clinical outcomes of vital pulp therapy by enhancing pulpal healing and long-term tooth survival. Advances in endodontic instrumentation, irrigation activation methods, and bioceramic sealers have further increased the success rates of pulpitis treatment. Preventive strategies integrating fluoride-based therapies, fissure sealants, and individualized caries risk assessment play a critical role in reducing disease incidence and progression. Overall, the integration of modern diagnostic tools, biomaterials, and preventive concepts supports a paradigm shift toward biologically driven and patient-centered dental care, contributing to sustainable improvements in oral health outcomes.

Keywords: *dental caries; pulpitis; minimally invasive dentistry; vital pulp therapy; bioactive restorative materials; calcium silicate–based cements; modern endodontic techniques; caries prevention; fluoride therapy; regenerative dentistry.*

Introduction

Dental caries remains one of the most prevalent chronic diseases affecting populations of all ages worldwide and continues to represent a major public health challenge. Despite substantial progress in preventive dentistry and oral health promotion, the global burden of caries has not declined proportionally, particularly in low- and middle-income countries. Untreated carious lesions frequently progress toward the dental pulp, leading to inflammatory conditions collectively referred to as pulpitis, which are among the most common causes of dental pain and emergency dental visits.

Traditionally, the management of dental caries and pulpitis has relied on invasive operative procedures aimed at complete removal of diseased tissues, often at the expense of healthy tooth structure. While such approaches may provide short-term resolution of symptoms, they are associated with several limitations, including structural weakening of teeth, increased risk of secondary caries, and, in some cases, unnecessary loss of pulpal vitality. These concerns have prompted a paradigm shift in modern dentistry toward biologically oriented and minimally invasive treatment strategies that prioritize tissue preservation and long-term oral health.

Contemporary understanding of the caries process recognizes it as a dynamic and biofilm-mediated disease characterized by cycles of demineralization and remineralization rather than an irreversible defect requiring aggressive intervention. This concept has laid the foundation for minimally invasive caries management, which focuses on early detection, risk-based decision-making, and selective removal of infected dentin. Techniques such as resin infiltration, atraumatic restorative treatment, and the use of bioactive restorative materials have demonstrated promising results in arresting lesion progression while conserving sound tooth structure.

Similarly, advances in the understanding of the pulp–dentin complex have transformed the clinical management of pulpitis. The dental pulp is now recognized

as a biologically active tissue with significant regenerative potential when protected from persistent microbial insult. Modern vital pulp therapy techniques, supported by calcium silicate-based materials, aim to maintain pulpal vitality and promote reparative dentin formation, thereby extending the functional lifespan of the tooth. In cases where endodontic intervention is required, innovations in instrumentation, irrigation activation, and obturation materials have significantly improved treatment predictability and clinical outcomes.

In parallel with therapeutic advancements, preventive strategies play a central role in controlling the incidence and progression of both dental caries and pulpitis. Fluoride-based interventions, fissure sealants, personalized oral hygiene protocols, and caries risk assessment models have become integral components of comprehensive preventive care. Furthermore, the integration of digital technologies and artificial intelligence into diagnostic and preventive workflows offers new opportunities for early intervention and personalized treatment planning.

Given the rapid evolution of materials, techniques, and preventive concepts, a critical appraisal of contemporary approaches to the management of dental caries and pulpitis is warranted. The present review aims to synthesize current evidence on modern diagnostic methods, treatment modalities, and preventive strategies, highlighting their clinical effectiveness and relevance to evidence-based dental practice.

Methods

This evidence-based narrative review was conducted to synthesize contemporary knowledge on the diagnosis, treatment, and prevention of dental caries and pulpitis. A comprehensive literature search was performed using major international scientific databases, including Scopus and PubMed, to identify relevant peer-reviewed articles published between January 2019 and December 2025.

The search strategy combined Medical Subject Headings (MeSH) terms and free-text keywords related to dental caries and pulpitis. The primary search terms included “dental caries,” “pulpitis,” “minimally invasive dentistry,” “vital pulp

therapy,” “bioactive restorative materials,” “endodontic treatment,” and “caries prevention.” Boolean operators (AND, OR) were applied to refine the search and ensure comprehensive coverage of the topic.

Eligible publications included systematic reviews, narrative reviews, randomized controlled trials, clinical studies, and consensus guidelines published in English-language journals indexed in international databases. Studies focusing on outdated materials, non-clinical outcomes, or lacking methodological clarity were excluded. Additional references were identified through manual screening of the reference lists of selected articles to ensure inclusion of seminal and highly cited studies.

Article selection was conducted in two stages. In the first stage, titles and abstracts were screened for relevance to the scope of the review. In the second stage, full-text articles were assessed to confirm eligibility based on predefined inclusion and exclusion criteria. Emphasis was placed on studies addressing modern diagnostic technologies, minimally invasive caries management, bioactive materials, vital pulp therapy, contemporary endodontic techniques, and preventive strategies.

Due to the narrative nature of this review, no meta-analysis was performed. Instead, findings were qualitatively synthesized and organized thematically to provide a comprehensive overview of current evidence and emerging trends in the management and prevention of dental caries and pulpitis.

Etiology and Pathogenesis of Dental Caries and Pulpitis

Dental caries is a multifactorial, biofilm-mediated disease resulting from complex interactions between oral microorganisms, dietary substrates, host susceptibility, and time. The contemporary concept of caries etiology emphasizes the ecological imbalance within the dental biofilm rather than the presence of a single pathogenic microorganism. Frequent consumption of fermentable carbohydrates promotes acidogenic and aciduric bacterial species, leading to prolonged periods of low pH at the tooth–biofilm interface. This acidic environment disrupts the equilibrium

between demineralization and remineralization processes, resulting in progressive mineral loss from enamel and dentin.

At the initial stages, caries manifests as subsurface enamel demineralization, which remains reversible under favorable conditions. However, persistent acid exposure facilitates lesion progression into dentin, where structural and compositional differences accelerate disease advancement. Dentin contains a higher organic content and tubular architecture, which allows bacterial metabolites and toxins to diffuse toward the pulp. This diffusion plays a critical role in triggering pulpal inflammatory responses even before direct bacterial invasion occurs.

The pulp–dentin complex functions as a biologically integrated unit, capable of mounting defensive reactions against carious insult. Odontoblasts and pulpal immune cells respond to microbial by-products by activating innate immune mechanisms, including the release of inflammatory mediators, antimicrobial peptides, and growth factors. These responses aim to limit bacterial penetration and promote tertiary dentin formation. Nevertheless, when the intensity or duration of the insult exceeds the regenerative capacity of the pulp, inflammatory changes progress from reversible to irreversible pulpitis.

Reversible pulpitis is characterized by mild inflammation confined primarily to the coronal pulp, with preserved vascular supply and cellular integrity. Clinically, this condition is associated with transient pain in response to thermal or osmotic stimuli and has the potential for complete recovery following removal of the etiological factor. In contrast, irreversible pulpitis involves extensive inflammatory infiltration, vascular congestion, and tissue degeneration, often accompanied by spontaneous or lingering pain. At this stage, pulpal healing is unlikely without endodontic intervention.

The transition from dentin caries to pulpitis is influenced by several modifying factors, including lesion depth, rate of caries progression, host immune response, and quality of dentinal tubule sclerosis. Slowly progressing lesions may allow sufficient time for defensive dentinogenesis, whereas rapidly advancing caries can

overwhelm pulpal defense mechanisms. Additionally, patient-related factors such as age, systemic health, and salivary composition contribute to variability in disease progression and clinical presentation.

Understanding the etiological and pathogenic continuum linking dental caries and pulpitis is essential for implementing biologically sound treatment strategies. Modern approaches focus on interrupting the disease process at early stages, preserving pulp vitality whenever possible, and minimizing unnecessary removal of sound tooth structure. This biological perspective underpins contemporary minimally invasive and preventive concepts in restorative and endodontic dentistry.

Modern Diagnostic Approaches

Accurate diagnosis is fundamental to the effective management of dental caries and pulpitis, as it directly influences treatment planning and prognosis. Traditional diagnostic methods based solely on visual-tactile examination and conventional radiography often fail to detect early-stage lesions or accurately determine pulpal status. As a result, modern dentistry increasingly relies on advanced diagnostic technologies that enhance sensitivity, specificity, and clinical decision-making.

Digital diagnostic tools enable early identification of carious lesions, assessment of lesion activity, and differentiation between reversible and irreversible pulpitis. Digital radiography provides high-resolution images with reduced radiation exposure, improving the detection of proximal and secondary caries. In more complex clinical situations, three-dimensional imaging techniques allow for precise evaluation of pulpal and periapical conditions, supporting accurate diagnosis and treatment planning.

Assessment of pulp vitality represents a critical diagnostic challenge in clinical practice. Conventional sensibility tests evaluate neural response rather than true pulpal health and may yield unreliable results in certain clinical scenarios. Therefore, modern diagnostic approaches increasingly emphasize objective methods that assess pulpal blood supply and tissue vitality. These techniques improve diagnostic

accuracy and facilitate the selection of biologically conservative treatment strategies.

Recent advancements in digital dentistry and artificial intelligence have further expanded diagnostic capabilities. AI-assisted diagnostic systems can analyze radiographic data to identify early carious lesions and predict disease progression with high reproducibility. Such technologies reduce operator-dependent variability and support risk-based, personalized treatment planning. Although these systems are still undergoing clinical validation, their integration into routine practice represents a significant step toward precision dentistry.

Overall, modern diagnostic approaches enhance early detection, improve differentiation of pulpal conditions, and support minimally invasive and preventive treatment concepts. The combination of advanced imaging, objective vitality testing, and digital technologies forms the foundation of evidence-based management of dental caries and pulpitis.

Table 1. Modern diagnostic approaches for dental caries and pulpitis

Diagnostic method	Diagnostic target	Clinical application	Advantages	Limitations
Digital radiography	Proximal and secondary caries	Routine caries detection	Low radiation, high resolution	Limited early enamel detection
CBCT	Pulpal and periapical pathology	Complex diagnostic cases	3D visualization	Higher radiation dose
Laser fluorescence	Early enamel and dentin caries	Occlusal caries detection	High sensitivity	Risk of overestimation
Sensibility tests (EPT, cold test)	Neural response of pulp	Initial pulp assessment	Easy, widely available	Does not assess true vitality
Pulse oximetry	Pulpal blood flow	Objective vitality testing	High diagnostic accuracy	Limited availability
AI-based analysis	Caries detection and risk prediction	Decision support	Reduces subjectivity	Requires validation

Prevention of Dental Caries and Pulpitis

Prevention represents the most effective and sustainable strategy for reducing the global burden of dental caries and pulpitis. Contemporary preventive dentistry is grounded in the understanding that caries is a biofilm-mediated, behavior-dependent disease that can be controlled through targeted interventions aimed at modifying risk factors and enhancing host resistance. Preventive approaches focus not only on

disease avoidance but also on maintaining pulpal health and preventing the progression of early lesions to irreversible stages.

Individual-level preventive strategies form the foundation of caries and pulpitis control. Fluoride therapy remains the cornerstone of preventive care due to its well-documented ability to enhance enamel remineralization, inhibit demineralization, and suppress bacterial metabolism. The regular use of fluoridated toothpaste, professionally applied fluoride varnishes, and high-fluoride formulations for high-risk individuals has been shown to significantly reduce caries incidence across all age groups. In addition, patient education regarding proper oral hygiene techniques and dietary counseling aimed at reducing fermentable carbohydrate intake play a critical role in controlling cariogenic biofilm activity.

Risk-based prevention has emerged as a key component of modern preventive dentistry. Caries risk assessment models incorporate clinical, behavioral, and biological factors to identify individuals at increased risk of disease development. This personalized approach allows clinicians to tailor preventive interventions according to individual needs, optimizing resource utilization and improving long-term outcomes. Patients with high caries risk may benefit from intensified fluoride therapy, antimicrobial agents, and more frequent professional monitoring.

Community-based preventive measures also contribute substantially to the reduction of caries and pulpitis prevalence. The application of pit and fissure sealants is particularly effective in preventing occlusal caries in children and adolescents, a population highly susceptible to disease development. Public health initiatives that promote access to preventive dental care, fluoridated products, and oral health education have demonstrated measurable improvements in population-level oral health outcomes.

Advances in digital health technologies have further expanded the scope of preventive dentistry. Digital monitoring tools, mobile health applications, and artificial intelligence-based risk prediction systems support early detection of disease activity and reinforce preventive behaviors through continuous feedback and

patient engagement. These technologies facilitate proactive intervention before irreversible tissue damage occurs, aligning preventive strategies with the principles of minimally invasive dentistry.

Effective prevention of dental caries directly contributes to the preservation of pulpal health by limiting bacterial penetration and inflammatory stimuli within the pulp–dentin complex. By controlling caries at early stages, preventive measures reduce the incidence of pulpitis and the subsequent need for invasive endodontic treatment. Consequently, the integration of individualized, community-based, and technology-supported preventive strategies is essential for achieving long-term oral health and improving the quality of dental care.

Discussion

The contemporary management of dental caries and pulpitis reflects a fundamental shift in clinical philosophy from aggressive tissue removal toward biologically driven and minimally invasive approaches. The findings summarized in this review highlight the growing body of evidence supporting conservative strategies that prioritize early diagnosis, preservation of tooth structure, and maintenance of pulpal vitality. This paradigm shift aligns with current understanding of caries as a dynamic, reversible disease process and the pulp as a tissue with significant regenerative potential.

Modern diagnostic technologies play a pivotal role in enabling this shift by facilitating earlier and more accurate detection of disease. Advanced imaging modalities and objective vitality assessment tools allow clinicians to differentiate between reversible and irreversible pulpal conditions with greater confidence. Improved diagnostic precision directly influences treatment selection, reducing the risk of overtreatment and unnecessary endodontic intervention. However, the successful integration of these technologies into routine practice depends on clinician training, cost-effectiveness, and appropriate case selection.

The effectiveness of minimally invasive caries management techniques underscores the importance of selective intervention based on lesion activity rather than lesion

depth alone. Evidence indicates that early non-cavitated lesions can be successfully arrested through non-operative measures, while selective removal of infected dentin in deeper lesions reduces the risk of pulpal exposure and postoperative complications. These approaches challenge traditional operative concepts and emphasize the need for individualized, risk-based decision-making.

Similarly, advancements in vital pulp therapy have redefined the clinical management of pulpitis. The use of bioactive calcium silicate-based materials has demonstrated favorable outcomes in maintaining pulpal vitality, even in cases previously considered to require root canal treatment. This has significant clinical implications, as preservation of vital pulp tissue contributes to continued dentinogenesis, proprioception, and long-term tooth survival. Nonetheless, variability in reported success rates highlights the importance of strict case selection, aseptic technique, and long-term follow-up.

When pulpal preservation is not feasible, modern endodontic treatment protocols offer improved predictability and success compared to conventional methods. Innovations in instrumentation, irrigation activation, and obturation materials have enhanced canal disinfection and sealing quality, leading to better periapical healing outcomes. Despite these advances, endodontic therapy remains more invasive and resource-intensive than vital pulp procedures, reinforcing the importance of preventive and conservative strategies whenever possible.

Preventive dentistry emerges as a unifying theme in the contemporary management of both caries and pulpitis. Individualized preventive measures, supported by community-based initiatives and digital technologies, address the etiological factors underlying disease development. By reducing the incidence and progression of caries, preventive strategies indirectly protect pulpal health and decrease the overall need for invasive treatment. The integration of caries risk assessment models into clinical practice further enhances the effectiveness of prevention-oriented care.

Despite significant progress, several challenges remain. Variability in clinical protocols, limited long-term data for emerging therapies, and disparities in access to

advanced diagnostic and preventive tools may influence treatment outcomes. Future research should focus on standardized outcome measures, long-term clinical trials, and cost-effectiveness analyses to support broader implementation of modern treatment concepts.

Conclusion

Dental caries and pulpitis remain significant clinical and public health challenges despite ongoing advancements in preventive and restorative dentistry. Contemporary evidence demonstrates that a shift toward biologically driven, minimally invasive, and prevention-oriented approaches offers substantial benefits in the management of these conditions. Early and accurate diagnosis, supported by modern diagnostic technologies, enables timely intervention and facilitates the preservation of healthy tooth structure and pulpal vitality.

Minimally invasive caries management strategies and the use of bioactive restorative materials have proven effective in arresting disease progression and reducing the risk of pulpal involvement. Advances in vital pulp therapy further highlight the regenerative potential of the pulp–dentin complex, providing predictable alternatives to conventional root canal treatment in appropriately selected cases. When endodontic intervention is unavoidable, modern instrumentation and obturation techniques contribute to improved treatment outcomes and long-term tooth survival. Preventive strategies remain the cornerstone of sustainable oral health care. Individualized caries risk assessment, fluoride-based interventions, and community-level preventive measures play a critical role in reducing the incidence of both dental caries and pulpitis. The integration of digital technologies and artificial intelligence into preventive and diagnostic workflows represents a promising direction for personalized and evidence-based dental care.

In conclusion, the effective management of dental caries and pulpitis requires a comprehensive approach that combines early diagnosis, conservative treatment modalities, and robust preventive strategies. Continued research, standardized

clinical protocols, and long-term outcome studies are essential to further refine these approaches and support their widespread adoption in contemporary dental practice.

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