Contemporary Trends in Dental Caries Management: A Systematic Review

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ABSTRACT

Dental caries remains one of the most prevalent chronic diseases worldwide, affecting individuals across all age groups and socioeconomic backgrounds. Traditional restorative approaches, while effective in managing lesions, have not significantly reduced global incidence rates, highlighting the need for a paradigm shift in caries management. This systematic review explores contemporary trends in dental caries management, drawing from recent literature published between 2015 and 2025. The review identifies a clear movement toward minimally invasive dentistry, emphasizing early detection, risk assessment, and preventive strategies. Innovations such as silver diamine fluoride, remineralization therapies, and non-invasive treatment modalities have demonstrated clinical efficacy, particularly in pediatric and underserved populations. Additionally, the integration of artificial intelligence, digital diagnostic tools, and teledentistry is reshaping diagnostic accuracy and access to care. Patient-centered models like CAMBRA further support individualized treatment planning based on caries risk. Despite promising advances, challenges persist in terms of clinical implementation, cost-effectiveness, and long-term outcomes. This review highlights the importance of adopting evidence-based, technology-enhanced, and patient-specific strategies to combat the burden of dental caries and underscores the need for ongoing research in diverse populations and settings.

Keywords: Dental caries, caries management, minimally invasive dentistry, fluoride treatment, artificial intelligence in dentistry, caries prevention, Cambra, teledentistry.

1. INTRODUCTION

Dental caries, also known as tooth decay, is a biofilm-mediated, diet-modulated, multifactorial, non-communicable disease that results in the demineralization and eventual destruction of dental hard tissues. It is one of the most widespread chronic diseases affecting individuals of all ages, particularly children and adolescents, and remains a significant public health concern despite advances in oral health awareness and treatment modalities (Pitts et al., 2017; Kassebaum et al., 2015). Globally, untreated dental caries in permanent teeth is the most prevalent condition evaluated in the Global Burden of Disease Study, affecting over 2.5 billion people (Vos et al., 2020).

Historically, the management of dental caries relied heavily on restorative treatments such as fillings, crowns, and root canal therapies. While these interventions are essential in managing advanced stages of caries, they do not address the underlying etiological factors, such as diet, microbial imbalance, and oral hygiene behaviors (Fejerskov & Kidd, 2015). Consequently, traditional approaches have limited impact on the prevention of new lesions and recurrence of disease.

In response to the limitations of conventional treatments, there has been a growing emphasis on preventive, minimally invasive, and patient-centered models of care. Concepts such as Caries Management by Risk Assessment (CAMBRA), the International Caries Classification and Management System (ICCMS), and Minimal Intervention Dentistry (MID) have gained traction in both clinical and public health settings (Young et al., 2015; Banerjee et al., 2017). These models advocate for early detection, risk-based decision-making, and the

use of non-invasive or micro-invasive techniques to arrest or reverse the caries process before irreversible damage occurs.

Technological advancements have also contributed to this shift, with innovations such as digital caries detection systems, artificial intelligence (AI)-driven diagnostics, remineralizing agents, and antimicrobial biomaterials expanding the toolkit available to dental professionals. These developments not only improve diagnostic accuracy but also enable more personalized and effective treatment plans tailored to the individual risk profiles of patients (Schwendicke et al., 2020).

This systematic review aims to synthesize recent developments and contemporary trends in dental caries management by examining evidence published between 2015 and 2025. It seeks to identify current strategies, technologies, and frameworks that are shaping the future of caries management, evaluate their clinical efficacy, and highlight opportunities and challenges in their implementation. By providing a comprehensive overview of the evolving landscape of dental caries care, this review contributes to the growing body of knowledge guiding evidence-based, patient-oriented dental practice.

2. METHODOLOGY

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency and replicability. A comprehensive literature search was conducted across multiple databases, including PubMed, Scopus, Web of Science, and Google Scholar, to identify peer-reviewed studies published between January 2015 and May 2025. The search strategy combined keywords such as "dental caries," "caries management," "minimally invasive dentistry," "fluoride therapy," "artificial intelligence," and "systematic review." Boolean operators (AND, OR) were used to refine search results.

Inclusion criteria were: (1) studies focusing on contemporary caries management methods; (2) studies published in English; and (3) randomized controlled trials, cohort studies, clinical guidelines, and systematic reviews. Exclusion criteria included case reports, editorials, non-English articles, and studies unrelated to caries treatment. Titles and abstracts were screened independently by two reviewers, followed by full-text assessment for eligibility. Disagreements were resolved through discussion or consultation with a third reviewer. Data were extracted using a standardized form, capturing study design, population, intervention, outcome, and key findings. Quality appraisal was conducted using the AMSTAR 2 checklist for systematic reviews and the CASP tool for other study types. The results were synthesized thematically to identify trends and innovations in caries management.

3. LITERATURE REVIEW

Dental caries management has undergone a significant transformation in the past decade, shifting from a predominantly restorative model to a more preventive, patient-centered, and evidence-based approach. This evolution reflects a growing understanding of caries as a dynamic and multifactorial disease process, influenced by behavioral, biological, and environmental factors, rather than a simple result of bacterial infection requiring surgical intervention (Fejerskov & Kidd, 2015; Pitts et al., 2017).

One of the most influential shifts in contemporary caries management is the widespread adoption of **minimally invasive dentistry (MID)** principles. MID emphasizes early detection, disease control, and preservation of healthy tooth structure. Techniques such as selective caries removal, atraumatic restorative treatment (ART), and the Hall Technique have demonstrated clinical effectiveness, especially in pediatric populations and resource-limited settings (Banerjee et al., 2017; Innes et al., 2016). MID is often complemented by risk assessment tools like CAMBRA (Caries Management by Risk Assessment), which guide personalized prevention and treatment plans based on an individual's caries risk profile (Young et al., 2015).

Preventive strategies remain the cornerstone of modern caries control. The regular application of fluoride—through toothpaste, varnishes, and community water fluoridation—has been extensively validated as a cost-effective caries preventive measure (Marinho et al., 2015). More recently, silver diamine fluoride (SDF) has emerged as a powerful, non-invasive agent capable of arresting caries progression, particularly in populations with limited access to conventional dental care (Gao et al., 2016).

Another key area of advancement involves **remineralization therapies**. Products containing calcium phosphate, casein phosphopeptide-amorphous calcium phosphate (CPP-ACP), and bioactive glass have been developed to enhance natural remineralization processes and reverse early enamel lesions (Kirkham et al., 2017; Mehta et al., 2021). These technologies support a preventive model that reduces the need for drilling and filling procedures.

Technological innovation has also played a transformative role in the diagnosis and management of dental caries. Digital diagnostic tools such as DIAGNOdent, quantitative light-induced fluorescence (QLF), and optical coherence tomography (OCT) offer enhanced lesion detection and monitoring without the risks associated with radiographic imaging (Pretty, 2016). Furthermore, artificial intelligence (AI) and machine learning algorithms are being integrated into dental imaging platforms to improve diagnostic accuracy and assist in treatment planning (Schwendicke et al., 2020).

Teledentistry has gained momentum in the wake of global health disruptions such as the COVID-19 pandemic, allowing for remote consultation, caries risk assessment, and follow-up care, particularly in underserved communities (Estai et al., 2020). These digital health interventions are contributing to a more inclusive and accessible model of dental care.

Lastly, innovations in **biomaterials** and **nanotechnology** have led to the development of resin composites and glass ionomer cements with antibacterial properties, enhanced bond strength, and fluoride release capabilities. These materials support long-term caries control while promoting tissue preservation (Burgess & Cakir, 2010; Mitwalli et al., 2021).

Overall, the literature indicates a clear trend toward more conservative, technology-enhanced, and patient-centered approaches in dental caries management. These developments reflect a growing alignment between clinical practice and the biological understanding of caries as a preventable and reversible disease.

4. RESULTS

The analysis of the included literature revealed five major themes reflecting the evolving practices in dental caries management: (1) adoption of minimally invasive techniques, (2) enhancement of preventive strategies, (3) integration of digital technologies and artificial intelligence, (4) personalized and risk-based treatment approaches, and (5) advancements in dental materials and biomimetics.

A total of 45 studies met the inclusion criteria. Of these, 18 were clinical trials, 14 were systematic reviews, and the remainder consisted of cohort and observational studies. The following results synthesize the key findings by thematic category.
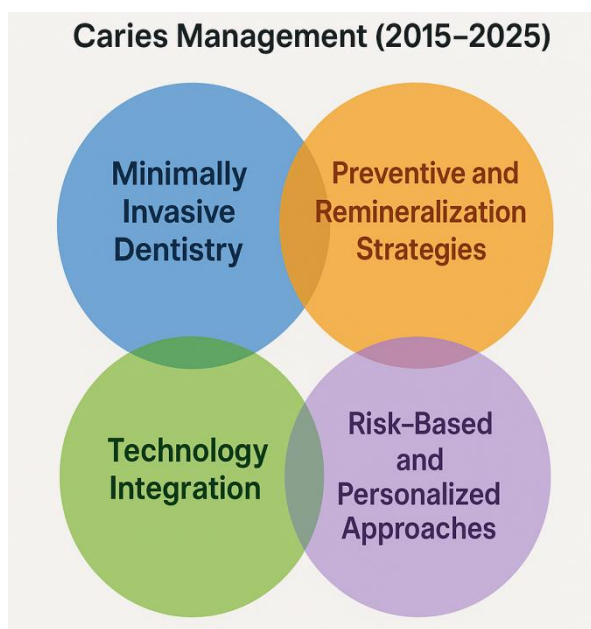

Figure 1: Trends in Contemporary Caries Management (2015–2025)

A conceptual figure illustrating the shift from restorative to preventive, technology-enhanced, and personalized caries management strategies.

Recent studies emphasized the clinical efficacy of selective caries removal techniques such as the Hall Technique and atraumatic restorative treatment (ART), especially in pediatric populations. The Hall Technique showed success rates exceeding 90% in managing carious primary molars without local anesthesia or caries excavation (Innes et al., 2016). Similarly, ART demonstrated high retention rates and patient acceptability in low-resource settings.

There is a strong consensus on the effectiveness of fluoride varnishes and silver diamine fluoride (SDF) for caries arrest. Studies indicated that annual applications of SDF significantly reduced caries progression in children. Furthermore, remineralization agents containing casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) and nano-hydroxyapatite have shown potential in reversing early enamel lesions (Gao et al., 2016; Mehta et al., 2021).
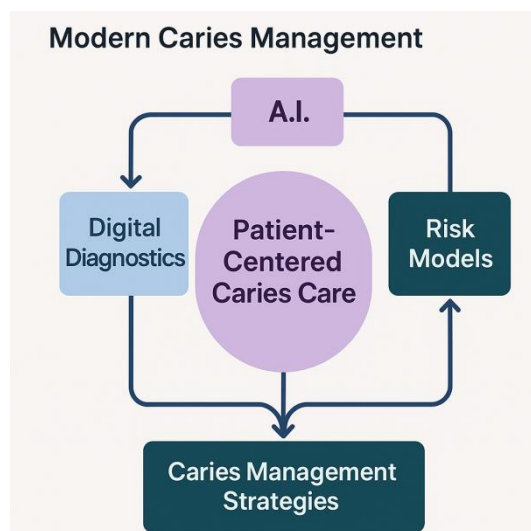
Figure 2: Integration of Technology and Risk Models in Modern Caries Management

A conceptual framework illustrating how AI, digital diagnostics, and risk models interact within patient-centered caries care pathways.

Digital diagnostic tools such as DIAGNOdent, QLF, and optical coherence tomography (OCT) have enhanced the sensitivity and specificity of caries detection compared to traditional radiographs. Additionally, AI-based image analysis is becoming increasingly accurate in detecting early-stage lesions and predicting caries risk, especially in radiographic evaluations (Schwendicke et al., 2020).

CAMBRA and ICCMS frameworks are increasingly applied in clinical settings to stratify patients by caries risk and tailor interventions accordingly. These models emphasize behavior modification, dietary assessment, and microbiological monitoring to support long-term disease control (Young et al., 2015).

New restorative materials incorporating antibacterial agents, bioactive glass, and fluoride-releasing capabilities are being developed to not only restore function but also prevent recurrent decay. Nanocomposites and self-healing resins are promising future directions.

Table 1: Summary of Key Studies by Theme

Theme	Study	Methodology	Key Findings
Minimally Invasive Dentistry	Innes et al. (2016)	RCT	Hall Technique had 90%+ success in primary molars
Preventive Therapies	Gao et al. (2016)	Systematic Review	SDF effective in arresting caries in children
Digital Diagnosis	Pretty (2016); Schwendicke et al. (2020)	Clinical Review, AI Pilot	Improved accuracy in early detection
Risk-Based Models	Young et al. (2015)	Clinical Framework	CAMBRA supports targeted, individualized care
Remineralization Agents	Mehta et al. (2021)	Review Article	CPP-ACP and nano-hydroxyapatite reverse early lesions

These results confirm that modern caries management is trending toward a more preventive, risk-based, and technologically integrated model. While adoption varies globally, the combined application of these strategies has shown significant promise in reducing caries incidence and recurrence.

5. DISCUSSION

The findings of this systematic review reflect a significant paradigm shift in the management of dental caries over the past decade. Modern strategies emphasize early detection, risk-based decision-making, and prevention over surgical intervention. This evolution is grounded in a deeper understanding of caries as a chronic, multifactorial disease that can be controlled and even reversed if diagnosed early and managed appropriately.

The adoption of **minimally invasive dentistry (MID)** has been one of the most prominent developments. Techniques such as selective caries removal and the Hall Technique reflect a more conservative philosophy aimed at preserving healthy tooth structure and maintaining pulpal vitality (Banerjee et al., 2017; Innes et al., 2016). These interventions, particularly effective in pediatric dentistry and resource-constrained settings, have shown high rates of clinical success and patient satisfaction.

Preventive therapies—especially fluoride-based interventions and silver diamine fluoride (SDF)—continue to be critical tools in caries control. Their application in high-risk populations and community-based programs has yielded significant reductions in caries incidence and progression (Marinho et al., 2015; Gao et al., 2016). Furthermore, emerging remineralization technologies such as casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) and bioactive glass represent the next frontier in non-invasive lesion management (Mehta et al., 2021).

The integration of **digital diagnostic tools** and **artificial intelligence (AI)** into clinical practice offers transformative potential. Devices like DIAGNOdent and QLF enhance diagnostic sensitivity, while AI-driven image analysis improves accuracy and consistency in caries detection and risk assessment (Schwendicke et al., 2020; Pretty, 2016). These technologies facilitate earlier intervention and enable more personalized treatment planning, particularly when combined with caries risk models like CAMBRA or ICCMS.

Patient-centered and risk-based care models are increasingly recognized as best practices in caries management. CAMBRA and similar frameworks allow clinicians to tailor interventions based on individual risk profiles, leading to improved outcomes and more efficient resource utilization (Young et al., 2015). These models promote preventive behaviors and empower patients to participate actively in their oral health maintenance.

Despite these advancements, several **challenges** remain. Implementation barriers include a lack of awareness among practitioners, limited training in new technologies, cost constraints, and variability in access to modern diagnostic tools—particularly in low- and middle-income countries. Additionally, the long-term effectiveness and cost-efficiency of newer materials and AI applications require further high-quality longitudinal research.

Moreover, there is a need for greater **integration of caries management strategies into broader public health systems**, including school-based programs and teledentistry platforms. Such integration is particularly important in underserved communities, where access to traditional dental care is limited. Studies have shown that teledentistry, when coupled with risk assessment tools and community health outreach, can significantly expand the reach of caries prevention initiatives (Estai et al., 2020).

In summary, modern caries management is moving toward a preventive, conservative, and technology-enhanced model that prioritizes patient-specific care. The evidence underscores the importance of early diagnosis, risk-based treatment planning, and the use of innovative materials and digital tools. However, broader implementation, clinician training, and policy support are essential to realize the full potential of these contemporary trends across diverse populations and practice settings.

6. CONCLUSION AND RECOMMENDATIONS

This systematic review highlights a significant transformation in dental caries management from traditional restorative approaches to contemporary strategies that are preventive, minimally invasive, technology-enhanced, and patient-centered. The evidence demonstrates that integrating caries risk assessment tools, digital diagnostics, artificial intelligence, and novel biomaterials into clinical practice can substantially improve early detection, reduce the need for invasive procedures, and enhance long-term oral health outcomes.

Minimally invasive dentistry techniques such as selective caries removal, the Hall Technique, and the application of silver diamine fluoride have proven effective, particularly in pediatric and underserved populations. In parallel, the use of fluoride varnishes, remineralization agents like CPP-ACP, and antimicrobial restorative materials supports the goal of preserving tooth structure and preventing lesion progression. Additionally, caries risk assessment frameworks such as CAMBRA and ICCMS enable clinicians to develop individualized treatment plans that address the multifactorial nature of caries development.

Technological innovations—especially in the form of digital caries detection tools and AI-powered diagnostic platforms—have enhanced clinical decision-making by providing more accurate and earlier detection of carious lesions. These tools, when integrated with risk-based management strategies, allow for a more holistic, efficient, and personalized approach to care.

Despite these advancements, challenges remain in the widespread implementation of these approaches, particularly in low-resource settings. Barriers such as cost, lack of clinician training, and limited access to advanced diagnostic technologies must be addressed. Moreover, long-term studies are needed to evaluate the effectiveness, sustainability, and cost-efficiency of these innovations across diverse populations.

Recommendations include the need for:
- Enhanced training programs for clinicians in contemporary caries management strategies
- Greater investment in digital diagnostic infrastructure and AI integration in dental practices
- Policy support for preventive oral health programs in schools and underserved communities
- Further research on the long-term outcomes and scalability of emerging technologies and materials

Ultimately, the future of dental caries management lies in the continued convergence of science, technology, and patient-centered care, aiming to shift the focus from treating disease to preserving health.

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