



Contemporary Management of Dental Caries: From Detection to Minimal Intervention

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ABSTRACT

Dental caries is a dynamic, biofilm-mediated disease requiring early detection and individualized management. Contemporary approaches have shifted from traditional surgical restoration toward prevention and minimal intervention. This review discusses modern caries detection methods, risk assessment, preventive strategies, remineralization, fluoride therapy, sealants, resin infiltration, and selective caries removal. Emphasis is placed on preserving healthy tooth structure and maintaining pulp vitality through evidence-based, minimally invasive treatment. Emerging materials and clinical approaches are also highlighted, along with current challenges and future perspectives in caries management.

INTRODUCTION

Dental caries is one of the most prevalent oral diseases worldwide and represents a major public health concern affecting individuals across all age groups.¹ It is currently recognized as a dynamic, multifactorial, biofilm-mediated disease influenced by dietary, behavioral, environmental, and host-related factors. The disease develops when repeated episodes of microbial acid production result in an imbalance between tooth mineral loss and repair. If this process continues unchecked, initially reversible lesions may progress to cavitation, dentinal involvement, and eventually pulpal and periapical complications.²

Historically, dental caries management focused pri-

marily on the mechanical removal of diseased tooth structure followed by restoration. However, improved understanding of caries biology has resulted in a paradigm shift toward prevention, early detection, lesion arrest, and preservation of healthy dental tissues. Contemporary caries management emphasizes controlling disease activity and addressing individual risk factors rather than treating the cavitated lesion alone. This approach forms the basis of minimal intervention dentistry, which aims to preserve tooth structure while maintaining long-term oral health.³

Advances in caries detection have also improved the ability to identify early, non-cavitated lesions before irreversible tissue destruction occurs. Alongside conventional clinical and radiographic examination, adjunctive diagnostic methods and standardized systems for assessing lesion severity and activity have become

increasingly important. Preventive and therapeutic strategies now include fluoride therapy, dietary modification, remineralization, fissure sealing, resin infiltration, selective caries removal, and the use of contemporary restorative and bioactive materials.⁴

Therefore, effective caries management requires an individualized approach incorporating disease detection, caries risk assessment, preventive intervention, and appropriate operative treatment when necessary. This review discusses the contemporary understanding of dental caries and summarizes current approaches ranging from early detection and risk assessment to minimally invasive management.

Understanding the Caries Process

Dental caries results from a complex interaction between the tooth, oral biofilm, dietary substrates, and time. The oral cavity contains a diverse microbial community that normally exists in a relatively balanced ecological environment. Frequent exposure to fermentable carbohydrates, particularly free sugars, can alter this environment by promoting the growth and activity of acidogenic and aciduric microorganisms. The resulting production of organic acids reduces plaque pH and promotes dissolution of the mineral component of enamel and dentin.⁵

Demineralization and Remineralization

The development of a carious lesion reflects an imbalance between demineralization and remineralization. During periods of low plaque pH, hydroxyapatite and other mineral components of dental hard tissues dissolve, releasing calcium and phosphate ions. Between acid challenges, saliva helps neutralize acids and provides calcium and phosphate required for mineral replacement. Fluoride enhances this repair process by promoting the formation of more acid-resistant mineral phases and reducing mineral dissolution.

When protective factors are sufficient, early mineral loss may be reversed or arrested. However, repeated or prolonged acid challenges can result in progressive mineral loss and structural breakdown. Thus, dental caries should be considered a dynamic disease process rather than a simple irreversible defect.⁵

Role of Dental Biofilm and Diet

The dental biofilm plays a central role in caries development. Frequent consumption of fermentable carbohydrates provides substrates for microbial metabolism and increases the frequency of acidic episodes. The frequency of sugar exposure may therefore be more im-

portant than the total amount consumed at a single occasion. Dietary habits, oral hygiene, fluoride exposure, salivary function, and individual susceptibility collectively influence the balance between pathological and protective factors

Progression of Carious Lesions

Caries may initially develop as a non-cavitated enamel lesion characterized clinically by changes in translucency or surface appearance. At this stage, the lesion may remain stable or become arrested through adequate plaque control, fluoride exposure, and modification of risk factors. Continued mineral loss can result in lesion progression, surface breakdown, and cavitation.

Once dentin becomes involved, lesion progression may accelerate because dentin is less mineralized and has a different structural composition from enamel. Advanced lesions may eventually approach or involve the dental pulp, potentially resulting in pulpal inflammation, necrosis, and periapical disease. Consequently, early identification and management of active lesions are essential for preventing disease progression and reducing the need for extensive restorative treatment.^{5,6}

Caries Activity

Caries activity refers to whether a carious lesion is progressing, stable, or arrested. Assessment of lesion activity is important for determining the appropriate treatment approach. Active lesions are associated with ongoing mineral loss and generally require preventive or therapeutic intervention, whereas inactive or arrested lesions may be monitored and maintained with preventive measures. Clinical assessment includes evaluation of lesion surface texture, appearance, plaque accumulation, and location. Incorporating caries activity into diagnosis allows clinicians to distinguish lesions requiring active treatment from those that can be managed conservatively, supporting the principles of minimal intervention dentistry and preservation of healthy tooth structure.⁶

Caries Risk Assessment

Caries risk assessment is an essential component of contemporary caries management because susceptibility to dental caries varies among individuals. It involves evaluating disease indicators, risk factors, and protective factors to determine the likelihood of caries development or progression. Important risk factors include previous caries experience, frequent sugar consumption, poor oral hygiene, inadequate fluoride exposure, reduced salivary flow, and cariogenic biofilm.

Protective factors include regular fluoride use, effective plaque control, adequate saliva, healthy dietary habits, and preventive dental care. Tools such as CAMBRA and Cariogram can assist in categorizing patients according to their risk level and guide individualized preventive and therapeutic strategies. Regular reassessment is important because caries risk can change over time.⁷

Contemporary Caries Detection and Diagnosis

Accurate detection and diagnosis of dental caries are essential for early intervention and appropriate treatment planning. Contemporary approaches focus not only on identifying cavitated lesions but also on detecting early non-cavitated lesions and assessing their activity. Several conventional and adjunctive methods are available.⁸

Visual-Tactile Examination

Visual examination under good lighting and after cleaning and drying the tooth remains the fundamental method for caries detection. Assessment of color, surface texture, opacity, and cavitation helps identify and characterize lesions. Gentle probing may assist in evaluating surface integrity, although sharp explorers should be avoided to prevent damage to early lesions.⁸

International Caries Detection and Assessment System (ICDAS)

ICDAS provides a standardized method for detecting and recording carious lesions based primarily on visual characteristics. It categorizes lesions according to their severity, ranging from sound surfaces to distinct visual changes, enamel breakdown, and extensive cavitation. Its standardized scoring improves communication, documentation, and research comparability.⁸

Bitewing Radiography

Bitewing radiographs are particularly useful for detecting proximal caries and estimating the depth of lesions that may not be clinically visible. They complement clinical examination but may have limitations in detecting very early enamel lesions and should not be considered a substitute for clinical assessment.⁸

Transillumination

Transillumination techniques, including fiber-optic transillumination, use transmitted light to identify changes in light transmission caused by demineralized tooth structure. They can be useful for detecting proximal and occlusal lesions without ionizing radiation.⁸

Laser Fluorescence

Laser fluorescence devices detect changes in fluorescence associated with bacterial metabolites and alterations in tooth structure. They may provide additional information regarding caries activity, particularly in occlusal surfaces. However, readings can be influenced by plaque, calculus, stains, and other factors, requiring interpretation alongside clinical findings.

Digital and Optical Detection Methods

Emerging digital and optical technologies include digital imaging, near-infrared transillumination, quantitative light-induced fluorescence, and other optical systems. These techniques can enhance visualization and documentation of early mineral changes and may assist in monitoring lesion progression or arrest. Their clinical usefulness depends on device characteristics, operator experience, and appropriate interpretation.

Overall, no single detection method can reliably identify all stages of caries. Combining clinical examination with appropriate adjunctive techniques provides a more comprehensive assessment and supports early, evidence-based, minimally invasive management.⁸

Prevention and Non-Operative Management

Prevention and non-operative management are central to contemporary caries management and aim to control disease activity, arrest early lesions, and preserve sound tooth structure. The choice of intervention should be based on caries risk, lesion activity, and the stage of disease.

Oral hygiene measures

Regular toothbrushing with appropriate fluoride toothpaste helps disrupt dental biofilm and reduce the accumulation of cariogenic microorganisms. Interdental cleaning is particularly important for controlling plaque in proximal areas that are difficult to access with a toothbrush.

Fluoride toothpaste

Fluoride toothpaste is a primary preventive measure that enhances enamel remineralization, reduces mineral dissolution, and increases resistance to subsequent acid challenges. The fluoride concentration and frequency of use should be appropriate for the patient's age and individual caries risk.^{9,10}

Professional fluoride application

Fluoride varnishes, gels, and foams can provide additional protection for individuals at increased risk of caries. Professional fluoride therapy is particularly useful for patients with active lesions, high caries risk, or inadequate fluoride exposure through routine home care.^{9,10}

Dietary counselling

Dietary modification focuses primarily on reducing the frequency of free sugar consumption and limiting repeated acid challenges throughout the day. Patients should be encouraged to choose nutritious alternatives and avoid frequent consumption of sugary snacks and beverages between meals.

Pit and fissure sealants

Sealants provide a physical barrier over susceptible pits and fissures, preventing bacterial accumulation and limiting exposure to dietary substrates. They are particularly valuable for caries prevention on newly erupted permanent molars and other anatomically susceptible surfaces.¹¹

Remineralizing agents

Remineralizing agents support the restoration of mineral lost during the early stages of caries development and may help arrest non-cavitated lesions. Their benefits are enhanced when combined with effective plaque control, fluoride exposure, and appropriate dietary modification.¹²

Calcium and phosphate-based therapies

Calcium and phosphate-based formulations provide mineral ions that can contribute to enamel repair and remineralization. Agents such as casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) and other calcium-phosphate technologies may be used as adjuncts to conventional fluoride-based preventive strategies.¹³

Management of non-cavitated lesions

Non-cavitated lesions can often be managed without surgical intervention through fluoride therapy, plaque control, dietary modification, sealants, or resin infiltration where indicated. Regular monitoring of lesion activity and progression is essential to determine whether the lesion remains stable or requires additional intervention.

Micro-Invasive and Conservative Management

Contemporary management of early carious lesions emphasizes preservation of sound tooth structure and arrest of disease progression. Several minimally invasive approaches can be used depending on lesion activity, depth, location, and patient caries risk.

Resin Infiltration

Resin infiltration is a micro-invasive technique primarily used for non-cavitated enamel lesions, particularly proximal lesions. A low-viscosity resin penetrates the microporosities of the demineralized enamel and forms a diffusion barrier against acids and cariogenic substrates. The technique generally involves cleaning, etching, drying, resin application, and light curing. Resin infiltration can reduce the progression of early lesions and may also improve the appearance of anterior white-spot lesions. Its limitations include the requirement for good isolation, appropriate case selection, and limited suitability for cavitated or extensively demineralized lesions.¹⁴

Silver Diamine Fluoride (SDF)

SDF is a topical fluoride-based agent used primarily to arrest active carious lesions. Its antimicrobial and remineralizing effects help inhibit bacterial activity and increase resistance of dental hard tissues to further demineralization. SDF is particularly useful for patients at high caries risk, young or uncooperative patients, and situations where conventional restorative treatment may be difficult. A major limitation is permanent dark staining of arrested carious dentin, which may restrict its acceptance in esthetically important areas.¹⁵

Minimal Intervention Operative Dentistry

Minimal intervention operative dentistry is based on the principle of preserving healthy tooth structure while controlling caries activity and maintaining tooth function. Advances in caries biology have shifted treatment away from routine complete removal of carious tissue toward conservative, biologically oriented approaches.

Concept of Tissue Preservation

The primary objective is to remove only the tooth structure necessary to control the disease and provide a durable restoration. Preserving enamel, dentin, and sound marginal tissues helps maintain tooth strength and reduces the risk of unnecessary pulpal exposure.

Selective Caries Removal

Selective caries removal involves removing carious tissue to a predetermined endpoint while leaving affected dentin near the pulp when complete removal could result in exposure. This approach is particularly useful for deep lesions and aims to balance caries control with preservation of pulpal health.¹⁶

Stepwise Caries Removal

Stepwise excavation involves an initial conservative removal of carious dentin, placement of a temporary restoration, followed by reassessment and further excavation after a period of time. Although historically used for deep lesions, current evidence has increasingly supported single-visit selective caries removal in many situations.¹⁶

Complete Caries Removal Versus Selective Removal

Complete removal aims to eliminate all clinically detectable carious dentin, whereas selective removal intentionally retains some affected or softened dentin near the pulp. For deep lesions in vital teeth, selective removal generally reduces the risk of pulpal exposure without compromising caries control when an effective restoration provides an adequate seal.

Preservation of Pulp Vitality

Maintaining pulp vitality is a major objective of contemporary caries management. Avoiding unnecessary excavation, minimizing operative trauma, and providing an effective coronal seal can help maintain the biological health of the pulp.

Management of Deep Carious Lesions

Deep carious lesions require careful assessment of symptoms, pulp status, lesion depth, and remaining dentin thickness. Selective caries removal, appropriate pulp-protective strategies, and a well-sealed definitive restoration are important components of conservative management.¹⁷

Caries Management in Children

Dental caries in children requires an individualized approach that considers the child's age, caries activity, behavioral characteristics, lesion severity, and risk of future disease. Contemporary pediatric caries management emphasizes prevention, early intervention, preservation of tooth structure, and avoidance of unnecessary operative procedures.

Early Childhood Caries

Early childhood caries (ECC) is a rapidly progressing form of dental caries affecting the primary dentition, particularly the maxillary anterior teeth and primary molars. Management requires early identification of risk factors, dietary counseling, oral hygiene instruction, fluoride exposure, and timely treatment of active lesions.

Individualized Preventive Programs

Preventive care should be tailored according to the child's caries risk, age, oral hygiene, dietary habits, fluoride exposure, and previous caries experience. High-risk children may require more frequent professional examinations, intensive fluoride therapy, dietary intervention, and closer monitoring.

Fluoride Varnish

Fluoride varnish provides a concentrated topical source of fluoride and is particularly useful for children with elevated caries risk. Its application can enhance remineralization, reduce demineralization, and help arrest early carious lesions when combined with appropriate home care.¹⁸

Hall Technique

The Hall Technique involves sealing a carious primary molar beneath a preformed metal crown without conventional caries removal or tooth preparation. By isolating the lesion from the oral environment, the technique can arrest caries progression while reducing the need for invasive treatment and pulpal exposure.¹⁹

Minimal Intervention Approaches in Primary Teeth

Management of caries in primary teeth should prioritize preservation of tooth structure and maintenance of pulp vitality whenever possible. Selective caries removal, therapeutic sealing, SDF, Hall Technique, and appropriate restorative materials provide conservative alternatives to extensive conventional cavity preparation.²⁰

CHALLENGES AND LIMITATIONS

Despite major advances in contemporary caries management, several challenges remain in translating minimally invasive concepts into routine clinical practice. Accurate detection of early lesions and assessment of their activity can vary with the diagnostic method and operator experience. Patient compliance with oral

hygiene, dietary modification, and regular preventive care also strongly influences treatment outcomes. Limited long-term evidence for some emerging remineralizing materials and minimally invasive techniques, differences in treatment protocols, and accessibility of preventive dental care may further restrict their widespread application. In pediatric patients, cooperation, parental acceptance, and esthetic concerns may also influence treatment selection.

FUTURE PERSPECTIVES

Future caries management is likely to focus increasingly on personalized, preventive, and biologically based approaches. Greater integration of risk assessment, early lesion detection, remineralization technologies, bioactive materials, and minimally invasive procedures may further reduce the need for extensive restorative treatment. Advances in biomimetic and regenerative materials may provide new opportunities for restoring mineralized tissues while preserving pulp vitality. Long-term clinical studies and standardized treatment protocols are needed to establish the effectiveness and durability of emerging approaches.

CONCLUSION

Contemporary dental caries management has evolved from a predominantly restorative approach toward prevention, early detection, lesion arrest, and preservation of healthy tooth structure. Accurate diagnosis, caries risk assessment, fluoride therapy, remineralization, resin infiltration, SDF, selective caries removal, and other minimally invasive approaches allow treatment to be tailored to individual disease activity and risk. Adopting a patient-centered and tissue-preserving approach can help maintain tooth structure, preserve pulpal health, and reduce the long-term burden of restorative treatment.

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