

FROM FINDING TO CATCHING: DIAGNOSTIC AND MINIMALLY INVASIVE METHODS FOR HANDLING NON-CAVITATED DECAYED LESIONS - CURRENT EVIDENCE AND CLINICAL VIEWS

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Abstract

Non-cavitated lesions are the earliest form of tooth decay. These lesions indicate that dental caries is present, and effective management strategies can be implemented to prevent further destruction of the tooth. Traditionally, management of tooth decay has been to remove the caries present and restore the tooth. With the emphasis on preservation of tooth structure, diagnosis of caries is shifted to the detection of non-cavitated lesions. Various methods to diagnose caries exist. These include traditional methods, such as dental examinations and x-rays, and more recently developed technologies. This includes different optical and artificial intelligence systems. This paper discusses the previously mentioned diagnosis methods and shifts focus to recent advances in caries management, including the use of bioactive materials and resin infiltration, as well as the traditional methods of prevention and management of tooth decay. The goal of this paper is to provide the dental community the recent advances in caries management and offer evidence-based practices. The evidence suggests that the best practices in dental caries management requires the simultaneous implementation of several prevention methods. The best practices in dental caries management is an ever-changing field, and research in this area should continue.

INTRODUCTION

One of the world's leading public health concerns is dental caries. With advancements in preventive dental care, dental caries continues to actively decay permanent teeth in both children and adults. Continuous changes in mineral structure of teeth lead to loss of tooth structure. This process can lead to eventual destruction of the tooth if left unmanaged. Pitts et al. (2017) documented that changing the focus of practice from management of advanced carious lesions to the management of high-risk and at-risk carious lesions will promote better caries management.

Within the caries process, the presence of an un-cavitated carious lesion represents an early stage of the process. Loss of tooth structure occurs as a result of mineral loss. Prior to the breakdown of the tooth structure sufficient prevention and care practices can prevent the lesion from progressing. What is essential to caries management is early diagnosis and prevention of further breakdown. Continuous loss of structure of the tooth can lead to further complications of the oral cavity. Early diagnosis and management of dental caries can facilitate oral health care practices.

In the past, dental practitioners resorted to the 'drill and fill' method for treatment of dental caries. This method comprises removal of the carious lesions and repair of the defect with restorative materials. However, this leads to the removal of an excessive amount of healthy tooth structure and results in the need for repeated dental treatments during an individual's lifetime. The concept of minimal intervention dentistry was proposed by Ericson and colleagues in 2003. The purpose of this approach is to intercept and prevent progression of caries lesions and other demineralization using resin based restorative materials to reinforce tooth structure. This methodology focuses on maintaining tooth structure and representing a shift in the approach of dentistry from a 'tooth-centered' approach to a 'patient-centered' approach.

Early detection of dental caries is vital for effective caries management. Traditional methods of assessing dental caries, such as visual and tactile examinations, have limitations in identifying early changes in mineralization. The International Caries Detection and Assessment System (ICDAS) is a methodology developed to standardize the process of clinical diagnosis of caries and has improved the identification and classification of early caries. Continuous improvements in the field of dental technology and material science have aided the development of new diagnostic tools to detect caries.

The prevention and minimally invasive treatments have altered how non-cavitated lesions are managed. Ranging from fluoride varnishes and remineralizing agents to dietary changes and restorative interventions, there are many management strategies. Which strategy is implemented depends on the activity of the lesion and the patient's risk level. Some management strategies involve the use of bioactive materials, resin infiltrations and sealants. Deep lesion activity and other factors should drive the decision-making process in the management of the lesions rather than relying on lesion depth. Of the micro-invasive treatment options, resin infiltration is one of the most progressive treatments. The approach has the benefit of sealing lesions and stopping the loss of mineral in the tooth enamel. Resin

infiltration has been shown to be effective in managing proximal caries. It has also been shown that the use of resin infiltration and sealing techniques to manage proximal lesions stops and reverses caries, respectively, compared to no treatment or management.

Background of Non-Cavitated Decayed Lesions

Dental caries is the chemical dissolution of teeth due to recurrent cycles of mineral loss and gain. This process leads to a range of conditions, from reversible enamel decay to cavitation. Most cavitated lesions develop as a result of the progressive mineral loss of enamel and dentin and the eventual breakdown of tooth structure. Lesions in the developmental stage of caries are clinically important. These lesions can be stopped and even reversed by strategies that integrate the principles of caries management and prevention. These strategies differ from traditional restorative practices and must be employed at an early stage to reduce the need for treatment and restorative care.

There are many conditions which can bring about the caries process. Interactions between bacteria and other microorganisms, diet, and the quality and quantity of saliva (buffer, enzymes, etc.) can combine to create an environment which promotes tooth decay. The various factors of the caries process can combine to lead to the formation of cavities. This has caused many to argue that caries should no longer be considered a disease of tooth decay, but a more comprehensive process.

Problem Statement

While dental technology has improved, identifying and helping patients with non-cavitated carious lesions remains difficult. Early stage lesions are often "invisible" to the examining dentist, leading to delayed treatment or prevention of decay and the need for unnecessary dental restoration. Moreover, there are differences in the long-term results of various approaches for minimizing intervention in carious lesions. It is important to review and assess existing articles to understand diagnostic and clinical approaches to appropriately manage non-cavitated carious lesions.

Aim of the Study

The purpose of this study is to assess existing evidence on the diagnosis of non-cavitated decay lesions and evidence on minimally invasive treatment strategies, and to define their potential in caries management and treatment.

Objectives of the Study

1. To Examine the techniques and methods used for diagnosing non-cavitated carious lesions.
2. To Analyze various caries detection methods, and identify their areas of incompetence.
3. To Review approaches for management of carious lesions, incorporating prevention and preservation of tooth structure.
4. To Analyze the existing body of evidence to understand where and when non-invasive and micro-invasive treatments for carious lesions are appropriate.
5. To Examine what lies ahead for diagnosis of carious lesions and the development of minimal-invasive and prevention-based treatments for carious lesions.

Research Questions

1. What methods can be used to diagnose non-cavitated decay lesions?
2. In what ways do recently developed diagnostic tools and traditional methods of caries diagnosis differ?
3. Which strategies, if any, exist for the management of early carious lesions that do not involve routine interventions?
4. What kind of information does the existing body of knowledge on non-cavitated lesions support?
5. Which potential advances do you think are likely to occur in the area of diagnosis and treatment of the caries process?

Significance of the Study

The focus of this research is to illustrate to the dental community the value and advantage of diagnosing and managing at an early stage to preserve dental tissue. We discuss how through an in-depth study of biology of non-cavitated lesions, the dental team can make evidence based decisions, and reduce the need for dental

restoration. This review outlines many available diagnostic and treatment modalities, and offers views on treatment of dental caries at an early stage. It is believed this research will enhance the body of literature available for the dental profession, and provides a means for the development of new preventative dental care models for various patient groups.

LITERATURE REVIEW

A lesion is defined as carious when the loss of tooth structure occurs by the action of dissolution. When the loss of structure occurs in both the enamel and/or the dentin without formation of a cavity, the lesion is termed non-cavitated. Non-cavitated lesions are reversible carious lesions and provide an opportunity to prevent or halt the carious process and to counteract the pathologic action of the causative organisms. When the lesion has not progressed to the point of cavitation and a definitive restoration is placed, the carious process may be halted.

The prevalent theory regarding the causation of dental caries, states that it is caused by the production of acids by microorganisms (cariogenic organisms) in association with fermentable carbohydrates (foods of poorly controlled satiety) which, in the presence of other factors, leads to the demineralization of the tooth structure.

The recognition of non-cavitated carious lesions has allowed for a shift in focus from treatment of the consequences of caries to prevention of the disease. It has allowed for the development of strategies to intervene before the deposition of dental restorations is required. The goal of these strategies is to change the balance toward remineralization.

Defining and Identifying Early Carious Lesions

Early carious lesions describe areas of decay on a tooth where the mineral has been lost and the decay has not yet broken through the enamel of the tooth. When this occurs the decay is said to be in the 'cavitated' stage, however, in the early stages of decay, it is often seen as a loss of the mineral on the enamel of the tooth and appears as a 'white spot' lesion. It is important to distinguish that the outer layer of enamel

may appear perfectly intact, but the inner layers of the enamel may have been completely mineralized and lost.

According to Featherstone (2004) the enamel of a tooth is made up of a number of crystals of calcium phosphate, and when the environment of the tooth becomes too acidic, due to the production of acid by plaque, the crystals begin to break down and dissolve. This then leads to the enamel of the tooth decaying and the formation of a carious lesion. It is important to recognize that if during this process, the

dissolving crystals of the tooth are lost, and the environment becomes less acidic, due to the presence of fluoride, for example, then the mineral may be redeposited and the decay process prevented.

Classification of Non-Cavitated Lesions

The classification of caries has been traditionally based on the location and extent of the caries. More recently, the activity level and the depth of the lesions are also taken into consideration.

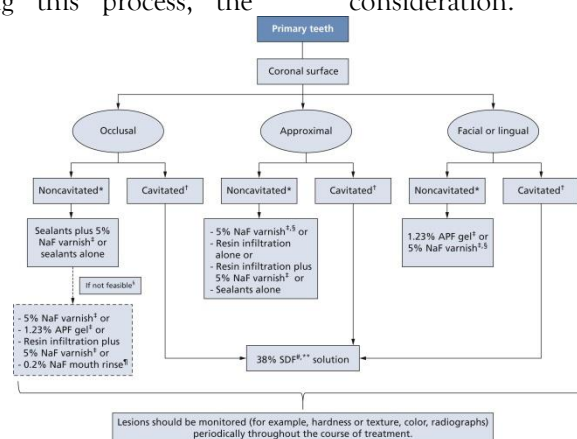


Fig 2.1 Classification of Non-Cavitated Lesions

The International Caries Detection and Assessment System (ICDAS) is one of the more popular caries assessment systems. The main premise of ICDAS is to provide universal definition and criteria for diagnosing early

carious lesions including dyschromia and cavitation. Defining criteria for caries enables clinicians to identify and manage carious lesions at an earlier, more preventable stage.

Table 2.1 Classification of Non-Cavitated Carious Lesions

Lesion Stage	Clinical Appearance	Mineral Loss Status	Management Approach
Initial Enamel Lesion	White spot lesion, no surface breakdown	Early subsurface demineralization	Fluoride, remineralization, monitoring
Moderate Non-Cavitated Lesion	Visible opacity, intact enamel surface	Increased mineral loss	Remineralization, resin infiltration
Advanced Non-Cavitated Lesion	Deep involvement without cavitation	Higher risk of progression	Micro-invasive treatment consideration

The other caries diagnostic criteria, developed by Nyvad and co-workers (1999), takes into consideration the biological activity of carious lesions. This allows clinicians to classify carious lesions as active and requires intervention to prevent lesion progression, and inactive lesions, which do not warrant any clinical intervention.

Mechanism of Demineralization and Remineralization

According to Featherstone (2004), demineralization occurs when the enamel is exposed to an acidic environment (pH < 5.5) for an extended period of time. Conversely, remineralization occurs when the saliva, which

is slightly alkaline and contains calcium and phosphate, restores minerals to the enamel. It is worth noting that demineralization of enamel is

irreversible. However, fluoride remineralization enhances the resistance of the tooth enamel to future acid attacks.

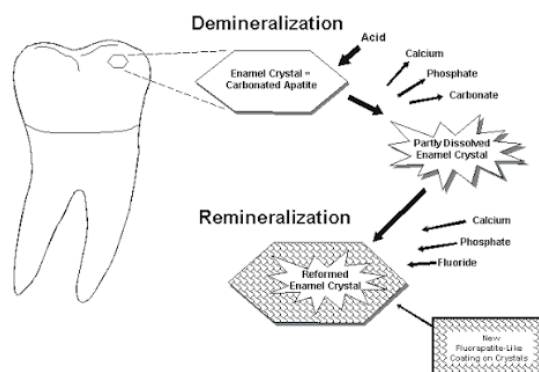


Fig 2.2 Mechanism of Demineralization and Remineralization

From a preventive perspective, Featherstone (2004) considers dental caries as a result of an imbalance between the pathological and protective factors, whereby the former results in loss of tooth minerals and the latter restores the lost minerals.

Factors Affecting Lesion Progression

Bio-psycho-social factors influence the development of non-cavitated lesions. The

presence of microorganisms, particularly cariogenic bacteria, and the frequent consumption of fermentable food and beverages, can increase the risk of lesion development and progression. Inadequate exposure to fluoride, diminished saliva, and poorly maintained oral hygiene also increase the risk of lesion progression.

Table 2: Factors Influencing Progression of Non-Cavitated Lesions

Risk Factor	Effect on Caries Progression	Relative Importance
Cariogenic bacteria	Acid production and mineral loss	High
Frequent sugar intake	Increases acid attacks	High
Low fluoride exposure	Reduces remineralization ability	High
Reduced saliva flow	Decreases natural protection	Moderate to High
Poor oral hygiene	Increases plaque accumulation	High
Previous caries experience	Predicts future lesion development	High

The age of the patient, the kind of food consumed, the lifestyle, and the oral hygiene practices, as well as the patient's previous experience with dental caries, help to explain the rate of progression of the lesions. Modern approaches to the management of dental caries require integration of various factors, including a detailed assessment of the lesions, and going beyond the conventional dental examination.

Diagnostic Procedures for Non-Cavitated Lesions

Non-cavitated lesions are often difficult to detect and require an in-depth assessment to determine the activity level and severity. Several traditional and newly developed methods are available for the assessment of caries.

Table 3: Comparison of Caries Detection Methods

Diagnostic Method	Principle	Radiation Required	Main Advantage	Main Limitation
Visual Examination	Direct clinical observation	No	Simple and inexpensive	Depends on examiner skill
ICDAS	Standardized visual scoring system	No	Improves diagnosis consistency	Requires training
Bitewing Radiography	Detects mineral changes using X-rays	Yes	Useful for proximal lesions	Early lesions may remain undetected
Laser Fluorescence	Detects bacterial fluorescence	No	Detects hidden lesions	Affected by stains/plaque
QLF	Measures fluorescence loss	No	Quantifies mineral loss	Expensive equipment
NIRT	Uses near-infrared light	No	Detects internal lesions	Limited availability
Artificial Intelligence	Image pattern recognition	Depends on input image	Improves diagnostic consistency	Requires validation

Traditional Methods

Dental practitioners use various methods for the examination of dental caries. Basic examination involves the use of an intra-oral mirror and an explorer to examine tooth surfaces. Other methods include the use of periodontal probes to determine the depth of the lesions and photo-stimulable phosphors to determine active and inactive lesions.

The reliability of visual examinations of dental tissues by clinicians varies, dependent on a number of factors including the clinician's level of experience and training, the degree of cleanliness of the dental tissues being examined, and standardization of the criteria against which examination findings are evaluated. Ekstrand et al. (1997), in their study, have described how clinicians can gain more information about the extent and/or severity of dental lesions through clinical judgment and visual assessments.

Visual examinations may be insufficient to detect certain types of dental lesions. This is mostly because changes in the organic and inorganic components of dental tissues may occur at the subsurface level, and appear on the enamel surface only at an advanced stage of lesion development.

International Caries Detection and Assessment System (ICDAS)

The International Caries Detection and Assessment System (ICDAS) is developed to standardize assessment of caries in dental tissues. It is based on the visual assessment of carious lesions by clinical members of the dental team. The system defines criteria for assessment of caries and describes the stages/levels at which assessment should be carried out.



Fig 2.3 International Caries Detection and Assessment System (ICDAS)

The ICDAS has been found to be advantageous in the assessment and documentation of carious changes at an earlier stage when compared to the conventional methods of caries assessment.

Radiographic Detection of Caries

The use of supplementary radiographs is an accepted method of caries diagnosis, and is especially helpful when cavities are in hard to see areas of the tooth, i.e. proximal surfaces. According to Wenzel (2004), when the early changes in the mineralization of the tooth occur, these changes may not be apparent on radiographs; and, in addition, changes may occur at the dentinoenamel junction (DEJ) without being evident on radiographs.

Laser Fluorescence and Other Optical Detection Systems

Devices based on laser fluorescence distinguish between healthy and decayed dentin based on the presence of fluorescence in the decayed structure and loss of minerals from the structure. Fluorescent products of decay-causing bacteria are also observed in caries lesions and are often used to identify decays.

In the study by Lussi et al. (2004), laser fluorescence was able to identify caries on the occlusal surfaces. However, the authors noted that stains and plaque, as well as calibration of the device, could have affected the final results. Noninvasive technologies, such as optical detection systems, are valuable for the diagnosis of caries and other dental diseases.

Quantitative Light-Induced Fluorescence (QLF)

Quantitative Light-Induced Fluorescence is an optical technology which evaluates the loss of minerals in tooth enamel by measuring and differentiating the fluorescence of normal and abnormal enamel. It is also used to visualize and evaluate enamel lesions.

According to Pretty (2006), QLF can be useful for assessing the efficacy of preventive measures

and determining the progression of dental caries.

Near-Infrared Transillumination (NIRT)

Near-infrared (NIR) transillumination is a technique to assess changes at the internal structure of teeth without using ionizing radiation. Decayed areas of the teeth do not fluoresce like normal teeth do and therefore, can be identified using NIR.

Artificial Intelligence in Caries Detection

Artificial Intelligence (AI) is still evolving in the field of caries detection. One of the approaches utilizing AI is the use of deep learning to study dental images, where the algorithm learns to identify different patterns of caries.

In their study, Schwendicke and colleagues (2020) claim that the main advantage of using AI in dentistry is the standardization of diagnostic process and consistency in rendering diagnosis. Nonetheless, the authors stated that prior to integrating AI in clinical settings, hundreds of studies should validate the effectiveness of the technology and integrate the innovation to the workflow of the dental office.

Accuracy of Caries Diagnostic Methods

Without a reliable diagnostic method, the dentist can not be certain if the presence of abnormal tissues in the oral cavity are true pathological conditions. In addition, a diagnostic method should classify the extent of the pathological condition and help determine the potential course of action for the patient.

Sensitivity and Specificity of Diagnostic Techniques

Sensitivity is easier to comprehend. In this context, sensitivity means that the diagnostic test is able to detect the presence of caries. As for specificity, it indicates that the test was able to rule out (i.e. be specific to) the absence of caries.

Table 4: Sensitivity and Specificity of Caries Detection Methods

Diagnostic Method	Sensitivity (%)	Specificity (%)
Visual Examination	20-60%	70-90%
ICDAS	40-90%	70-95%
Bitewing Radiography	30-70%	80-95%
Laser Fluorescence	60-90%	70-90%
QLF	60-85%	80-95%
NIRT	70-90%	80-95%
AI-based Detection	80-95%	85-98%

In general, diagnostic tests in dentistry can be improved to increase sensitivity. However, Lussi and colleagues (2004) noted that the use of advanced technologies in diagnosis can help improve diagnosis and ultimately maximize sensitivity.

Reliability of a diagnosis increases when explicit and measurable definitions of diagnostic terms, such as those used in ICDAS, exist. Ismail et al. (2007) said that to standardize caries assessment, calibration of the clinicians being trained is essential.

Limitations of Current Diagnostic Approaches

There are several shortcomings in existing methods of diagnosing carious lesions. The experience of the examiner, inherent limitations of the technologies used, and inadequate resources constrain the diagnostic approach.

Because of the above limitations, there is ongoing research to standardize the methods for accurate assessment of caries activity.

MINIMALLY INVASIVE MANAGEMENT OF NON-CAVITATED LESIONS

Minimally invasive dentistry (MID) is based on a concept of disease management and Positive Protection of Tooth Tissue (PPTT). MID keeps more dentin than traditional, drill-and-fill approaches. Whereas, the latter focuses on removal of carious tissues and subsequent restoration of the tooth, minimally invasive dentistry looks at means to control caries process. According to the authors, the foundation of minimally invasive dentistry was the shift in the caries paradigm from considering dental caries as an infectious disease to the view that caries is a process that affects hard tissue, and if left untreated, it may lead to loss of hard tissue. Caries lesions in the enamel may be treated by non-restorative approaches.

Table 5: Comparison Between Conventional and Minimally Invasive Dentistry

Feature	Conventional Dentistry	Minimally Invasive Dentistry
Treatment philosophy	Disease removal	Disease control
Main objective	Restore damaged tooth	Preserve tooth structure
Caries management	Drill and fill approach	Prevention and remineralization
Tissue removal	More extensive	Conservative
Patient involvement	Limited	Strong focus
Long-term goal	Repair damage	Maintain natural tooth

From the point of view of current caries management, evaluation of lesion activity is combined with assessment of the potential of the body to repair the lesion.

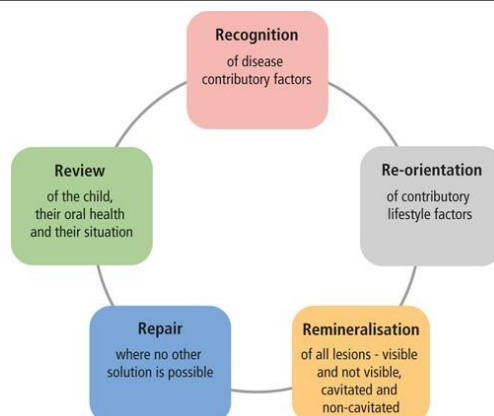


Fig 3.1 Principles of Minimally Invasive Dentistry

The focus of minimally invasive dentistry is on preservation of tooth structure and prevention of further caries disease progression. Concepts of minimally invasive dentistry envisage avoidance of extended removal and subsequent replacement of tooth tissue and use of more conservative approaches to repair the tooth.

Preservation of tissue relies on the control of infectious activity to maintain as much structural dentin and enamel as possible. Tyas et al. (2000) noted that complete restoration of natural tooth structures is not achievable and that the focus of treatment should be preventing further caries development and loss of tooth structure.

Preservation of tissue may also be accomplished through the use of various techniques to slow the activity of the lesions and increase the fluoride uptake of enamel. Fluoride, in combination with other remineralizing agents, may be used to help restore enamel and reduce lesion activity. The use of remineralizing agents, along with the control of the activity of the lesion, may allow clinicians to manage the lesion and reduce the risk of iatrogenic injury. Non-invasive treatment approaches also rely on the use of remineralizing agents and casein phosphopeptide-amorphous calcium phosphate. These agents help restore the affected hard tissue by inhibiting the activity of the cariogenic organisms and stimulating the natural remineralization process.

Fluoride Remineralization

Reversal of enamel carious lesions is achieved through the use of fluoride. Fluoride promotes the remineralization of enamel lesions by facilitating the formation of calcium and phosphate ions and crystals of a harder substance known as fluorapatite, which protects the enamel from the attack of acid.

According to Featherstone (2004), the use of fluoride assists in the remineralization of the enamel and promotes the re-integration of the lost mineral content of the enamel. Fluoride is available for use in varying forms including toothpastes and mouthrinses, and also in professional applications as gels and varnishes. Fluoride varnish applications are beneficial for at-risk individuals as the varnish seals the tooth surface for an extended period of time and prevents the loss of remineralization.

Fluoride, along with other preventive agents, plays an important role in the management of carious lesions.

Oral Hygiene Measures

Balance in dietary consumption and the incorporation of healthy eating habits can also help reduce caries. Moynihan and Kelly (2014) report that limiting the consumption of fermentable sugars can help diminish the risk of caries.

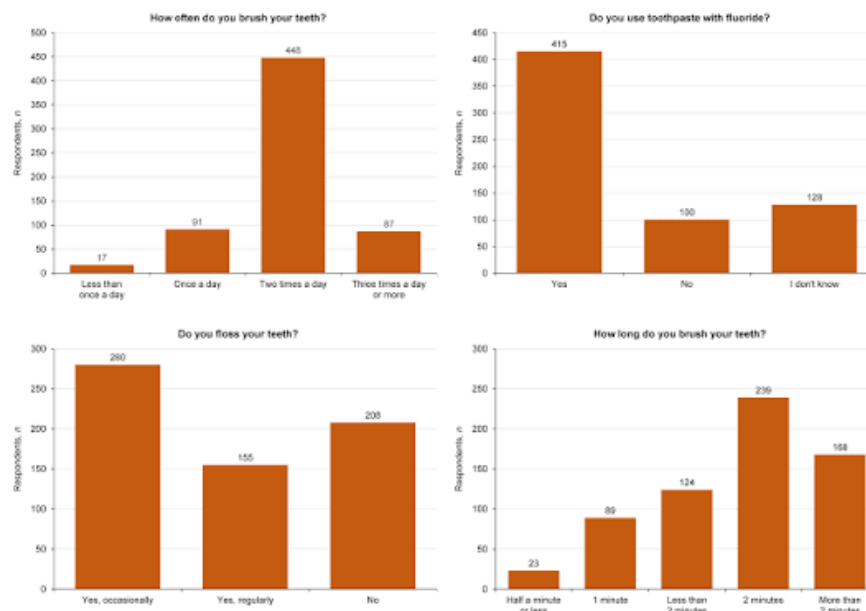


Fig 3.1 Oral Hygiene Measures

To prevent the accumulation of bacteria and acid production, practice effective oral hygiene procedures. Effective oral hygiene practices enhance the beneficial effect of fluoride and remineralization.

Remineralization Agents

To repair and remineralize damaged dental structures and enhance the process of dental repair, the use of bioactive materials has gained popularity. The materials contain ions of calcium and phosphate, fluoride and other components that promote mineralization. Of all the bioactive materials, Casein Phosphopeptide (CPP) and Amorphous Calcium Phosphate (ACP) have been researched the most. CPP is a small peptide that is able to complex with calcium and phosphate. Reynolds (2008) researched the ability of CPP-ACP to promote mineralization of early enamel lesions.

Calcium and Phosphate based bioactive materials are able to remineralize tooth enamel, and decrease the rate of progression of dental caries.

Resin Infiltration

Resin infiltration is a minimally invasive procedure that treats early caries lesions of tooth enamel. Resin is infiltrated into the lesions to obstruct the passage of acid through the lesions and to stabilize the lesions.

This method consists of removing the outermost mineral layer of enamel, drying the carious lesion, and finally infiltrating resin into the lesion. Resin infiltration has been shown to stop the progression of non-cavitated proximal lesions and, therefore, has a positive impact on the health of permanent dentition.

Pit and Fissure Sealants

Pit and fissure sealants are used to protect caries-susceptible regions of back teeth. Deep pits and fissures provide areas for the retention of bacterial plaque and food, which may cause caries.

Without intervention, the caries process inevitably progresses, and sealants remain the only means of preventing caries in high risk individuals. Advances in the formulation of sealant materials have improved the seal and adhesion of sealants to the tooth structure.

Silver Diamine Fluoride Application

Silver diamine fluoride (SDF) is abrasive- and drill-less alternative to manage caries. SDF is indicated for the arrestment of caries lesions of primary and permanent teeth. SDF is most effective when used at an early stage of caries.

It is well established that SDF has the potential to protect, strengthen and regenerate arrested caries lesions. Therefore, it can be used to manage carious lesions as an alternative or in conjunction with other restorative materials.

Horst et al. (2016) reported that SDF can be used for patients with high caries rate and for patients who cannot undergo a dental treatment due to medical reasons. Caries can be managed by the use of SDF. The side effect

of SDF is discoloration of lesions. It should also be noted that caries lesions occur on teeth which are highly visible. Hence, some patients may refuse to use SDF.

Table 6: Non-Invasive and Micro-Invasive Treatment Options

Treatment	Mechanism	Indication	Expected Outcome
Fluoride Varnish	Enhances remineralization	Early enamel lesions	Reduces progression
Fluoride Toothpaste	Provides topical fluoride	Daily prevention	Strengthens enamel
CPP-ACP	Provides calcium and phosphate ions	Early mineral loss	Promotes remineralization
Resin Infiltration	Blocks lesion pathways	Non-cavitated proximal lesions	Arrests progression
Pit/Fissure Sealants	Creates physical barrier	Occlusal risk areas	Prevents initiation
Silver Diamine Fluoride	Arrests bacterial activity	High-risk patients	Stops lesion progression
Bioactive Materials	Releases therapeutic ions	Early lesions	Supports enamel repair

Bioactive glass, calcium phosphate and hydroxyapatite can be used to remineralize early carious lesions of enamel. Further, bioactive materials enhance the mineral content of dental tissues and increase their resistance against acid challenges.

There is high potential for further development of bioactive materials for the conservative management of non cavitated caries lesions. More clinical studies should be conducted to assess the impacts of such materials and to standardize their usage.

CURRENT EVIDENCE ON DIAGNOSTIC AND TREATMENT APPROACHES

Identifying dental caries at earlier stages, in particular before the development of cavitation, allows dental professionals to formulate, implement and evaluate strategies to prevent further tissue loss and/or structural alteration of the tooth. According to available evidence, early caries intervention enables the retention of more tooth substance and helps to limit the progression of the disease.

Cavitation is the final stage of caries development and, therefore, traditional methods used to detect carious lesions focused on identifying this stage. Other steps in the development of caries contain varying degrees of mineralization and, therefore, can be identified using specific means of diagnosis. Visual examination, along with the use of systems and standards such as ICDAS, has been shown to enhance the ability to diagnose carious lesions in the initial stages of development. Ismail et al. (2007) evaluated and concluded that ICDAS helps to standardize the detection of caries and increases inter-examiner agreement.

Bitewing radiographs are a useful aid to identify caries in proximal surfaces. However, to be visible, the carious lesion must contain a critical level of demineralization. As a consequence, radiographs are not ideal to detect caries in the initial stages. Wenzel (2004) stated that, for the diagnosis of caries in its early stages, radiographs must be integrated with other methods.

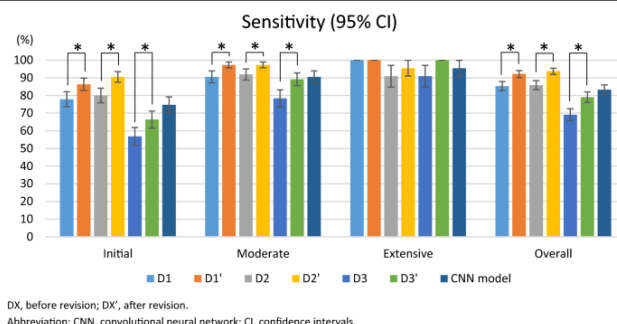


Fig 4.1 Evidence Supporting Early Caries Detection

Early caries lesions can be identified using laser fluorescence and near infrared trans-illumination. Fluorescence also allows the detection of caries in covered and occluded surface of teeth. The use of QLF has shown to enhance the detection of caries lesions, including those in the early stage of development. However, fluorescence may be influenced by several factors, including the presence of plaque.

The use of artificial intelligence (AI) in detecting caries is increasing. Certain machine learning frameworks allow for detection of caries in dental X-rays. While the technology is promising, integration into dental practices is still waiting on the results of clinical tests. As indicated by Schwendicke et al. (2020), the use of AI in dental practices will allow dentists to properly identify abnormal changes and provide a higher level of service to their patients.

Table 7: Evidence Supporting Treatment Approaches

Intervention	Evidence Level	Reported Clinical Effect
Fluoride Varnish	High	Reduces development and progression of lesions
Resin Infiltration	Moderate to High	Arrests progression of proximal lesions
Sealants	High	Prevents occlusal caries development
CPP-ACP	Moderate	Improves mineral recovery
Silver Diamine Fluoride	High	Arrests active caries lesions
AI Diagnosis	Emerging	Improves consistency of detection

Cavities and caries activity are challenges in modern-day dentistry. Preserving healthy tooth structure is the aim of dental practitioners and the use of minimally invasive approaches is advocated. This allows for the proactive management of caries activity and facilitates the control of disease progression. The use of minimally invasive approaches has been shown to prevent or postpone the need for invasive restorative care.

Comparison of Traditional and Recent Strategies

The focus in the management of dental caries has shifted from fixing the problems caused by decays to preventing the decays. Traditional dentistry aimed at removing decayed tooth structure and restoring the defects.

Contemporary dentistry is aimed at management of diseases to maintain the health of the individual and preserving the natural structures in the mouth.

It is important to perform traditional restorative dental treatments to resolve the problems caused by dental caries. However, it is inappropriate to perform traditional treatment on carious lesions if they have not broken through the enamel. Non-cavitated lesions contain irreversibly degenerated tooth structure. Removing such structures may result in the unnecessary loss of tooth structure. It has been shown that traditional restorative treatments are not always appropriate to resolve problems caused by dental caries.

Long-Term Outcomes of Lesion Management

Non-cavitated lesions require ongoing assessment to evaluate if preventive interventions have been effective in arrested or improving the condition of the lesion.

Long-term findings from studies conducted to evaluate the efficacy of resin infiltration have demonstrated the potential of this approach to arrest proximal lesions. The authors of one such study observed that lesions treated by this method showed less progression of decay compared to untreated lesions.

The caries process is dynamic and the evidence indicates that proactive interventions to minimize the loss of tooth structure and improve the health of dental hard tissues should be instituted.

Challenges in Clinical Implementation

Early detection of carious lesions allows their management prior to the loss of tooth structure. However, predicting the activity of a lesion, and determining with certainty the extent to which a lesion will progress and adversely affect a tooth, continue to challenge the field of dentistry.

There is also variability in clinical decision making among dental professionals which affects the implementation of minimally invasive dentistry. Some clinicians may prefer active treatment in the form of a cavity preparing and restoring vs. monitoring or preventive treatment.

There are a number of patient factors that affect the success of prevention and minimally invasive dentistry. Oral conditions such as periodontal disease or poor oral hygiene, consistent consumption of cariogenic foods, low patient compliance, and high dental anxiety can decrease the positive impact of prevention.

CLINICAL PERSPECTIVES AND DECISION-MAKING

As Dwork & Frieden suggest, current concepts of caries management require assessment of the activity level of caries process (caries in cavity) and the factors that put the individual at risk for developing caries process. The traditional approach focused on the diagnosis and assessment of the depth and extent of the

carious lesions. Caries activity is an indicator of the biological status of a carious lesion and describes whether the lesion is active (or decay is ongoing) or inactive (or decay is not ongoing). The activity level of a carious lesion is of major importance in planning treatment, since an active carious lesion is in need of treatment or prevention, whereas an inactive carious lesion has to be monitored. The assessment of caries risk requires consideration of a variety of risk factors that may be present in the individual. The risk factors may be grouped into biological, behavioral and social risk factors. Biological factors include the individual's history of caries experience, bacterial levels, salivary levels and flow, diet and habits, as well as medical conditions. Behaving in a caries preventive manner, clinicians can assess the caries risk level and develop an appropriate preventive plan for patients at a high caries risk.

Criteria for Monitoring and Intervention

The management of risk factors associated with disease includes the consideration of all components of the disease process, including the lesion and patient risk factors, as well as the likelihood that the disease process is active and progressing. Based on prevention-oriented research, lesions may remain quiescent and/or revert to a healthy state with appropriate preventive care; therefore, not all early-stage lesions require advanced care and intervention. The management of risk factors associated with disease process includes preventive care; therefore, non-cavitated lesions that are quiescent, and exist in a patient for whom other carious lesions have been managed, may be appropriate for preventive care.

Preventive care may include the provision of fluoride and/or other remineralizing agents. Management of lesions may also include the use of adjunctive therapy to facilitate lesion remineralization.

In the absence of prevention and other risk management strategies, progressive disease is managed by the removal of infected/cavitated tissues.

For lesions without cavitation, a range of treatment options are available, from non-invasive options (e.g. fluoride,

remineralization), to slightly invasive (e.g. resin infiltration). The choice of treatment depends on the behavior of the lesion, as well as the patient.

Factors Influencing Treatment Selection

The treatment of a lesion without cavitation may require preventive management, a micro-invasive procedure, or a restoration. The decision is dependent on various factors.

Table 8: Factors Influencing Treatment Selection

Factor	Influence on Decision
Lesion activity	Active lesions require intervention
Lesion depth	Determines treatment intensity
Patient caries risk	High-risk patients require stronger prevention
Age	Influences treatment choice
Diet habits	Determines recurrence risk
Oral hygiene	Affects treatment success
Patient preference	Guides final management plan

The characteristics of the lesion, including the site, depth, and activity, contribute to treatment-planning. Other factors, including the patient's age and motivation, diet and oral hygiene, as well as the patient's previous experience with caries and their interest in maintaining their oral health, must also be taken into account.

When multiple preventive treatment options are available, the clinician must also consider the context in which they practice. The clinician may be limited by available resources, and may need to adjust their treatment plan accordingly.

Role of Patient-Centered Care in Caries Management

Patient-centered care is centered around incorporating patient participation to change behavior in order to better manage caries. Using this approach requires understanding patient preferences while taking into account lifestyle to help facilitate adoption of preventative measures.

Behavioral changes in patients help control caries. Thus patient education is essential in helping patients understand why caries occurs and how dietary and behavioral modifications along with preventive oral health care help control caries.

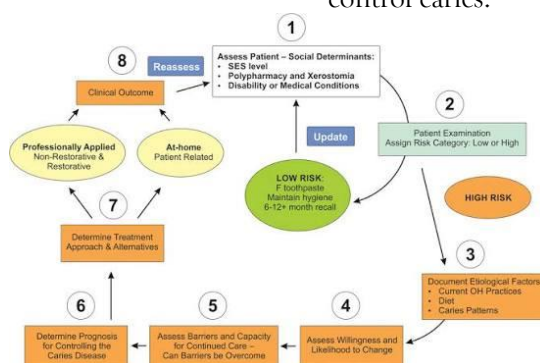


Fig 5.1 Role of Patient-Centered Care in Caries Management

Patients should participate in the planning of their treatment and be provided information on all treatment options to help them make an informed decision about their treatment. Only 13% of American adults have a positive perception of their dentist and trust their dentist to act in their best interest. Thus, it is

the duty of the dentist to educate their patients on the benefits of available preventive measures and the risks of not availing preventive options. Patient participation in preventive care along with behavior modification helps control and manage the disease process.

Clinical Recommendations for Non-Cavitated Lesions

Maintaining the health of the tooth by removing the carious lesion is not always necessary; however, controlling the caries process is of utmost importance.

Assessment of the early lesion begins with an appropriate diagnostic test, and may require other aids and technologies. The activity level of the lesion and the patient's caries risk need to be evaluated when determining an appropriate treatment.

Patients at low risk for caries with early lesions may be observed and their caries risk reduced

through the use of preventive measures. Improvements in oral hygiene and dietary modifications may also be included.

FUTURE PERSPECTIVES

Digital diagnostics is the future of caries management. Improvements in digital diagnostic tools will help detect dental caries and other degenerative lesions. The help of digital diagnostics will provide the dental field with a less-invasive method to detect changes which were formerly undetectable.

Table 9: Future Technologies in Caries Management

Technology	Current Status	Future Potential
Artificial Intelligence	Developing	Automated diagnosis and personalized care
Digital Imaging	Established	Better monitoring of lesion changes
Bioactive Materials	Research stage	Enamel regeneration
Smart Remineralizing Agents	Experimental	Environment-responsive treatment
Genetic Risk Assessment	Early research	Personalized prevention

Various imaging systems such as digital radiography and 3-D imaging have enhanced the field of dentistry by providing the means to electronically capture and store images. The incorporation of digital technology has allowed the dental field to become more proactive by identifying potential problems which were previously undetectable.

There are new methods of digital diagnostics, including NIRT, QLF, and OCT, which can help assess changes occurring in enamel. These methods have the ability to provide measurable data that can help monitor the status of a degenerative lesion.

Digital diagnostics can help detect changes occurring in carious lesions and provide the dental field with a better means of evaluating treatment and its outcome. The use of digital diagnostics will create an electronic record of treatment and help provide personalized treatment and prevention plans.

Artificial Intelligence in Dentistry

Artificial intelligence (AI) finds several uses in dentistry, including in the diagnosis and management of caries. Some studies suggest AI holds greater efficiency in detecting caries when compared to humans.

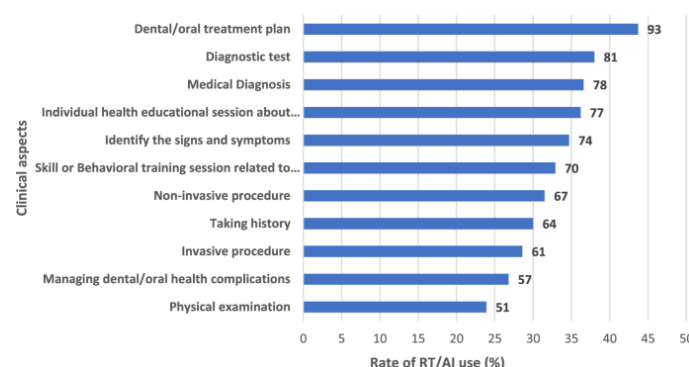


Fig 6.1 Artificial Intelligence in Dentistry

AI is also useful in recognizing camouflaged (hidden) carious lesions by helping dentists comprehend minor changes in dental hard tissues. Schwendicke et al. further add that AI has the potential to improve diagnostic accuracy and consistency by reducing the inter-examiner (dentist to dentist) variation.

CNNs (convolutional neural networks) can help analyze dental images and help in diagnosis of caries, and other dental conditions. Certain studies suggest that these neural networks can help in interpretation of dental images and can help in diagnosing large numbers of dental images, in a more efficient and effective manner, when compared to humans.

Development of New Preventive and Remineralizing Agents

The development of novel remineralizing and preventive agents will largely impact the management of carious lesions in the future. Currently, research has been conducted to create agents that help repair enamel damage, release beneficial ions, and provide anti-cariogenic activity.

Enamel remineralization can also be achieved by the use of various bioactive materials. Calcium and phosphate based materials and hydroxyapatite can provide resistance to demineralization.

Hydroxyapatite based bioactive materials can also help to remineralize and harden the enamel. Moreover, these materials can help to fill enamel defects and help reduce the adherence of plaque and other oral biofilms.

Release of calcium and phosphate ions by bioactive glasses helps to remineralize and repair dental enamel.

It can be anticipated that in the future, preventive materials may be designed to change their properties in response to the fluctuations in the oral environment. Innovations in this area can assist in managing non cavitated carious lesions by promoting enamel healing and repair.

Future Research

Research on non-cavitated lesions should focus on raising the certainty of diagnosis, individualized treatment, and generation of

clinical evidence for innovations in therapy. Considerable advancements have been made in the field of early caries detection and minimally invasive treatment, and there are numerous opportunities for further research.

The improvement of caries diagnosis is one of the major research opportunities. The use of artificial intelligence (AI) in combination with other diagnostic methods is a highly regarded research area.

Durable restorations and the retention of minimally invasive treatments remain major concerns. Additional research should focus on the development of innovations in therapy.

Prioritization of research on individualized caries management is warranted. Further, research should focus on the use of genetic data, digital health and other omics technologies to predict caries and disrupt caries progression.

DISCUSSION

The last decade has seen major changes in the way the profession thinks about and manages dental caries, specifically about the management of carious lesions that do not yet have a cavity. Traditionally, the focus of caries management was about identifying and managing cavitated lesions. There are now many publications that encourage a different, more proactive and interventionist approach to manage caries.

A number of studies have looked at different ways to identify caries and have focused on how well different methods aid in the identification of cavitated lesions. It has been suggested that while many methods increase the overall detection of caries, no individual method is always able to identify lesions that do not have a cavity. It has been well described that health care professionals with more experience are usually better at identifying carious lesions. The use of systems such as ICDAS has also aided in the better and more consistent identification of carious lesions.

With the rapid advancement of technology, new and more effective ways of identifying caries lesions are likely to become available. Artificial Intelligence (AI) and other technologies are likely to transform caries management. These should be integrated into

clinical practice in order to improve management.

Earlier management of dental caries (cavitation or decay) preserves more of the natural tooth. Various treatments have been shown to help arrest or slow the progression of dental caries. Sodium fluoride varnish and other resin and sealant based treatments have been shown to help in the remineralization process of cavitated lesions. Further, the complete and partial remineralization of incipient lesions has been shown using resin infiltration.

Going forward, the focus of dental caries management will be more preventive and biological, as opposed to ameliorative. It will be important to ensure effective communication among dentists and researchers to establish and implement standards to evaluate the outcome of treatment for dental caries.

Artificial Intelligence (AI) will also impact dental practices. Dental images are often complicated and may require the assistance of radiologists for interpretation. AI may help dental professionals identify vague areas in dental images, thereby standardizing interpretations. AI has the potential to change the diagnosis and management of patients by facilitating evidence-based decisions. However, further clinical studies must be conducted to validate such claims. Precise and personalized diagnosis and treatment of dental diseases are likely to become a standard of care in the future. With such advances, dentists may be able to treat certain oral lesions and/or reduce their activity instead of passively managing them.

Benefits and Limits of Minimally Invasive Treatment

There are numerous benefits of using a minimally invasive approach in comparison to a traditional dental approach. Preserving tooth structure using a minimally invasive approach helps maintain the integrity of the tooth and lessens the chance of restorative failures.

Also, minimally invasive approaches help address caries, a preventable, infectious disease. Other preventive and micro-invasive measures to manage caries exist, and, when combined with other treatment modalities, may help retain tooth structure.

The goal of minimally invasive approaches is to align treatment with the biological nature of the disease; in the case of caries, this involves treating the disease before it causes structural damage to the tooth.

While there are many benefits to minimally invasive management, there are some limits. For example, sometimes it is hard to determine if a lesion can be managed conservatively or if it requires treatment. In some cases, a care provider may mistakenly treat a lesion and, in other cases, a care provider may fail to act and let a lesion become more severe.

The success of minimally invasive management is also related to outside factors. For example, the success of preventive resin therapy is related to a patient's adherence to preventive measures, and poor adherence may affect the success of the treatment. Also, not all care providers may have the right skills or equipment to perform resin infiltration treatments.

Research focused on the relationship between genetic factors and caries is also necessary, as is research focused on other biological factors. Added to these, there are other behavioral and environmental factors that can influence the risk and progression of carious lesions.

CONCLUSION

This research shows that caries is a dynamic process and that lesions can be viewed as the combined result of continuous demineralization and remineralization processes. Therefore, classification of dental caries as a process that ultimately requires restorative treatment may not be entirely correct.

According to the studies analyzed in this research, early diagnosis of caries is of high importance to manage the condition. Besides the conventional clinical examinations, recent developments in the diagnostic field enabled early lesion detection and aided in assessment of the progression of carious lesions.

With regard to non-cavitated lesions, the available evidence suggests that the focus should be on preventing further lesion progression rather than on restorative measures. In this context, it should be noted that prevention of caries includes a wide range of possibilities, for example, modification of

diet and lifestyle, oral hygiene and remineralization, as well as the use of artificial intelligence. Similarly, the focus of caries management should be on prevention and, if necessary, early intervention, rather than on restorative care.

It is expected that, in the future, conservative treatment of dental caries, including the use of remineralization agents, will largely replace the current, more invasive treatment methods.

Clinical Recommendations

Current evidence suggests that the management of non cavitated carious lesions should involve minimally invasive strategies and approaches. The aim should be early identification using a clinical examination supplemented with diagnostic aids as required. Before any interventional strategy is adopted the clinician should assess the activity and the true extent of the carious process.

The clinician must take into account individual patient factors which predispose to the development of caries including dietary and oral hygiene factors as well as salivary, fluid, and fluid balance factors.

Where there is a low risk for lesion progression, then a watchful waiting approach supplemented by the use of preventive strategies is justified.

The use of remineralizing agents and resin infiltration as well as preventive sealants should be considered for patients at high risk for caries where lesions are active. Interventional strategies for caries management should be aggressive enough to impact lesion progression while not being so aggressive as to promote unnecessary and unwise removal of tooth structure. Communication with the patient is an important element of care and treating carious lesions should include strategies designed to enhance patient understanding and participation.

Future Directions in Caries Management

It is likely that modification and expansion of existing preventive approaches to caries will utilize digital technologies and artificial intelligence. Continuous and real time assessment of caries risk will become a routine part of clinical practice.

Artificial intelligence (AI) can provide dental professionals with an EDGE in diagnoses, analyze more complicated imaging, and suggest individualized treatment options. There are, however, questions regarding the legalities, ethics and ways in which this technology can appropriately and effectively integrate clinical practice.

It is anticipated that progress in biomaterials science will lead to improved management of dental caries. The use of bioactive and remineralizing materials that incorporate therapeutic ions to stimulate remineralization and tissue repair will aid in the management of this condition.

It is essential that research encompass a variety of approaches and methodologies to achieve individualized care, including prevention of dental caries and other oral diseases based on risks and the cost to incorporate advanced technology.

There is an overarching trend to move from restorative care to preventive care and the use of minimally invasive techniques. Combining these techniques with a well-articulated diagnosis will positively impact caries management.

REFERENCES

- Ekstrand, K. R., et al. (1997). Reproducibility and accuracy of three methods for assessment of demineralization of the occlusal surface. *Caries Research*, 31, 224-231.
- Wenzel, A. (2004). Digital radiography and caries diagnosis. *Dental Clinics of North America*, 48(2), 351-362.
- Lussi, A., Hibst, R., & Paulus, R. (2004). DIAGNOdent: An optical method of caries detection. *Journal of Dental Research*, 83(Special Issue C), C80-C83.
- Pretty, I.A. (2006). Novel technologies in caries diagnosis and management. *Journal of Dentistry*, 34(10), 727-739.
- Schneiderman, A., et al. (1997). Assessment of dental caries with Digital Imaging Fiber-Optic Transillumination (DIFOTI). *Journal of Dental Research*, 76(9), 1474-1479.

- Swendicke, F., et al. (2020). Artificial Intelligence (AI) in Dentistry. Potentials and Restrictions. *Journal of Dental Research*, 99(7), 769-774.
- Featherstone, et al. (2007). Caries Risk Assessment. *Journal of the California Dental Association*, 35(10), 703-707.
- Marinho, et al. (2013). Fluoride Varnishes for Preventing Dental Caries. *Cochrane Database of Systematic Reviews*.
- Reynolds, E.C. (2008). Casein Phosphopeptide-Amorphous Calcium Phosphate (CPP-ACP): The Scientific Evidence. *Advances in Dental Research*, 21(1), 25-29.
- Meyer-Lueckel, H., & Paris, S. (2008). Resin Infiltration of Natural Caries Lesions. *Journal of Dental Research*, 87(12), 1112-1116.
- Parise et al. (2010) Paris, S., Bitter, K., Naumann, M., Dörfer, C. E., & Meyer-Lueckel, H. (2010). Resin infiltration of proximal caries lesions varying in International Caries Detection and Assessment System (ICDAS) codes. *European Journal of Oral Sciences*, 118, 573-578.
- Griffin et al. (2008) Griffin, S. O., Oong, E., Kohn, W., Vidakovic, B., & Gooch, B. F. (2008). The effect of dental sealants on caries lesions. *Journal of Dental Research*, 87(2), 169-174.
- Horst et al. (2016) Horst, J. A., Ellenikiotis, H., & Milgrom, P. M. (2016). The UCSF Protocol for Caries Arrest: Use of Silver Diamine Fluoride. *Advances in Dental Research*, 29(1), 51-57.
- Gandolfi et al. (2011) Gandolfi, M. G., Taddei, P., Tinti, A., & Prati, C. (2011). Apatite-forming ability of bioactive materials. *Dental Materials*, 27(7), 719-728.
- Roveri et al. (2009) Roveri, N., Battistella, E., Bianchi, C. L., Foltran, I., Foresti, E., Iafisco, M., & Tampieri, A. (2009). Enamel surface remineralization with hydroxyapatite. *Journal of Nanoscience and Nanotechnology*, 9(8), 4474-4480.
- Moynihan and Kelly (2014) Moynihan, P. J. & Kelly, S. A. M. (2014). Restricting carbohydrate intake to reduce caries. *Journal of Dental Research*, 93(1), 8-18.
- Walsh et al. (2010) Walsh, T., Worthington, H. V., Glenny, A. M., Appelbe, P., Marinho, V. C., & Shi, X. (2010). Fluoride toothpastes for the prevention of dental caries. *Cochrane Database of Systematic Reviews*, (12).
- Tellez et al. (2013) Tellez, M., Gomez, J., Pretty, I., Ellwood, R., & Ismail, A. (2013). Caries risk assessment systems: a review of the evidence. *Journal of the American Dental Association*, 144(11), 1183-1190.
- Zero (2006) Zero, D. T. (2006). Dentifrices and mouthrinses for the prevention and treatment of dental caries and caries arrest. *BMC Oral Health*, 6(Suppl 1), S9.
- Featherstone JDB, Chaffee BW. The Evidence for Caries Management by Risk Assessment (Cambra). *Adv Dent Res*. 2018;29(1):9-14.
- Frencken JE, Peters MC, Manton DJ, Leal SC, Gordan VV, Eden E. Minimal Intervention Dentistry for Managing Dental Caries. *Int Dent J*. 2012; 62(5):223-243.
- Innes NPT, Frencken JE, Björndal L, Maltz M, Manton DJ, Ricketts D, Van Landuyt K, Banerjee A, Campus G, Doméjean S. Managing Carious Lesions: Consensus Recommendations on Terminology. *Adv Dent Res*. 2016;28(2):49-57.
- Swendicke F, Frencken JE, Björndal L, Maltz M, Manton DJ, Ricketts D, Van Landuyt K, Banerjee A, Campus G, Doméjean S. Managing Carious Lesions: Consensus Recommendations. *Adv Dent Res*. 2016; 28(2): 58-67.
- Kidd EAM, Fejerskov O. What is Dental Caries? *Histopathology of Carious Dentin and Enamel*. *J Dent Res*. 2004; 83(Special Issue C):C35-8.

- Zero, D. T., Fontana, M., Martinez-Mier, E. A., Ferreira-Zandona, A., Ando, M., Gonzalez-Cabezas, C., & Bayne, S. (2009). Biology, Prevention, Diagnosis and Treatment of Dental Caries. *Journal of the American Dental Association*, 140(Suppl 1), 25S-34S.
- Bader, J. D., Shugars, D. A., & Bonito, A. J. (2001). A systematic review of the evidence of the methods available to identify carious lesions. *Journal of Public Health Dentistry*, 61(4), 197-209.
- Gomez, J. (2015). The early caries lesion: detection and diagnosis. *BMC Oral Health*, 15(Suppl 1), S3.
- Zandona, A. F., & Longbottom, C. (2019). Detection and Evaluation of Caries. In *Detection and Assessment of Caries* (pp. 5-18). Springer.
- Pitts, N. B., & Ekstrand, K. R. (2013). International Caries Detection and Assessment System (ICDAS) and associated work. *Community Dentistry and Oral Epidemiology*, 41(1), e1-e12.
- Cury, J. A., Tenuta, L. M. A., Ribeiro, C. C. C., & Paes Leme, A. F. (2004). Fluoride and the control of dental caries. *Brazilian Dental Journal*, 15(3), 167-174.

