Caries Process and Prevention Strategies: Diagnosis

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Conflict of Interest Disclosure Statement

- Dr. Ismail is a member of the Board of Director SS White Inc., a company that manufactures special burs for conservative management of caries. Temple University holds the patents to the Smart Bur and Fissurotomy Bur.

Introduction

This is part 6 of a 10-part series entitled *Caries Process and Prevention Strategies*. This course introduces the dental professional to the importance of caries diagnosis in prevention of the disease, as well as the intricate link between caries diagnosis and treatment. The two main methods of lesion diagnosis used today—the visual–tactile or visual methods and bitewing radiography—are discussed, including recent advancements that improve their sensitivity, as well as their limitations. Topics also include newer approaches to caries diagnosis and management, a brief discussion of why too-early caries lesion diagnosis can be counterproductive and the benefits of enlisting the help of pediatricians in diagnosing caries in children.

Course Contents

Overview

This course introduces the dental professional to the importance of caries diagnosis in prevention of the disease, as well as the intricate link between caries diagnosis and treatment. The two main methods of lesion diagnosis used today, the visual-tactile or visual methods and bitewing radiography, are discussed; particularly with regard to their application in the ICDAS system.

Clinical Significance Snapshots

What is the difference between Diagnosis and Assessment of dental caries?

Dental caries assessment identifies the presence or absences of disease indicators. Diagnosis links the level of appropriate care to the stage of the disease. Diagnosis is performed at the tooth surface or tooth level. Risk assessment is conducted at the patient level and should include evaluation of medical and dental histories, biological, social and behavioral risk factors, and all clinical evidence gained from a thorough examination using visual and tactile methods. Further evidence gained from other tests such as bitewing radiography is also considered. Once identified, the individual lesions should be assessed for their activity status, which will determine the specific management strategies for each caries lesion. Preventive care should be risk-based and provided for all patients. Low, medium and high caries risk patients should receive preventive and behavioral interventions adjusted to their risk status. Lesion severity (initial, moderate, or extensive) should determine the need for non-surgical or surgical dental care to control caries or eliminate it. The inclusion of non-cavitated lesions in this assessment is essential, as the measurement of these lesions is a relevant indicator for long-term dental health.

Learning Objectives

Upon completion of this course, the dental professional should be able to:

- Understand how a change from surgical repair of caries to prevention has influenced caries diagnosis methods.
- Explain why caries diagnosis is important.
- Discuss the difference between the medical and dental perspective of caries diagnosis.
- Identify the tools and diagnostic criteria of visual–tactile methods.
- Be familiar with the benefits and limitations of visual–tactile methods.
- Identify diagnostic criteria of the bitewing radiography method, as well as its benefits and limitations.

- Be familiar with newer methods of caries lesion detection and assessment, including methods based on X-rays, light, and electrical current.

Glossary

biofilm – An aggregation of microorganisms in which cells adhere to each other, forming small communities that are held together by an extracellular polymeric matrix. Different communities are co-dependent on each other, and the whole biofilm forms a defensive mechanism requiring much higher concentrations of antimicrobials to control its growth. Dental plaque is a previous name for what is now called the biofilm. However, recent understanding of the biofilm leads to the development of the "microbiome" ecological model; because bacteria are normally present in the oral cavity.

bitewing radiography – The process of creating radiographic images of the posterior teeth, with the specific objective of identifying carious lesions on the proximal surfaces that may be inaccessible to visual and tactile examination. Less mineralized tissues permit more x-rays to pass through (radiolucency) and therefore create greater levels of exposure to radiographic film or a digital transducer.

demineralization – The chemical process by which minerals (mainly calcium) are removed from the dental hard tissues - enamel, dentin, and cementum. The chemical process occurs through dissolution by acids or by chelation, and the rate of demineralization will vary due to the degree of supersaturation of the immediate environment of the tooth and the presence of fluoride. Under optimal conditions, the minerals may be replaced through the process of remineralization.

dental plaque – An organized community of many different microorganisms that forms itself into a biofilm and is found on the surface of the tongue and all hard surfaces in the oral cavity. Dental plaque is present in all people and can vary from being comprised of totally healthy microorganisms (commensals) to being very harmful (pathogenic), predisposing the patient to dental caries or periodontal diseases.

Note: Dental plaque is not food debris, nor does it contain food debris. Dental plaque can only be completely removed by mechanical means such as toothbrushing or prophylaxis. Food debris can be removed by rinsing.

ICCMS – An acronym for the International Caries Classification and Management System (ICCMS™) which is a standardized system focused on improving long-term caries outcomes; it combines history taking, clinical examination, risk assessment and personalized care planning at the individual patient level.

ICDAS – An acronym for the International Caries Detection and Assessment System, which is an integral aspect of the ICCMS™ approach. While the ICCMS™ represents a new, enhanced approach to the diagnosis and management of caries, the ICDAS System provides a standardized method for assessing and tracking changes in caries activity.

lesion – Any abnormal well-circumscribed change in any tissue due to disease or injury. In terms of dental caries, the lesion is the part of the tooth that has undergone the caries process. Lesions are currently classified in the following ways: 1) non-active lesions (which do not require intervention because biofilm metabolic activity is unlikely to lead to mineral loss); 2) non-cavitated lesions, which may be restored through the use of non-operative approaches, such as remineralization therapies (i.e. brushing with fluoridated toothpaste); 3) active lesions, which indicate ongoing mineral loss, and may be responsive to non-operative therapies; and 4) cavitated lesions, where a hole has developed in the tooth that requires restoration via surgical intervention, such as a filling.

microbiome – Normal bacterial species that are present at all the times in the human body and their presence is necessary for maintaining health, especially in the digestion of foods and in keeping away detrimental bacterial species.

microporosity – An area of the enamel surface that has developed a level of porosity not clearly visible to the naked eye; the resulting change in surface texture may be detected by a

dental probe/explorer. Microporosity is a sign of demineralization, and could be indicative of the initiation of a caries lesion.

remineralization – The chemical process by which minerals (mainly calcium) are replaced into the substance of the dental hard tissues - enamel, dentin and cementum. The process requires an ideal environment that includes supersaturation with calcium and phosphate ions, and adequate buffering. In the presence of fluoride, the remineralization process is enhanced.

tomography – Use of radiography to create a focused image of structures in a defined plane or 'slice,' ignoring all other structures that would normally appear in three dimensions. A series of tomography scans can help build a clearly focused 3D image.

Introduction

For much of the last century, the diagnosis of dental caries entailed detecting only cavitation.[1] Over the last few decades, however, the caries process has been recognized as a biofilm disease characterized by prolonged periods of low pH in the mouth leading to dissolution and net loss of minerals from the teeth. The demineralization of the teeth is now understood as a physiological continuum, and the understanding of caries shifted from a discrete episode of cavitation to an understanding of demineralization as a spectrum that ranges from microporosity to cavitation.[2] Because the emphasis in dealing with caries has shifted from surgical repair to strategies that prevent decay, the challenge now to professionals is to provide better criteria for establishing the true state of a given tooth. Therefore, the primary purpose of caries diagnosis is to identify the biofilm disease process and also early signs of tooth demineralization in order to halt its progression.[1,2,3]

The scientific literature points to three main reasons why caries lesion diagnosis is important:

1. To achieve the best health outcome for the patient by classifying caries lesions corresponding to the best management options for each lesion type. Lesions are currently classified in the following way:
   - non-active lesions (which do not require intervention because biofilm metabolic activity is unlikely to lead to mineral loss).1
   - non-cavitated lesions, which may be restored through the use of non-operative approaches, such as remineralization therapies (i.e. brushing with fluoridated toothpaste)
   - active lesions, which indicate ongoing mineral loss, and may be responsive to non-operative therapies
   - cavitated lesions, where a hole has developed in the tooth that requires restoration via surgical intervention, such as a filling.
2. To inform the patient. The patient is the key in the management process because their cooperation is crucial in controlling the disease and slowing or reversing caries progression. Therefore, providing them with as much information as possible about the caries diagnosis is very important.[1]
3. To monitor the clinical course of the disease. Long-term monitoring of all stages of caries lesions and recording changes in activity status or surface integrity is the only way to tell if caries is reversing or progressing. An active lesion that becomes inactive is a positive outcome, while active lesions that remain active reflect a lack of compliance or cooperation on the part of the patient, and professional intervention may be needed.[1]

What follows is a discussion of the different methods of caries lesion diagnosis and how diagnosis and management of the disease are intricately linked.

In the past, clinicians relied primarily on the use of caries measurement systems that relied solely on the assessment of the incidence and severity of cavitated lesions. As our knowledge of caries has matured, we now recognize that caries is a dynamic process, with the ability of non-cavitated lesions to either reverse (remineralization) or progress (demineralization), depending on the conditions occurring with each individual patient. Due to the ability of early lesions to reverse through the use of preventative therapies, such as the use of

fluoridated toothpastes, mouthrinses or other remineralization therapies, it has become increasingly important to detect caries at the earliest stages possible, which maximizes the potential to maintain as much of the natural tooth as possible in the longer term.

More recently, significant efforts have been directed toward the development of comprehensive measurement systems that include assessment of caries across the continuum of the disease process, beginning with non-cavitated lesions. The most widely used system now available is the ICDAS System, an integrated system that includes all of the best understanding of caries to provide a standardized method for monitoring both the initiation and progression of caries across this continuum.

Caries Diagnosis: Definition

The Medical Perspective

Dentistry has often turned to medicine when searching for clarification of concepts and methodology, including when it comes to caries diagnosis. The medical perspective of caries diagnosis is as such: "the recognition of a disease or a condition by its outward signs and symptoms."[4] It involves recognition of signs and symptoms, devising tentative hypotheses about the underlying disease based on these signs, gathering information by doing a physical examination, running what are thought to be the most appropriate diagnostic tests, using the test results to confirm or refute the tentative diagnosis, and, if necessary, choosing an alternative diagnosis. A doctor is encouraged to repeat the cycle of symptom recognition and testing of alternative hypotheses until the final diagnosis is reached, or if the prescribed treatment does not have the desired effect and the doctor needs to revise the diagnosis.[1,3,4]

The Dental Perspective

However, the medical perspective of caries may not work perfectly when it comes to dental caries. The main task for the dentist is not to find out what disease the patient has, but having identified a patient with dental caries, to determine the best course of treatment for controlling the disease process in the biofilm. Also, the dentist needs to identify whether or not individual teeth have caries lesions, with the help of screening even patients who do not have obvious signs of caries, and determining which treatment can best help the patient. Therefore, in the dental perspective of caries diagnosis, diagnosis consists of both identifying caries as a biofilm disease and managing it, and identifying specific signs and symptoms of caries, the non-cavitated to cavitated lesion continuum and managing the lesion activity; working under the logic that caries can be prevented, slowed, stopped, or even reversed through the process of remineralization if it is detected and treated before it progresses to a point that requires invasive intervention.[1,3,4]

Diagnosis vs. Detection and Assessment

The diagnosis of dental caries should be based on known disease indicators and risk factors for the disease. Caries disease indicators include: visible cavitations, active white-spot lesions, interproximal radiographic lesions penetrating to the dentin, and a history of any cavitations in the previous 2 to 3 years.[5] While diagnosing caries requires a dentist to conduct a thorough evaluation of all information related to a patient, lesion detection employs an objective process to establish whether any signs of the disease are present at the time of evaluation. If demineralization at any stage is observed—at whatever stage—it is labeled as dental caries. Once it has been determined that a lesion is present, the function of lesion assessment is to classify the lesion and observe it over time.[5,6]

Caries Lesion Diagnosis: Visual–Tactile Methods

Visual and tactile methods typically go hand in hand, because most dentists use dental probes and other tools to examine teeth during the clinical examination. The exam can be annually, twice a year, or more frequently, depending on the dentist's recommendation. The first visual indication of caries in enamel is generally a small white lesion on smooth surfaces or a light to dark brown lesion in pits or fissures, where demineralization has occurred under the dental plaque.[2,3,7] However, grayish lesions also can be seen at the level of dentin, and in more advanced stages, caries can appear as open cavities on enamel, dentin layers, or all the way to the pulp.[2,3]

Tools

The traditional method of detecting caries signs is by visual inspection of dental surfaces, with the aid of a bright light and dental mirror, if necessary, to see the teeth from all angles. Reflecting light onto the mouth mirror also can be done to search for dark shadows that could indicate dentin lesions.

While the use of a dental probe continues to be controversial, it is extremely helpful when used correctly and judiciously. A dental probe can be used to remove plaque that may be covering lesion, and when the blunt side of the probe is used, it can help remove biofilm to check for signs of demineralization and to assess the surface roughness of a lesion. Studies show that gentle probing does not disrupt the surface integrity of non-cavitated lesions, while vigorous poking can cause irreversible damage to the surface of a developing lesion.[8,9] The accuracy of caries detection does not increase if probing is used. A probe is unnecessary if visual inspection detects a cavity.[7] During a visual-tactile examination, the dentist will also use a syringe or drying tool to blast air on to the tooth, which makes it easier to see some lesions.[2]

Other tools used in visual–tactile examination may include magnifying devices to look at teeth, or orthodontic elastic separators to separate teeth over the course of 2 to 3 days for a closer look between teeth prone to caries lesions. Fiber-optic transillumination is also sometimes used. This is a method by which visible light is emitted through the tooth using an intense light source. If the transmitted light reveals a shadow, this may indicate a carious lesion.[2,4]

Diagnostic Criteria

WHO Method

Numerous methods have been suggested for recording lesions and carious lesion activity. In the recent past, one of the most commonly used visual–tactile or visual criteria that have been used include the WHO method,[10] which limits the assessment to one in which only cavitated lesions are recorded. The rationale for this approach was an assumption that reliable diagnosis of all non-cavitated lesions was unlikely. Because the focus is only on open cavities, it ignores the fact that non-operative interventions (such as fluoride) can help reduce caries risk by enabling reversal of the disease process through the remineralization process. Therefore, most dentists in developed countries today do not rely solely on this criterion.[2,3]

ICCMS™ and ICDAS Systems

The ICCMS™ approach. Over the past few decades, there was a clear awareness of an urgent need for a more robust, standardized method of classifying caries with a focus on more than just listing the various stages of the disease. In addition, there was a recognized need for making sense of clinical trial results in systematic reviews and for aligning research outcomes with modern clinical caries measurement and management of caries. Numerous meetings, workshops and conferences were held with the goal of developing an international standard of diagnostic measurement and care. A key outcome of these efforts was the International Caries Classification and Management System (ICCMS™) a standardized method based on the current best approaches. This system, which is focused on improving long-term caries outcomes, combines history taking, clinical examination, risk assessment and personalized care planning at the individual patient level.[11]

This system was designed to develop a comprehensive care plan that incorporates:

- Preventing caries initiation (primary prevention)
- Preventive management of early caries (secondary prevention)
- Tooth preserving operative plan (minimally invasive)
- Review, monitoring and recall

This comprehensive care plan takes into account key risk factors for the individual patient, recommends inclusion of caries detection aids and lesion activity assessments and then lays out clear caries management strategies to obtain optimal results.

In some respects, such as in the area of lesion activity assessments, the ICCMS™ system is a further evolution of several criteria systems that have been in place since the late 1990s.[12] Other systems have also been incorporated into the

new structure, whenever they represented the best thinking in a particular area.

The ICDAS System is an integral aspect of the ICCMS™ approach. While the ICCMS™ represents a new, enhanced approach to the diagnosis and management of caries, the ICDAS System provides a standardized method for assessing and tracking changes in caries activity. The ICDAS System was developed in 2002 (ICDAS I) and was later modified to ICDAS II in 2005.[13] The ICDAS I and II criteria incorporate concepts from the research conducted by Ekstrand et al,[14,15] Nyvad[16] and other caries detection systems, as reported in the systematic review of Ismail and colleagues[12] is broadly considered to be the most appropriate and reliable caries reporting system currently available. As a result, the ICDAS lesion evaluation criterion serves as the basis for determining the stages of the caries process and lesion activity for the purpose of caries management within the ICCMS™ approach.[17]

The ICDAS criteria for visual examination and, when indicated, for radiographic examination, should be followed to assess the extent and severity of caries lesions. The ICDAS categories of caries lesion severity correlate well with histological depth of caries demineralization in both enamel and dentin. It should be noted that the histological depth of lesions correlates with demineralization but not necessarily with bacterial penetration.

For background, some of the measures of lesion activity that have been incorporated into ICDAS are based on previous studies that helped define key aspects of caries activity, such as ways to assess lesion depth, lesion activity, and considerations regarding root caries and recurrent caries.

Lesion depth assessment. To understand the classification for lesion depth assessment, it is important to know how moisture on the tooth surface affects the visibility of a lesion. White spot lesions become more opaque in dried dental tissue compared to wet dental tissue because of increased light scattering. Typically, non-cavitated lesions that are visible on a wet tooth have penetrated deeply, while a non-cavitated lesion that is only visible after drying has penetrated less deeply into the tooth.

Based on these concepts, Ekstrand and colleagues[14,15] suggested a visual, ranked scoring system for lesion depth assessment that is still commonly used. Using no probe, they examined tooth surfaces according to the following criteria:

- no or slight change in enamel translucency after 5 seconds of air-drying
- opacity or discoloration that is hardly visible on wet surfaces, but visible after 5 seconds of air drying
- opacity or discoloration that is visible without air-drying
- localized enamel breakdown with opaque or discolored enamel and/or grayish discoloration from underlying dentin
- cavitation in opaque or discolored enamel exposing dentin.

Lesion activity assessment. This method, developed in 1999 by Nyvad et al,[16] focuses on the surface characteristics of lesions, namely activity as reflected in the surface texture of the lesion, and surface integrity, as indicated by the presence or absence of a cavity or microcavity in the surface. The rationale behind the method is that the surface characteristics of enamel change in response to changes in the biofilm covering the tooth surface. The diagnostic categories are as follows: active, non-cavitated; active, cavitated; inactive, non-cavitated; inactive, cavitated; filling; filling with active caries; filling with inactive caries.

- Active, non-cavitated enamel caries lesions have a whitish/yellowish opaque surface, with a chalky or neon-white appearance, and the surface feels rough when a probe is moved across it.
- Inactive, non-cavitated lesions, on the other hand, are shiny and can vary in color from white, brown, or black, and will feel smooth with gentle probing.
- Active, cavitated lesions feel soft or leathery, while inactive, cavitated lesions are shiny and feel hard with probing.
- In general, active, non-cavitated lesions have a higher risk of progressing to a cavity than inactive, non-cavitated lesions, which have a higher risk of becoming a cavity than healthy surfaces.[2,16]

Recording root-surface caries. This is a classification specific to root caries lesions that integrates activity assessment and surface integrity assessment. The diagnostic categories are as follows:

- inactive lesion without surface destruction
- inactive lesion with cavity formation
- active lesion without surface destruction
- active lesion with surface destruction (cavitation), but visually cavity does not exceed 1 mm in depth
- active lesion with a cavity depth exceeding 1 mm, but does not involve pulp
- lesion expected to penetrate into pulp
- filling confined to root surface or extending from a coronal surface to root surface
- filling with an inactive lesion (secondary) confined to the margin.[18]

Recording recurrent caries. This refers to caries at the margins of restorations, with recurrent caries reflecting the result of unsuccessful plaque control. These are typically found on the gingival margins of all classes of restorations, with the exception of class I restorations, which affect pit-and-fissure crevices on occlusal, buccal, and lingual surfaces of posterior teeth and lingual surfaces of anterior teeth.[19] Diagnosis is accomplished using the Nyvad criteria in the lesion activity assessment section described previously.

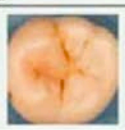
Diagnostic Criteria for Assessing Coronal Caries Lesion Activity

Based on the outcome of numerous symposia on the topic of caries diagnostics and assessment, ICDAS criteria were developed to describe various aspects of caries activity. The following figure and tables provide a summary of these criteria, along with the six different ICDAS codes used to identify each occlusal condition.

In general, the following criteria apply:

- An **Active Lesion** is considered to have a greater likelihood of transition (progression, arrest or regression) than an inactive lesion.
- An **Inactive (arrested) Lesion** is considered to have a lesser likelihood of transition than an active lesion.

Occlusal Protocol ***

ICDAS code	0	1	2	3	4	5	6
							
Definitions	Sound tooth surface; no caries change after air drying (5 sec); or hypoplasia, wear, erosion, and other noncaries phenomena	First visual change in enamel; seen only after air drying or colored change "thin" limited to the confines of the pit and fissure area	Distinct visual change in enamel; seen when wet, white or colored, "wider" than the fissure/fossa	Localized enamel breakdown with no visible dentin or underlying shadow; discontinuity of surface enamel, widening of fissure	Underlying dark shadow from dentin, with or without localized enamel breakdown	Distinct cavity with visible dentin; frank cavitation involving less than half of a tooth surface	Extensive distinct cavity with dentin; cavity is deep and wide involving more than half of the tooth
Histologic depth		Lesion depth in P/F was 90% in the outer enamel with only 10% into dentin	Lesion depth in P/F was 50% inner enamel and 50% into the outer 1/3 dentin	Lesion depth in P/F with 77% in dentin	Lesion depth in P/F with 88% into dentin	Lesion depth in P/F with 100% in dentin	Lesion depth in P/F 100% reaching inner 1/3 dentin
Sealant/restoration Recommendation for low risk	Sealant optional DIAGNOdent may be helpful	Sealant optional DIAGNOdent may be helpful	Sealant optional or caries biopsy if DIAGNOdent is 20-30	Sealant or minimally invasive restoration needed	Minimally invasive restoration	Minimally invasive restoration	Minimally invasive restoration
Sealant/restoration Recommendation for moderate risk	Sealant optional DIAGNOdent may be helpful	Sealant recommended DIAGNOdent may be helpful	Sealant optional or caries biopsy if DIAGNOdent is 20-30	Sealant or minimally invasive restoration needed	Minimally invasive restoration	Minimally invasive restoration	Minimally invasive restoration
Sealant/restoration Recommendation for high risk *	Sealant recommended DIAGNOdent may be helpful	Sealant recommended DIAGNOdent may be helpful	Sealant optional or caries biopsy if DIAGNOdent is 20-30	Sealant or minimally invasive restoration needed	Minimally invasive restoration	Minimally invasive restoration	Minimally invasive restoration
Sealant/restoration Recommendation for extreme risk **	Sealant recommended DIAGNOdent may be helpful	Sealant recommended DIAGNOdent may be helpful	Sealant optional or caries biopsy if DIAGNOdent is 20-30	Sealant or minimally invasive restoration needed	Minimally invasive restoration	Minimally invasive restoration	Minimally invasive restoration

* Patients with one (or more) cavitated lesion(s) are high-risk patients. ** Patients with one (or more) cavitated lesion(s) and xerostomia are extreme-risk patients.

*** All sealants and restorations to be done with a minimally invasive philosophy in mind. Sealants are defined as confined to enamel. Restoration is defined as in dentin. A two-surface restoration is defined as a preparation that has one part of the preparation in dentin and the preparatio extends to a second surface (note: the second surface does not have to be in dentin). A sealant can be either resin-based or glass ionomer. Resin-based sealants should have the most conservatively prepared fissures for proper bonding. Glass ionomer should be considered where the enamel is immature, or where fissure preparation is not desired, or where rubber dam isolation is not possible. Patients should be given a choice in material selection.

Figure 1. The International Caries Detection and Assessment System (ICDAS).[20]
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In alignment with Figure 1, the characteristics of active coronal lesions (not all characteristics need to be present to decide activity status) are as follows in Table 1.[17]

For the purpose of caries management, individual tooth surfaces are categorized and described, based on an evaluation of each surface affected, using the following criteria:

For pits and fissures, the evaluation criteria are as follows in Table 2.

For mesial and distal surfaces, the evaluation criteria are as follows in Table 3.

For buccal-lingual smooth surfaces, the evaluation criteria are as follows in Table 4.

Diagnostic Criteria for Detection of Root Caries and Assessing Root Lesion Activity

- For the purpose of root caries detection, removal of calculus and plaque is recommended.
- The characteristics of the base of the discolored area on the root surface can be used to determine whether or not the root caries lesion is active.
  - These characteristics include texture (smooth, rough), appearance (shiny or glossy, matte or non-glossy) and perception of texture on gentle probing (soft, leathery, hard).
  - Active root caries lesions are usually located within 2mm of the crest of the gingival margin.

Evaluation criteria for assessing root caries are as follows in Table 5.

In addition to the use of these diagnostic criteria for evaluating both coronal and root caries, the ICCMS™ system calls for an assessment of surfaces surrounding restorations and sealants, to ensure that no surface is overlooked. Another important diagnostic aspect of the ICCMS™ system is an evaluation of the biofilm, particularly with regard to its location and thickness. The data indicate that dental caries infection occurs due to a shift in the microbial ecology within the oral cavity and further suggest there is increased caries risk associated with plaque/

Table 1. Characteristics of Active Coronal Lesions.

ICDAS Code	Characteristics of Lesion	
	Signs of Active Lesion	Signs of Inactive Lesion
Initial to Moderate Stage Caries (1-4)	Surface of enamel is whitish/yellowish; opaque with loss of luster; feels rough when the tip of the probe is moved gently across the surface. Lesion is in a plaque stagnation area, i.e. in the entrance of pits and fissures, or near the gingiva, and in approximal surfaces below the contact point. Lesion was covered by thick plaque prior to cleaning.	Surface of enamel is whitish, brownish or black. Enamel may be shiny and feels hard and smooth when the tip of the probe is moved gently across the surface. For smooth surfaces, the caries lesion is typically located at some distance from the gingival margin. Lesion was not covered by thick plaque prior to cleaning.
Extensive Stage Caries (5-6)	Dentin feels soft or leathery on probing	Dentin is shiny and hard on probing

Table 2. Pits and Fissures Evaluation Criteria.

Tooth Surface Description	Evaluation Criteria	ICDAS Code
Sound surfaces	No visible caries when viewed clean and dry. Non-carious white or brown marks on tooth surfaces must be differentiated from early caries lesions.	0
Initial stage caries	Characterized by the first visual change in enamel (seen only after prolonged air drying or restricted to the confines of a pit or fissure). **OR** A distinct visual change in enamel (seen on a wet or dry surface).	1 2
Moderate stage caries	Characterized visually by either localized enamel breakdown (without visual signs of dentinal exposure). - Enamel breakdown is often viewed best when the tooth is air dried. **OR** An underlying dark shadow from dentin. - Shadowing from dentinal caries is often best seen with the tooth surface wet.	3 4
Extensive stage caries	Characterized by distinct cavitation exposing visible dentin. - Lesions exhibiting cavitation involving less than half the tooth surface. - Lesions involving half of the tooth surface or more.	5 6

Table 3. Mesial and Distal Surfaces Evaluation Criteria.

Tooth Surface Description	Evaluation Criteria	ICDAS Code
Sound surfaces	No visible caries when viewed clean and dry. Non-carious white or brown marks on tooth surfaces must be differentiated from early caries lesions.	0
Initial stage caries	Characterized by the first visual change in enamel (seen only after prolonged air drying). **OR** A distinct visual change in enamel (seen on a wet or dry surface). - These lesions are usually seen directly from the lingual or buccal directions but may be viewed from the occlusal direction as a shadow confined to enamel.	1 2
Moderate stage caries	Characterized visually by either localized enamel breakdown (without visual signs of dentinal exposure). - Enamel breakdown is often viewed best when the tooth is air dried. **OR** An underlying dark shadow from dentin. - Shadowing from dentinal caries is often best seen with the tooth surface wet.	3 4
Extensive stage caries	Characterized by distinct cavitation exposing visible dentin. - Lesions exhibiting cavitation involving less than half the tooth surface. - Lesions involving half of the tooth surface or more.	5 6

Table 4. Buccal-lingual Smooth Surfaces Evaluation Criteria.

Tooth Surface Description	Evaluation Criteria	ICDAS Code
Sound surfaces	No visible caries when viewed clean and dry. Developmental defects like enamel hypoplasias, fluorosis, tooth wear (attrition, abrasion and erosion), and extrinsic or intrinsic stains should be recorded as sound in the absence of other signs of caries lesions, as described below.	0
Initial stage caries	Characterized by the first visual change in enamel (seen only after prolonged air drying). **OR** A distinct visual change in enamel (seen on a wet or dry surface). - Initial stage lesions on free smooth surfaces are located in close proximity (in touch or within 1 mm) to the gingival margin or adjacent to orthodontic or prosthetic attachments on a tooth surface.	1 2
Moderate stage caries	Characterized visually by either localized enamel breakdown (without visual signs of dentinal exposure). - Enamel breakdown is often viewed best when the tooth is air dried. **OR** An underlying dark shadow from dentin. - Shadowing from dentinal caries is often best seen with the tooth surface wet.	3 4
Extensive stage caries	Characterized by distinct cavitation exposing visible dentin. - Lesions exhibiting cavitation involving less than half the tooth surface. - Lesions involving half of the tooth surface or more.	5 6

Table 5. Assessing Root Caries Evaluation Criteria.

Code	Evaluation Criteria
E	If for any reason a root surface cannot be visualized directly, or with the assistance of gentle air drying, code E (excluded) can be recorded on the dental chart.
0	The root surface does not exhibit any unusual discoloration that distinguishes it from the surrounding or adjacent root areas nor does it exhibit a surface defect either at the cemento-enamel junction or wholly on the root surface. The root surface has a natural anatomical contour, **OR** The root surface may exhibit a definite loss of surface continuity or anatomical contour that is not consistent with the dental caries process. This loss of surface integrity usually is associated with dietary influences or habits such as abrasion or erosion. These conditions usually occur on the facial (labial) surface. These areas typically are smooth, shiny and hard. Abrasion is characterized by a clearly defined outline with a sharp border, whereas erosion has a more diffuse border. Neither condition shows discoloration.
1	There is a clearly demarcated area on the root surface or at the cemento-enamel junction (CEJ) that is discolored (light/dark brown, black) but there is no cavitation (loss of anatomical contour).
2	There is a clearly demarcated area on the root surface or at the cemento-enamel junction (CEJ) that is discolored (light/dark brown, black) and there is cavitation (loss of anatomical contour ≥ 0.5 mm) present.

biofilm accumulation. Therefore, an ongoing evaluation of the biofilm is recommended to monitor for any significant changes that might be indicative of lesion activity.

Radiographic Examination in the ICCMS™
There is a unanimous agreement that more caries lesions can be identified by combining radiographic information with clinical findings, compared to visual inspection alone. For this reason, ICCMS™ recommends the inclusion of radiographic examination, if possible and appropriate based on local safety standards. Radiographic examination is useful to confirm the extent of caries, to detect lesions where visual examination of the tooth surface is hampered and to serve as an aid in making appropriate clinical decisions.

In addition to the use of radiographic evaluation, the ICCMS™ recognizes the potential benefits that can be gained by the use of additional, supplemental detection aids as a means of enhancing caries detection. These can include Fiber-optic Transillumination (FOTI), electrical conductivity measures and optical fluorescence techniques and are briefly discussed later in this course.

Benefits of Visual Diagnosis

Visual diagnosis is quick and easy to perform, does not require expensive equipment, and can be completed without unnecessary radiation. Currently, activity assessment according to the criteria suggested by the ICDAS/ICCMS™ is considered the best choice for performing a caries diagnosis. Surprisingly, data show that when non-cavitated lesions are included in classification, the yield of visual or visual-tactile caries examination is greater than that of radiographic examination because minor mineral losses cannot be detected in radiographs.[21,22]

Table 6. The ICCMS™ Radiographical Scoring System.

	ICCMS Score	
RA (Initial Stages)	1	Radiolucency in the outer 1/2 of the enamel
	2	Radiolucency in the outer 1/2 of enamel ± EDJ
RB (Moderate Stages)	3	Radiolucency limited to the outer 1/3 of dentin
	4	Radiolucency reaching the middle 1/3 of dentin
RC (Extensive Stages)	5	Radiolucency reaching the inner 1/3 of dentin, clinically cavitated
	6	Radiolucency into the pulp, clinically cavitated

Limitations of Visual or Visual–Tactile Lesion Diagnosis

These include the fact that visual or visual-tactile diagnosis requires subjective evaluations to be made by the practitioner, lesions can go undetected because teeth are typically examined by the naked eye, and there is need for supplemental analysis when faced with clinical signs that will leave a dentist uncertain, including dark occlusal or approximal shadows.[2]

Caries Lesion Diagnosis: Bitewing Radiography

The most commonly used radiographic method for detecting caries lesions is the bitewing technique. It is meant to find lesions that are hidden from a clinical visual examination, such as when a lesion is hidden by an adjacent tooth, as well as help the dental professional estimate how deep the lesion is.[2]

To get the radiographic images, a central beam of X-rays is positioned to pass at right angles to the long axis of the tooth. If film is used, a beam-aiming device on the film holder guides the position, directing the beam at right angles to the film. However, digital radiography is replacing radiography based on film. It has been proven as accurate as traditional radiography for detecting caries, and it comes with additional advantages of using a lower radiation dose, being less time-consuming, and does not require wet chemicals in the processing of the image.[2,23]

Concerns about Radiation

Possible health risks of exposure to low-dose radiation in children, who appear to be more at risk than adults, include parotid, bone marrow, and thyroid cancer.[24] Even though there is no conclusive evidence that the small, infrequent doses of radiation from dental radiographs increase risk of malignant disease, unnecessary radiation to the patient should be avoided, and care used to reduce radiation exposure if radiography is necessary.[2,25] This can include use of a thyroid shield, use of a rectangular collimation which limits the shape of the X-ray beam and reduces radiation exposure by 50%, or use of the fastest film type (the F-type) or digital radiography.[2]

Factors that Influence the Quality and Interpretation of Radiographic Images

There are a number of factors that affect the usefulness and quality of the radiographic examination.[2]

1. A certain amount of mineral must be lost before it can be detected in a radiograph. Technical aspects, such as film contrast and viewing conditions, determine this minimum amount of mineral loss.
2. The shape, extent, and location of the lesion, together with the anatomy of the tooth, also influence the radiographic depiction. A shallow, widespread lesion may create an image of being deeper than a deep lesion that is narrowly spread on the surface.
3. The direction of the X-rays affects the image. Most dentists now use film-holders or beam-aiming devices that prevent deviations of the rays that cause a decreased image contrast, and could result in the under- or over-estimation of the extent of a lesion.
4. An important aspect of correctly diagnosing caries using radiography is the interpretation by the professional. Having no expectation to detect caries may result in insufficient examination of the image, a neglected diagnosis, and insufficient treatment. On the other hand, there is also the possibility of over diagnosis and overtreatment if a dentist assumes almost all patients have caries. Therefore, it is important to understand caries prevalence of the population under treatment, meaning that not all patients should be handled in the same way.

Diagnostic Criteria

The most commonly used criteria for assessing the depth of caries lesions are as follows:

Timing of Bitewing Radiography

For populations with low caries prevalence, or in individuals who are at low risk for caries based on their medical and dental history, yearly bitewing radiographs are no longer justified.[26] Instead, the decision to use radiography should depend on the benefit to the individual patient as it relates to the

risk and cost of low-dose radiation exposure. Studies have confirmed that in low-risk populations, intervals of up to 3 years between bitewing radiographs do not jeopardize dental health.[27] Based on epidemiological data, four key ages have been identified when bitewing examinations are beneficial.[28] These are at:

- **Age 5**, when it gives a considerable diagnostic yield of otherwise undetected approximal lesions in primary molars.[2]
- **Age 8–9**, when the first permanent molar has been in contact with the second primary molar for about 2 years, and these surfaces are, therefore, at risk of approximal caries.[2]
- **Age 12–14**, when even in low caries-prevalence populations, one in five children has at least one approximal lesion that has been overlooked without bitewing radiography.[2]
- **Age 15–16**, when it is the first 3 to 4 years after tooth eruption and the establishment of approximal contacts create the risk of new approximal lesions.[2]

In adults, the caries process is slow compared to children and adolescents, but rapid behavior and lifestyle changes can quickly increase caries risk and progression. Keeping an eye out for these changes by taking a patient's medical and dental history can help a dentist decide when it might be useful to do a bitewing examination. Special attention should be paid to the third molar and distal surface of the second molar because the location is usually associated with plaque removal difficulty.[2]

Bitewing Radiography as a Complement to the Visual–Tactile Examination

Occlusal caries lesions (which develop on surfaces that contact an opposing surface of a tooth in the opposing jaw) are difficult to diagnose by visual examination only. Using bitewing radiography raises the sensitivity of the diagnosis if obvious dentin caries activity is to be detected, but can be inaccurate if diagnosing enamel occlusal caries activity. Visual-tactile examination alone also fails to detect a number of occlusal and approximal caries lesions in deciduous teeth in children. Complementing the clinical examination with bitewing radiography has also been found to increase the sensitivity of detecting caries lesions in these teeth. Another way in which bitewing radiography complements the visual-tactile examination is in the diagnosis of recurrent caries lesions. A radiolucent area typically indicates that residual carious tissue was left behind when the restoration was placed. Occlusal caries lesions (which develop on surfaces that contact an opposing surface of a tooth in the opposing jaw) are difficult to diagnose by visual examination only. Using bitewing radiography raises the sensitivity of the diagnosis if obvious dentin caries activity is to be detected, but can be inaccurate if diagnosing enamel occlusal caries activity. Visual-tactile examination alone also fails to detect a number of occlusal and approximal caries lesions in deciduous teeth in children. Complementing the clinical examination with bitewing radiography has also been found to increase the sensitivity of detecting caries lesions in these teeth. Another way in which bitewing radiography complements the visual-tactile examination is in the diagnosis of recurrent caries lesions. A radiolucent area typically indicates that residual carious tissue was left behind when the restoration was placed.[2]

Benefits of Bitewing Radiography Diagnosis

As mentioned previously, bitewing radiography allows accessibility to surfaces that may not be seen in the clinical visual-tactile examination, and it allows the depth of lesions to be assessed. Other advantages are that it is not invasive and does not damage tooth structure like an incorrectly used dental probe might. Radiographs can also be filed and re-examined at a later date to compare with a more recent image to detect whether a lesion is progressing or not.[2]

Limitations of Bitewing Radiography Diagnosis

Besides concerns about low-dose radiation and variations in how images are interpreted by dentists, the main limitation is that the validity in diagnosing early lesions is rather low. Also, the bitewing radiograph cannot always distinguish between sound surfaces, those with initial caries activity and cavitated lesions, or non-carious demineralizations; so clinical inspection is still needed to determine what is happening to the tooth. Bitewing radiographs

also tend to underestimate the depths of lesions, so a lesion that appears confined to the inner enamel on an image is often actually in the dentin, and this can lead to insufficient or improper treatment.[2]

Caries Lesion Diagnosis: Newer Methods of Caries Detection and Assessment

This section will briefly address some of the newer methods being used to detect and diagnose caries lesions. They can be divided into methods that are based on X-ray, methods based on light emission, and methods based on electrical current.

Methods Based on X-Ray

These include:

- **Digital radiography** – which is increasingly replacing bitewing radiography and that is as accurate as film for the detection of caries lesions.
- **Digital image enhancement** – which studies show can provide superior results to radiographs when enhanced correctly but takes a significant amount of technical skill.
- **Digital subtraction radiography** – which is not typically used in a clinical setting, also because of the high level of technical skill needed to perform correctly.
- **Tuned aperture computed tomography** – which shows improved diagnostic accuracy in caries lesion detection, but with equipment that is too expensive for most clinical practices.

Methods Based on Light

These include:

- **Laser light-induced fluorescence**, based on the phenomenon that caries lesions, plaque, and microorganisms all contain fluorescent substances that can be distinguished from each other and the autofluorescence of enamel and dentin. An example of this type of product is the **Canary System™**.
- **Quantitative laser-light induced fluorescence**, such as the **Inspektor QLF™**, which can quantitatively detect the difference in fluorescence between sound tissue and that of a caries lesion.
- **DIAGNOdent**, which uses red light to induce fluorescence and handy tools/probes, such as the DIAGNOdent*pen*, which can fit into smaller spaces and fissures in occlusal and approximal surfaces of teeth to capture differences in fluorescence that could indicate a lesion.
- **Fiber-optic transillumination (FOTI)** and the more sensitive **digital imaging fiber-optic transillumination (DIFOTI)**, which are qualitative diagnostic methods by which teeth are trans illuminated to detect shadows, which has been associated with the presence of carious lesions.

Methods Based on Electrical Current

These include **electrical conductance** and **electrical impedance**, such as the **CarieScan PRO** system. With the understanding that dentin is more conductive than enamel, and that porous (lesioned) enamel is more conductive than sound enamel, measuring the electrical conductance of the tooth can detect demineralized sites in enamel, sites that have become porous (indicating a lesion), and cavities. Also, with the knowledge that every material has different electrical impedance determined by its molecular composition, it is theoretically possible to detect carious lesions because they have lower electrical impedance than sound tissue.

A recent study that compared results of the DIAGNOdent pen and the CarieScan Pro to ICDAS in both *in vitro* and *in vivo* conditions reported: "The *in vivo* results of ICDAS and DIAGNOdent pen were satisfactory and comparable to those obtained *in vitro*, with ICDAS performing better. The CarieScan PRO performed poorly under both conditions."[29] These results suggest that, although some of the diagnostic methods might provide some level of useful information, they should be used with caution. At present, the ICDAS criteria are the most clinically relevant approach available for accurate assessment of caries.

The Limited Use of Newer Methods in Dental Practice

It should be noted that because of the high level of technical skill needed to use some of these methods, or the expense of the necessary equipment, the only technique that

Video 1. What new instruments or techniques are currently available for caries detection?
Click on image to view video online.

is currently widely used in dental practice is digital radiography.[2] The DIAGNOdent tends to be used in some practices as a second opinion during the diagnostic process on occlusal surfaces. The other methods tend to be used mostly in a research setting.

Caries Diagnosis: Important Points to Consider

How early is too early when it comes to caries detection?

It has been established that the signs and symptoms of caries form a continuum of changes ranging from barely discernible at the ultrastructural level to overt cavities. This has led to the development of diagnostic methods that aim to identify caries lesions at the earliest stage of development possible, in order to increase the opportunity for success with non-operative interventions, such as fluoride treatment. However, some argue that there may be consequences to "too early" detection. These include the possibility of more false-positive diagnoses because caries lesion diagnosis (like any other measurement process) is prone to certain levels of error, and this could lead to unnecessary non-operative treatment.[2] Also, many subclinical lesions regress without active intervention thanks to the natural remineralization processes that take place in biofilm.[30] In order to avoid the potential for unnecessary treatment of any kind, the use of techniques more advanced than the visual-tactile examination should continue to be used with caution, with the clinician recognizing these are tools to help them determine the best approaches to follow. By following the ICDEA criteria closely, coupled with any assessment tools they have available, it is likely that better clinical outcomes can be achieved for all ages of patients.

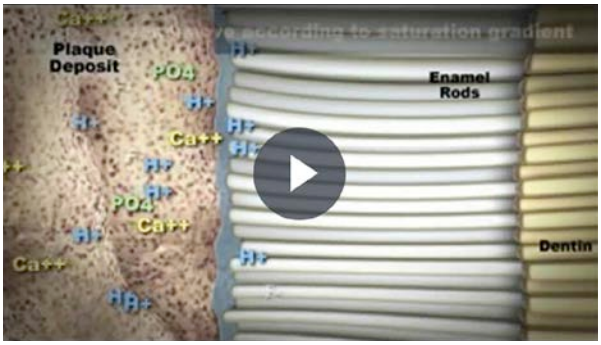
Should pediatricians help in diagnosing caries?

Caries is the most common American chronic childhood disease, yet not all pediatricians are trained in oral care and oral health of infants and children. It is becoming increasingly evident that it is important to educate healthcare providers about how to detect early signs of caries, because this will help to increase the opportunity for non-operative interventions. Pediatricians see children more frequently than dentists because of nationally and internationally recommended vaccination schedules, and because of the frequency of well-visits in infancy and early childhood. One study conducted in the United States found that pediatric primary-care providers who did 2 hours of training on the oral health of infants were able to identify a cavitated lesion with a level of accuracy similar to that of pediatric dentists.[31] A more recent study reported that "the American Academy of Pediatrics recommends periodic oral health risk assessments (OHRAs) for young children to prevent early childhood caries and promote oral health."[32] It would be advisable for pediatricians to be familiar with the ICDAS scoring criteria, as their partnership with pediatric dentists could prove to be even more beneficial.

Conclusion

As signs of the caries process became recognized as a physiological continuum ranging from microporosity to cavitation, caries lesion diagnosis made an important shift from focusing only on cavitation (and expensive, time-consuming surgical repair) to identifying early signs of demineralization to allow the opportunity for non-surgical intervention. To that end, improvements have been made on current methods of diagnosis. The ICCMS™ approach, coupled with the ICDAS criteria for visual examination and, when indicated, for radiographic examination, should be followed to assess the extent and severity of caries lesions, represents the most current approach

for diagnosing and managing caries; it is a dynamic approach that is open to change as new information comes available. Further research and progress in the classification of caries lesions can continue to improve diagnosis for all ages of patients.



Video 2. Caries Lesion Initiation and Progression (Animation).
Click on image to view video online.

Course Test Preview

To receive Continuing Education credit for this course, you must complete the online test. Please go to: *www.dentalcare.com/en-us/professional-education/ce-courses/ce373/test*

1. What is the primary purpose of caries diagnosis?

A. To only detect cavitations.
B. To help identify early signs of tooth demineralization in order to halt its progression.
C. To only detect non-cavitated tooth lesions.
D. To only prevent teeth from falling out.

2. The most widely system now used to assess the status of caries across the continuum of the disease process is the _____?

A. ICCMS
B. WHO
C. ICDAS
D. Ekstrand

3. Caries disease indicators include _____.

A. active white-spot lesions
B. a recent change in diet
C. a history of oral malodor
D. darkening of the occlusal surfaces

4. What are the basic tools for detecting caries lesions by visual inspection?

A. Bright light and a dental mirror
B. An x-ray
C. Fiber-optic transillumination
D. Electrical current

5. Which of the following is true about using a dental probe?

A. Vigorous poking cannot cause irreversible damage to the surface of a developing lesion.
B. Gentle probing does not disrupt the surface integrity of non-cavitated lesions.
C. The blunt side should never be used to remove biofilm.
D. Dental probes are no longer used in modern dentistry.

6. How does the ICDAS differ from the WHO Method of Caries Diagnostic Criteria?

A. ICDAS is focused on measuring fully cavitated lesions.
B. The WHO method is focused on measuring fully cavitated lesions.
C. There is no real difference between the two caries diagnostic methods.
D. The WHO method takes into account the entire continuum of the caries progression process.

7. Which of the two Caries Diagnostic Methods (WHO or ICDAS) is considered to be the most useful?

A. The WHO Method
B. The ICDAS Method
C. Both methods are considered equally useful.
D. Neither of these two methods is considered to be useful for caries diagnosis.

8. How many ICDAS codes are used to classify occlusal caries?

A. 4
B. 6
C. 8
D. 9

9. Considering the ICDAS system, which of the following conditions generally apply?

A. An active lesion is considered to have a greater likelihood of transition than an inactive lesion.
B. An inactive (arrested) lesion is considered to have a lesser likelihood of transition than an active lesion.
C. All lesions are considered to be likely to transition.
D. A and B

10. Which of the following factors influence the quality and interpretation of radiographic images when diagnosing caries lesions?

A. The shape, extent and location of the lesion.
B. The patient's insurance coverage specifications.
C. The number of potentially affected sites.
D. A and B

11. Which of the following is true about the usefulness of complementing the clinical visual–tactile examination with bitewing radiography?

A. Bitewing radiography does not help diagnose recurrent caries lesions.
B. Complementing the clinical examination with bitewing radiography increases the sensitivity of detecting occlusal and approximal caries lesions in children's deciduous teeth.
C. Bitewing radiography lowers the sensitivity of diagnosis of dentin caries lesions.
D. Bitewing radiography can accurately diagnose enamel occlusal caries lesions in adult teeth.

12. Which of the following is a benefit of bitewing radiography?

A. It is only mildly invasive and painful.
B. It has limited surface accessibility.
C. It can completely replace the need for a visual-tactile examination.
D. Radiographs can be filed and reexamined at a later date to detect whether a lesion is progressing or not.

13. What is the main limitation of bitewing radiography?

A. The validity in diagnosing early lesions is rather low.
B. It does a bad job of detecting caries in children's teeth.
C. It requires too much equipment.
D. Most dentists find radiographic images too hard to understand.

14. Which of the following methods of caries lesion detection and assessment is the only technique that is currently widely used in dental practice?

A. Quantitative laser-light induced fluorescence
B. The DIAGNOdent
C. Digital radiography
D. B and C

15. What is one reason behind having pediatricians help in caries diagnosis?

A. Children do not like dentists, but they like pediatricians.
B. Pediatricians have more tricks for making children keep their mouths open to be examined.
C. One study found that pediatricians who did two hours of training were able to identify a cavitated lesion with an accuracy level similar to that of dentists.
D. Most dentists do not include children in their practice.

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Additional Resources

- No Additional Resources Available.

About the Author

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Dr. Ismail is the dean of Temple University's Maurice H. Kornberg School of Dentistry. He joined Temple from the University of Michigan in Ann Arbor where he was professor of health services research and cariology at the School of Dentistry and professor of epidemiology and director of the program in dental public health at the School of Public Health. Throughout his career, Dr. Ismail has spurred collaborative programs and research projects to better meet the needs of society's underserved populations, particularly Mexican-Americans and African-Americans. In Detroit, he has led two such initiatives, both funded by the National Institutes of Health: the five-year, $1.6 million Detroit Oral Cancer Prevention Project, and the seven-year, $6.9 million Detroit Center for Research on Oral Health Disparities. He was also the principal investigator of a $6.9 million NIH grant to study a Web-based resource on evidence-based dentistry.

A consummate leader, Dr. Ismail has held positions of stature at numerous professional associations. Currently chair of the American Dental Association's (ADA) Curriculum Development Committee of the Community Dental Health Coordinator program, he formerly chaired the ADA Council on Scientific Affairs and the National Affairs Committee of the American Association for Dental Research. He has also organized and co-organized several national and international conferences that led to major changes in evidence-based health care and dental practice, including the NIH Consensus Conference on Dental Caries Management Throughout Life and the ADA Clinical Recommendations Panels on Fluoride Supplements and Professional Topical Fluoride. Additionally, he has been active in the ADA's Dental Economics Advisory Committee and the Division of Science, and co-chairs the Coordinating Committee of the International Caries Detection and Assessment System.

Dr. Ismail received his dental degree (BDS) from the University of Baghdad. Prior to joining the University of Michigan, from which he earned an MPH, a DrPH, and later, an MBA, he served on the faculties of Dalhousie and McGill Universities in Canada. Dr. Ismail is a prolific scientist, having published and presented over 200 abstracts, manuscripts and editorials, and co-authoring the chapter, "*Dental Care Delivery System*," in the Surgeon General's 2000 landmark report on Oral Health. His work, focused on oral and overall health issues facing the underserved, such as cancer risk, depression and diet, has appeared in such scholarly journals as *The Lancet*, the *Journal of the American Medical Association*, the *Journal of the American Dental Association*, and *Pediatric Dentistry*.

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