Caries Management: A New Paradigm

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Abstract: *In 2001, The National Institutes of Health (NIH) published its first consensus statement on the management of dental caries in response to the Surgeon General's 2000 report, Oral Health in America: A Report of the Surgeon General. Since then the dental profession has seen the introduction of evidence-based dentistry (EBD) and the classification of risk factors for dental caries, as well as the introduction of many new tools and technologies to augment current diagnostic and treatment applications. This article reviews the literature to explore dentistry's current understanding and management of dental caries. The new paradigm no longer focuses on caries detection and restoration, but on the integration of risk factors and the incorporation of new tools to facilitate early detection and potentially prevent or repair caries lesions.*

The National Institutes of Health (NIH) published its first consensus statement on the management of dental caries in 2001, and as a result many dentists have begun to rethink the current handling of dental caries, the most common infectious disease affecting our population. Dental caries is the single most common chronic childhood disease; it is 5 times more common than asthma and 7 times more common than hay fever.[1] Nearly 20% of children between the ages of 2 and 4 years have detectable caries, and by 17 years of age almost 80% of young people have had a cavitated lesion. Among adults 35 to 44 years old, 66% have lost 1 tooth to dental caries.[2]

This is a silent epidemic that can have devastating consequences for some population groups, especially children and the elderly living below the poverty level, and members of certain racial and ethnic groups. Even though tooth decay has been remarkably reduced over the last 30 years, there are still striking disparities in dental disease by income. For instance, poor children and adolescents suffer twice as much dental caries as their wealthier peers, and their disease is more likely to go untreated. Uninsured children are 2.5 times less likely than insured children to receive dental care.[1] Eighty percent of dental caries are found in 25% of the population.[3] This information should prompt dentists to rethink treatment protocols and tailor treatment to meet the needs of patients based on individual risk levels for the disease.

Evidence-based Dentistry

This leads to the topic of evidence-based dentistry (EBD) and the determination of a patient's risk factors before treatment. Changing from the traditional model of caries detection and diagnosis to a risk-based management model requires complex decision making that is unlikely to occur unless a system is developed that can easily be adapted into the current dental practice model. Benn and colleagues have published several articles dealing with EBD and possible solutions.[4-6] Dental caries is a multifactorial disease that involves a susceptible host, specific bacteria, a food substrate, and time. All these factors need to be controlled to minimize the consequences of this disease, which causes the demineralization of tooth structure. The body's

Table 1A—New Clients Age Category

	Child/Adolescent	Adult
Low Risk*	No decayed, missing or filled surfaces (DMFS=0)	No decayed, missing or filled surfaces (DMFS=0)
Moderate Risk*	Past caries experience (DMFS>0) **and/or** 1 active lesion	Past caries experience (DMFS>0) **and/or** 1 active lesion
High Risk*	Past caries experience (DMFS>0) **and/or** 2 active caries or 1 smooth surface lesion Current orthodontic treatment	Past caries experience (DMFS>0) **and/or** 2 active lesions or 1 smooth surface lesion Current orthodontic treatment

*To assess which category is appropriate, assess past caries history to determine level of caries risk. If no caries activity is present, evaluate additional factors listed to determine level of risk.

immune system and professional intervention can reverse the process. Proper treatment can change the oral environment to arrest the caries process and remineralize noncavitated carious lesions.

Traditionally, dental examinations focused on the detection of caries, its removal, and the restoration of the tooth. New applications allow dentists to focus more on diagnosis, which involves distinguishing disease from its signs and symptoms.[7] Diagnosis is a balancing act in which a clinician gathers a set of signs and symptoms from interviews, clinical exams, and supplementary tests and uses them to develop a treatment decision that is expressed in terms of probability of present and future occurrence of caries. This means that a caries lesion is evaluated by risk of progression. The treatment may include remineralizing pharmaceuticals, plaque control, and dietary counseling; the tooth may be restored; or a combination of both treatments may be used.

Current Understanding of Dental Caries

Dental caries is an infectious, communicable disease[8] that is an ongoing dynamic process of demineralization and remineralization.[9] This balance between pathologic and protective factors determines the state of health or disease. Demineralization is the loss of mineral (calcium and phosphate) from the tooth, resulting from attack by bacteria that produce organic acids during their metabolism. Remineralization is the natural repair process that replaces some of the lost minerals. This occurs when the acid in the plaque is buffered by saliva, allowing calcium and phosphate to flow back into the tooth and form new mineral. The new mineral becomes more resistant to subsequent acid attacks, especially in the presence of sufficient fluoride.[10,11]

The dental profession's present understanding dental caries can be described in terms of 5 interrelated factors.[12]

1. Caries is a bacterial disease primarily resulting from 2 specific cariogenic groups: *mutans streptococci* (*Streptococcus mutans* and *Streptococcus sobrinus*) and several of the *lactobacilli* species.[9] Caries risk factor increases as the number of *mutans streptococci* and *lactobacilli* within dental plaque increase.
    a. 2% to 10% makes a host high risk
    b. <0.1% makes a host low risk
    c. Infection happens early in childhood, usually from the patient's mother,[8,13] but also could be transmitted by other family members and peers.[14]
2. Caries depends on fermentable carbohydrates (glucose, fructose, sucrose, lactose, maltose, cooked starch). If dietary sucrose is present then glucans will be formed, which help with bacterial adhesion and colonization, facilitating the caries process.
3. Caries is driven by frequency of eating.
    a. Each time plaque bacteria come in contact with fermentable carbohydrates, the carbohydrates metabolize into organic acids that dissolve the apatite crystals of adjacent teeth.
    b. The pH level of plaque falls within seconds of contact with dietary sugars and can last up to 2 hours.
    c. Frequent eating increases caries risk.
4. Caries is modified by fluoride.
    a. Apatite of newly formed teeth is rich in carbonate with relatively little fluoride and is relatively soluble.
    b. Cycles of demineralization and remineralization in a fluoride-rich environment create apatite, which has less carbonate and more fluoride than the original tooth structure, and can be up to 10 times less soluble.
    c. Topical fluoride inhibits acid production.
    d. Fluorides in food, drink, toothpastes, rinses, and filling materials can reduce the solubility of teeth, helping caries reduction.

5. Caries is modified by saliva.
   a. Normal flow rate of saliva is a very effective buffer and can increase the remineralization potential. Normal stimulated salivary flow rate is >1.0 mL/min.
   b. Decreased flow rate can significantly affect caries risk. A stimulated salivary flow rate of <0.7 mL/min is associated with high caries risk.
   c. Factors that decrease salivary flow:
      - salivary gland pathology
      - radiotherapy
      - chemotherapy
      - many prescription drugs, and multiple prescription drugs in combination
      - dehydration during sleep

Caries Risk Assessment

Recent research has resulted in a major paradigm shift in etiology, prevention, assessment, and treatment of dental caries. In 2001, the NIH Consensus Panel on Diagnosis, Treatment, and Management of Dental Caries published a summary of its findings based on expert testimony and a systematic review of 1,407 diagnostic studies and 1,478 dental caries management studies. The affect of that conference has brought national attention to the dental profession's successes and shortcomings concerning caries management. Dental schools throughout the country are revising and rebuilding their teaching and protocols for the management of dental caries. The University of Illinois has a very thorough program by Arnold Steinberg, DDS, MS, and Steven Steinberg, DDS, called "Dental Caries Treatment as an Infectious Disease,"[15] a course on the diagnosis and management of dental caries. Several California dental schools have embraced procedures published in the *Journal of the California Dental Association* that propose practical risk assessment forms and procedures based on reviews of the literature [available at http://cdafoundation.org/journal].

In June 1995 the *Journal of the American Dental Association* published a special supplement on caries management[16] and established a classification for caries risk (Tables 1A and 1B).

Table 1B—Recare Clients Age Category

	Child/Adolescent	Adult
Low Risk*	• No carious lesions in last year • Well coalesced pits and fissures • Good oral self care • Appropriate fluoride use • Regular recare intervals	• No carious lesions in last 3 years • Sound restorations • Good oral self care • Regular recare intervals
Moderate Risk*	• 1 carious lesion in last year • Deep pits and fissures • Fair oral self care • Inadequate fluoride intake • White spot lesions and/or interproximal radiolucencies • Irregular recare intervals	• 1 carious lesion in last 3 years • Exposed root surfaces • Fair oral self care • White spot lesions and/or interproximal radiolucencies
High Risk*	• ≥ 2 carious lesions in last year • Past history of smooth surface caries • Current orthodontic treatment • Deep pits and fissures • Elevated *mutans streptococci* count • Little or no systemic/topical fluoride exposure • Poor oral self care • Frequent sugar intake • Irregular recare intervals • Inadequate saliva flow • Inappropriate bottle feeding or nursing (infants)	• ≥ 2 carious lesions in last year • Past history of root caries • Current orthodontic treatment • Numerous exposed root surfaces • Deep pits and fissures • Elevated *mutans streptococci* count • Poor oral self care • Frequent sugar intake • Inadequate use of topical fluoride • Irregular recare intervals • Inadequate saliva flow

*To assess which category is appropriate, assess past caries history to determine level of caries risk. If no caries activity is present, evaluate additional factors listed to determine level of risk.

Early Diagnosis of Dental Caries

Dentists now have the opportunity to diagnose dental caries before irreversible loss of tooth structure occurs, and in those cases can change the local biochemistry and the patient's behavior to heal the lesion without restoration. The key to "curing" dental caries rests on early diagnosis, patient education, and behavior modification.

The traditional method of treating dental caries was detecting the lesion, removing it, and restoring the tooth. Visual inspection and an explorer were used to feel for rough or softened areas of tooth structure, with the aid of bitewing radiographs to find interproximal lesions. Dentists now have more tools available to aid in better decision making, especially when a combination approach is taken to treat the bacterial challenge with antibacterial therapy such as chlorhexidine gluconate rinses.[17] The remineralization potential can be bolstered with fluoride applications[18] and the anticariogenic properties of xylitol.[19]

Today, treatment consists of not merely detecting carious lesions, but of using all the signs, symptoms, and supplementary tests in conjunction with the patient's risk factors to diagnose the status of the disease and its appropriate treatment.

Tools for Identifying a Lesion

Several new tools are available to help dentists make early and accurate diagnoses, which can be added to dentists' arsenals to supplement more traditional tools and protocols.

The first step in making a diagnosis is to visually examine the tooth, making sure it is clean and dry. The NIH Consensus Panel concluded that the use of sharp explorers to detect primary occlusal caries adds little diagnostic information and may prove detrimental to remineralization because the surface must be intact to repair or reverse the caries process.

Magnification

Magnification with loupes, surgical microscopes, or intraoral cameras significantly improves the ability to observe color changes, translucencies, imperfections, or breaks in the enamel surface. Some specific things to look for:

- chalky white areas of decalcification
- grayish-white or gray discolorations around marginal ridges and margins of restorations
- yellowish-brown or brown discolorations in occlusal pits and fissures
- shadowing or translucent areas on proximal surfaces
- black discolorations (usually a sign of arrested caries)

I personally have found the intraoral camera to be one of the finest tools in detection of early lesions or changes in tooth morphology. If these images are captured and stored in a patient's clinical record, reevaluation is simplified and monitoring of early demineralization can be objectified. Analyzing digital clinical images was shown to be an effective modality, even with the use of 35 mm clinical slides that were digitized.[20]

Transillumination

Transillumination has been used as a guide for detection of interproximal lesions for many years, simply by shining a fiber optic light source at the proximal contacts of teeth. This modality was significantly improved when the images were digitized and stored in a digital file. Digital Imaging Fiber-Optic Trans-Illumination (DIFOTI)[a] uses visible light to create high resolution digital images of occlusal, interproximal, and smooth surfaces that allow dentists to confirm the presence of decay before either film or digital radiography.[21]

[a]Electro-Optical Sciences, Inc, Irvington, NY 10533; (914) 591-3783

Laser Fluorescence

DIAGNOdent[b] detects caries using red laser fluorescence that readily transmits through dental enamel. Several bacterial byproducts are readily taken up into the porous carious lesions. These byproducts fluoresce when the red light hits them and sends back a longer wavelength of IR **[Author: What does "IR" stand for?]** light, which is detected as an audible and numerical signal in the device.[22,23] DIAGNOdent appears to have the potential for being both a sensitive (true disease) and specific (true health) test for the detection of dental caries, especially in dentin below apparently sound enamel. It shows high levels of test/retest reliability and comparative validity with other techniques.[24,25]

Laser fluorescence is more sensitive than traditional diagnostic methods, but because of the possibility of a false positive diagnosis, it is not intended to be the principal diagnostic tool.[26] When combined with a thorough examination and risk assessment protocol, it is a powerful tool in managing and treating dental caries. This instrument was incorporated into a software program EviDent[c], which was developed at the University of Florida Dental School, as a diagnostic protocol to detect, measure, and correlate the data with the patient's risk factors to determine a treatment protocol.[27]

Quantitative Light Induced Fluorescence (QLF)

The term quantitative laser fluorescence (QLF)[d] refers to the research method of measuring induced tooth fluorescence after using laser light (at or near 488 nm range) to quantify tooth demineralization and lesion severity.[28] Inspektor Research Systems and OMNII Oral Pharmaceuticals[e] are now making this technology available in the United States with the Inspektor Pro Pre-invasive Caries Diagnostic Imaging system, which uses a computer to store all information, including probe location and placement. The device is based on filtered blue

[b]KaVo Dental, Lake Zurich, Il 60047; (800) ASK-KAVO
[c]Healthy Outcomes Technology, Inc, Gainesville, FL 32601; (352) 392-5210
[d]Inspektor Research Systems, 1072XX Amsterdam, the Netherlands; 31-20-6764988

light so it is more correctly termed quantitative light fluorescence. The method measures changes in fluorescence that result from carious lesions scattering the light and thereby giving a different signal from sound enamel. This makes QLF very suitable for longitudinal evaluation of lesions, and potentially gives us the ability to measure remineralization protocols.

Electrical Conductance Measurements

Electrical conductivity in teeth changes with demineralization, even if the surface of the tooth appears intact. Electrical conductance measurements increase with demineralization. This modality has been used in several studies with high sensitivity and specificity results.[29-31] To my knowledge, there are no products that are available for use in private practice; however, it is likely that this technique will be one of the tools of the future for dental practice.

Digital Radiography

By the time lesions are seen radiographically they are actually more invasive than they appear. Radiographs have helped detect and treat lesions that were already in dentin, so they are hardly a modality for early detection. However, that may be changing with the increased incorporation of digital radiography[32] and software applications embedded in programs to help dentists discern more of the information captured on the radiograph. Most digital radiology systems are capable of detecting interproximal lesions and can determine the density factors necessary for radiographic analysis.[33] The best hope for improved diagnosis of incipient or noncavitated lesions rests with the software and firmware applications, which can extract data from digital radiographs that the human eye cannot. Most digital radiology software programs have developed a set of tools that significantly aid in the detection of caries by using electronic image processing.[34] One study[35] demonstrated that dentists were able to detect 20% more dentinal caries using the software tool Logicon Caries Detector (LCD)[f] than using sight alone. LCD extracts features related to tooth decay and looks for patterns unique for proximal caries. It then correlates the data with a unique database of known caries problems to ascertain the probability of finding caries in new images.

[e]OMNII Oral Pharmaceuticals, West Palm Beach, FL 33401; (800) 445-3386

Microbiological Assessment

Microbiological assessment for *mutans streptococci* and *lactobacilli* in saliva is now available for use in the office with the Caries Risk Test[g]. It is sufficiently sensitive to provide a level of low, medium, or high cariogenic bacterial challenge with results available after a 48-hour incubation. Although these tests are a major advance in convenience and are the best tools we have so far, exciting work is being done by Shi and colleagues[36] using species-specific monoclonal antibodies that recognize the surface of cariogenic bacteria. This technology will hopefully enable quantitative analysis of bacteria levels within minutes.

Future Applications

Each day dental researchers are investigating new applications and possible solutions for dental caries. There is interesting work being done in Europe and Canada using ozone as an antimicrobial device system that can arrest the caries process. The product is called HealOzone[b] and its effectiveness has been documented in reducing the levels of total microorganisms to <1% of control values.[37] A clinical study has shown that ozone is capable of reversing root surface caries immediately when measured by DIAGNOdent readings.[38] Ozone is a gas that kills bacteria and allows the saliva and the normal remineralization process to do its repair job. The jury is still out on how effective ozone really is for caries control.

Conclusion

The NIH Consensus Statement of 2001 acknowledged the progress dentistry has made in substantially reducing the incidence of dental caries over the last 30 years. On the other hand, it is clear that the overall quality of the dental profession's clinical data set is significantly lacking. The panel asserted that "clinical caries research is underfunded, if not undervalued[2]." When we look carefully at the literature and the affected disparity of the disease among the United States population, it is evident that education and access to preventive and interceptive care are essential cornerstones of controlling this chronic infectious disease.

The tools described are aids to diagnosis and not merely a means for early detection in the

[f]Logicon Europe Ltd, Southhampton, Hampshire SO167NS; 023-8076-0484

[g]Ivoclar Vivadent, Amherst, NY 14228-2231; (800) 533-6825

hopes of easier, faster, and more numerous restorations. The real benefit for early diagnosis is in the hope of remineralization and repair of the caries lesion. Being proactive, understanding the intricacies of dental caries, and promoting evidence-based diagnosis and treatment regimens allow dentists to benefit patients and themselves. Only approximately 50% of the United States population receives dental treatment, and of those, many do not maintain good oral hygiene. By adopting a medical model with a good understanding of the risk factors and their changing patterns throughout life, dentists can help patients maintain their dentition for a lifetime.

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