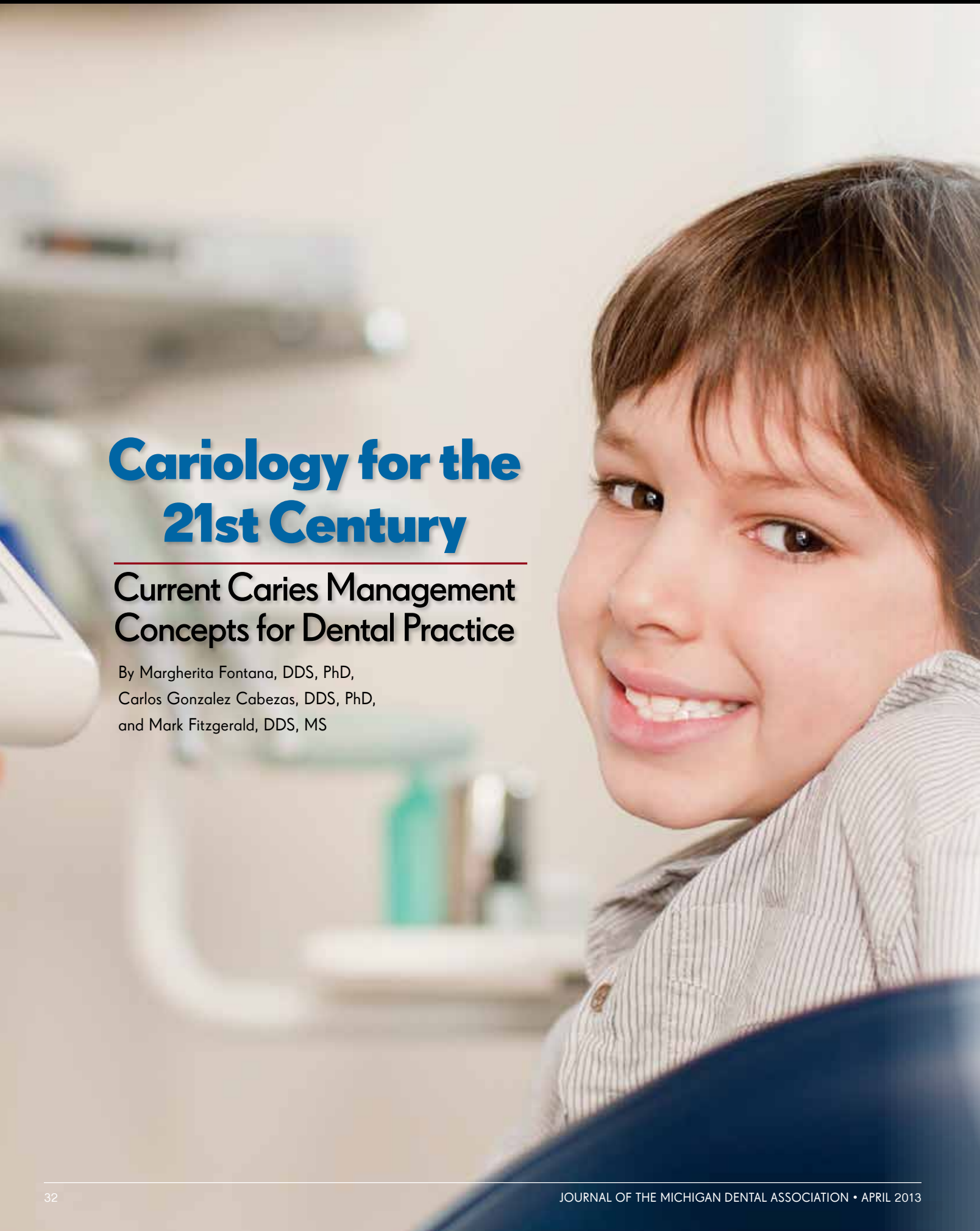

Cariology for the 21st Century

Current Caries Management Concepts for Dental Practice

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Abstract

The objective of this manuscript is to provide an overview of currently accepted, evidence-based and/or expert opinion recommendations for the prevention and management of dental caries in dental practice. Discussions are centered on current concepts for caries lesion detection (e.g., cavitated and non-cavitated lesions) and diagnosis (e.g., active vs. arrested lesions), including thresholds for non-surgical (e.g., fluorides, sealant) and surgical (i.e., restorative) interventions, risk assessment, and a review of caries management interventions for caries disease management. The goal is to prevent and manage the caries disease process using patient-centered, risk-based interventions supported by the best available evidence, taking into account the dentist's clinical expertise and the patient's treatment needs and preferences, in order to maintain or re-establish health and preserve tooth structure.

Introduction

Dental caries is the localized destruction of susceptible dental hard tissue by acidic by-products from bacterial fermentation of dietary carbohydrates.[1] At the demographic level, the disease is unequally distributed across the population, with certain groups (e.g., lower socio-economic status groups, minorities) experiencing larger numbers and greater severity of caries lesions.[1,2] If allowed to progress, over time the disease will result in the development of detectable changes in the tooth structure, or caries lesions,[4] which initially are non-cavitated (i.e., macroscopically intact, sometimes referred to as "white spot" or "incipient" lesions), but which eventually might progress to cavitation. In fact, the more advanced and severe the lesion, the more likely it will progress, with non-cavitated lesions having a much lower probability than initially small cavitated lesions of progressing over time.[5]

This has implications for the management of caries lesions as will be discussed later in this article. Because dental caries starts in this non-cavitated state, it is not always the "cavity" in the tooth that we need to focus on, and thus, we cannot "remove all the caries" as our only treatment model.[6] In fact, dentistry has entered an era of personalized care (i.e., "personalized dentistry"), and the "medical model" for caries management, where the individual etiologic disease-driving agents are balanced against protective factors, in combination with risk assessment,[7] offers the possibility of patient-centered disease prevention and management before there is irreversible damage done to the teeth and need for restorative treatment (i.e., an active cavitated caries lesion).[8,9]

This approach requires the practitioner to start by differentiating between the caries disease process and the caries lesion, and shift their focus from a primary surgical intervention model directed at the "cavity" to a prevention and preservation first approach focused on disease management and remineralization.

Unfortunately, the methods used for treating dental caries in practice today remain largely limited to the use of surgical tooth restoration (i.e., restorative treatment), even though there is no evidence that traditional restorative care effectively prevents or manages the dental caries disease process. The fact that the existence of recent restorations is the greatest indicator of risk for the development of new lesions[10,11] only proves that the act of surgically treating the caries lesion does little to reduce the risk of developing the next lesion.

The NIH Consensus Development Conference on Diagnosis and Management of Dental Caries Throughout Life supported this concept in 2001 when it identified the need to use new strategies "to provide enhanced access for those who suffer disproportionately from the disease; to provide improved detection, risk assessment, and diagnosis; and to create — and enhance use of — improved methods to arrest or reverse the non-cavitated lesion while improving surgical management of the cavitated lesion."[11]

Interestingly, since 2001 numerous systematic reviews have started to question the amount of carious tissue that must be removed, with very strong evidence-based recent reviews suggesting that sealing non-cavitated lesions can effectively reduce their progression and can reduce the numbers of microorganisms in them.[12,13] In addition, other reviews suggest that removal of all infected dentin in deep cavitated lesions might not be required for success of restorative intervention if the lesion can be isolated from the external environment,[14] and that this partial caries removal is preferred to reduce risks of pulp exposure.[15]

Modern caries management stress-

es a preventive philosophy with individualized risk assessment and disease management, accurate and early detection of caries lesions, and efforts to remineralize and/or arrest non-cavitated lesions in order to preserve tooth structure and maintain health.[16] When restorative intervention is unequivocally required, typically for an active cavitated lesion, the procedure used should be as minimally invasive as possible while considering the patient as a whole to achieve the best long-term results. Some have referred to this strategy as "CAMBRA" (caries management by risk assessment),[7] others as "minimally invasive dentistry",[17] yet shouldn't all "modern" dentistry be "minimally invasive"?[18]

Risk-based clinical decision-making for caries management in everyday clinical practice should be based on the best available evidence while taking into account the dentist's knowledge and expertise and focusing on the needs and desires of the patient.[19] In an era of evidence-based care, the question of how much evidence is needed to implement changes into practice becomes central to this paradigm shift in caries management.

This article discusses how evidence has changed our understanding of caries detection and diagnosis criteria, leading to a better understanding that non-cavitated lesions can not only be arrested or stopped (e.g., by using sealants) but in many cases reversed (e.g., by using fluorides) by non-surgical, risk-based caries management approaches.

Caries Detection and Diagnosis, Stages of Caries Severity and Activity, Thresholds for Surgical and Non-Surgical Intervention

In order to manage caries lesions using the most current evidence, based on a patient's risk, and with the goal of preserving tooth structure, we must start with a clear understanding of caries detection and diagnosis. These terms are defined in detail in a glossary of terms in cariology, published by Fontana et al.[1] The glossary was developed by representatives of the International Caries Detection and Assessment System (ICDAS), the European Organization for Caries Research (ORCA), the European Association of Dental Public Health (EADPH), and the American Dental Education Association (ADEA) Cariology Section, in response to the expressed need for a common language to discuss modern cariology and preventive caries care.

In dentistry, the terms caries diagnosis and caries detection are often used incorrectly and interchangeably. This is possibly due to the fact that the earlier stages of the disease process are virtually symptom free, giving the perception by many, in the restorative dominated strategies of the past, that a diagnostic step is not needed,[20,21] and that caries assessment becomes ultimately a question of detection, i.e., whether caries lesions are present or not. Furthermore, the detection of frank cavitations in teeth requiring restoration is still considered by many as the main focus of caries treatment plans.

In contrast, modern dental caries management should also focus on the detection of earlier stages of the disease process (e.g., non-cavitated caries lesions), and the practitioner's ability to diagnose whether or not caries lesions are likely to be "active" (e.g., currently developing or progressing) or arrested (e.g., a scar of past disease).

Thus, a clinician diagnoses the disease "dental caries" in a patient not based on the detection of the lesion only but on the combination of a variety of signs and symptoms (at a tooth level diagnosis involves an assessment of disease activity). Without undertaking a diagnostic decision as to whether a lesion is active, be it progressing slowly or rapidly, or arrested, a coherent clinical treatment decision cannot be made.[22] Associated with diagnosis is the assessment of the patient's risk of developing new caries lesions. Both diagnosis and risk assessment should help the clinician to decide on treatment options.

Of utmost importance is to clearly define lesion thresholds and clinical conditions that separate surgical from non-surgical interventions, as these have immediate treatment consequences. Thus, the detection of caries lesions in its earlier clinical stages is crucial in deciding the appropriate and effective preventive intervention which will stop or reverse the caries

Figure 1 — Non-cavitated caries lesion.

Figure 2 — Cavitated caries lesion with a dark shadow.

Figure 3 — Cavitated caries lesion with dentin exposed to the oral cavity.

process over time.[6,9] The ability to differentiate between the stages of lesion development, or to establish the appropriate detection thresholds for these stages, depends on the detection method and/or criteria being used.

Many criteria have been developed for the visual examination of teeth for caries lesion assessment.[4,23] As an example, an international effort created a set of harmonized criteria building on best evidence, the International Caries Detection and Assessment System (ICDAS),[23,24] which is designed to be a unifying, predominantly visual set of criteria codes based on the characteristics of clean, dry teeth at both the enamel and dentin caries levels, which is capable of assessing both caries severity and activity, and has supporting histological validation.[25,26]

Based on these criteria, a non-cavitated lesion,[1,24] commonly referred to as a "white spot lesion", can be defined as a subsurface lesion, with an apparently intact surface layer, but with demineralization present under it (Figure 1). In fact, many visually detected non-cavitated lesions have demineralization reaching dentin. These lesions may appear as white/yellow/brown coloration, which may be limited to the confines of the pits and fissures on occlusal surfaces, or extend beyond them. Initial incipient "white" lesions are only seen visually when teeth are dried, while more advanced "white" lesions can be seen both wet and dry. If the lesions have picked up extrinsic stain, they will be seen as "brown" lesions both wet and dry regardless of whether they are incipient or more advanced.

Because dental caries follows a dynamic but not necessarily continuous process, caries lesions can be arrested or reversed, for example by use of fluorides, before progressing to cavitation. In addition, current evidence-based recommendations by both the American Dental Association (ADA) and the Centers for Disease Control and Prevention (CDC) support the use of dental sealants to arrest the caries process in non-cavitated lesions.[27,28]

A cavitated lesion[1,24] is a lesion in which there is a discontinuity or break in the surface. By the time this occurs, demineralization has in most cases progressed histologically, radiographically and/or clinically into the dentin, and bacterial invasion of dental tissues has occurred. This is still the accepted threshold where operative intervention may be required, depending on disease activity and patient risk. The break can be limited to enamel, can include signs of undermining enamel (dark shadow around the pit and fissure; Figure 2), or can expose dentin directly into the oral cavity (Figure 3).

Forceful use of a sharp explorer for the sole purpose of detecting caries lesions is highly discouraged in today's practice of dentistry. In fact, many dental schools today, including the University of Michigan, strongly discourage the use of an explorer under force for caries detection.

The presence of dentinal involvement, such as an underlying dark shadow, can be determined without extensive drying of the tooth surface. Use of an instrument (explorer or probe) to confirm cavitation ("catch"), especially in pits and fissures, was one of the most commonly used criteria to measure dental caries in the National Institute of Dental Research original survey protocol,[29] and was taught for many decades as the gold standard for caries detection. Thus it should be of no surprise that this method is still commonly used by some in practice.

However, forceful use of a sharp explorer for the sole purpose of detecting caries lesions is highly discouraged in today's practice of dentistry.[30] In fact, many dental schools today, including the University of Michigan, strongly discourage the use of an explorer under force for caries detection.[31] The evidence clearly shows that non-cavitated lesions can become damaged/cavitated simply through pressure from the explorer during examination,[32] and, in turn, accelerate lesion progression and undermine non-surgical management opportunities.[33] Furthermore, the use of the explorer does not improve accuracy of the detection pit and fissure lesions.[34]

The appropriate use of the explorer is to gently clean debris or remove plaque, very gently help confirm cavitation when in doubt, help aid in determination of lesion activity (e.g., soft dentin or rough-opaque enamel), and once the tooth is sealed or restored, to help assess the dental material's integrity and retention.[35]

Magnification may be useful for surface assessment; however, there is relatively little research on its use to assess occlusal surfaces of primary or permanent teeth. Among the in vitro studies that do exist, comparisons of visual assessment with or without magnification present conflicting results.[35] Some of the preliminary clinical data suggest that use of magnification by expert clinicians may not affect their ability to distinguish between different stages of lesion severity, but that increasing magnification may lead to more aggressive treatment decisions.[36] Thus, if magnification is to be used, it should be used with caution. It is possible that with increased magnification, non-cavitated lesions might appear cavitated, thus leading to more aggressive interventions.

There has been a concerted effort in dentistry over the last decade to identify more technologically advanced measures to detect/quantify demineralization in non-cavitated lesions.[37] These are aids to help with detection and monitoring of non-cavitated lesions, but are not stand alone diagnostic methods that can be used in place of the dentist's clinical judgment. When used correctly, they can play an important role in diagnosis of

lesion activity through monitoring changes over time, and help stage the severity of a caries lesion,[38] thus helping select the most appropriate treatment choice/regimen for a particular patient in a private practice setting. Furthermore, systematic reviews have concluded that these instruments have higher sensitivity but lower specificity than traditional visual caries detection methods to detect the earlier, non-cavitated stages in the caries process.[39]

This means that because the caries rates have fallen and caries progression rates have slowed in the US, the indiscriminant use of these technologies might result in a high number of false positive caries diagnoses, which could then, depending on how the instrument's "caries" call is interpreted by the user, decrease the number of teeth that could benefit from noninvasive caries management interventions.[39] Thus, these instruments can be valuable aids to allow more objective monitoring of non-cavitated lesions over time and thus help determine "lesion activity" and effectiveness of treatment, but require expertise and training for correct use and data interpretation. These are not stand alone diagnostic methods, but aids to clinical decision-making.

Risk Assessment

Risk-based, patient-centered decision-making, supported by best available evidence is an essential component for the prevention and management of dental caries. Because of the multifactorial nature of the dental caries disease process, and the fact that the disease is very dynamic (e.g., lesions can progress and/or regress), studies on risk assessment tend to be complex, with a multitude of variables challenging the prediction at different times during the life of an individual.[40,41] Opponents of this strategy maintain that it is difficult to accurately identify at risk patients, and that even if we could, the evidence on preventive measures for high-risk individuals is still not very strong.

All of this is in part true. In fact, most studies on risk assessment have been conducted in children, and there is very little evidence from adults or the elderly to help guide practitioners on how to apply risk assessment models to adult populations.[40] However, most experts and organized dentistry organizations contend that when the well-being of the patient is considered, it is more important to carry out a risk assessment incorporating the best available evidence than just doing nothing due to lack of strong evidence.

Others allege that similar preventive measures should be administered to the whole population, regardless of the risk. However, for the current environment of increasing health care costs and resource constraints, targeted health care delivery has become paramount, depending profoundly on risk assessment. If a clinician practices in an environment in which all patients have a similar risk of caries, then we agree that doing individual risk assessments would add no value to the clinician or the patient.[40] But, dental caries is unequally distributed in most populations around the world, including the United States, with a small percentage of individuals carrying the heavier burden of caries disease.[2,3] For most dentists in private practice, it becomes imperative to be able to identify a patient's risk status in order to be able to develop the most cost-effective treatment strategy for that individual. Yet, a recent survey of clinical practices within a U.S. Practice-Based Research Network suggests that a significant proportion of dentists had yet to adopt treatments based on assessment of caries risk.[42]

For most dentists in private practice, it becomes imperative to be able to identify a patient's risk status in order to be able to develop the most cost-effective treatment strategy for that individual.

Based on the existing literature, most of the information needed for a caries risk assessment is readily available in a properly done health/dental history and a clinical examination, without the need of additional testing, with the subjective impression of the clinician having been shown to be very useful.[43] However, for monitoring purposes it is clear that an objective record of risk must be included in the patient's chart.

The most important factor in predicting future risk is recent caries experience and current disease activity.[11,44] This is probably because past caries experience summarizes the cumulative effect of all risk factors and protective factors to which an individual has been exposed over a lifetime, and presence of current activity would indicate a high likelihood that if conditions do not change, activity will continue in the future. This is a simple, inexpensive and fast predictor, as it only requires a dental examination.

If interproximal lesions are included in the risk analysis, then radiographs, especially radiographic follow-up of existing lesions, would enhance the diagnosis. However, a careful analysis including not only past caries experience but also all other risk (e.g., presence of plaque, frequent consumption of carbohydrates, decrease in salivary flow rate) and protective factors (e.g., exposure to fluorides) will allow the dental team and patient to understand the specific reasons for the caries disease and thus will allow them to tailor a personalized treatment plan and recall interval specifically designed to address the patient's needs.[40]

Many expert based risk forms are now available for the clinician to use, and further describe biofilm, saliva, diet and protective factors involved in caries progression and protection. Examples include the American Dental Association's Caries Risk Tool,[45]

the Caries Management by Risk Assessment (CAMBRA) tool for adults,[46,47] and the Cariogram.[48] However, the evidence on the validity for existing systems for caries risk assessment is still limited,[49] and more evidence-based protocols are still needed.

In general, in all these forms a low caries risk assessment is based on a combination of the following factors: no caries lesion development or progression for a recent period of time (e.g., 3-5 years); low amount of plaque accumulation; low frequency of the patient's sugar intake; no presence of salivary problems; adequate exposure to protective factors. In addition, the following factors, whether appearing singly or in combination, would yield a moderate to high risk assessment of caries: the development of new caries lesions, the presence of active lesions, and the placement of restorations due to active disease since the patient's last examination, together with a detrimental change in amount of plaque, incremental frequency of carbohydrate consumption, decrease in saliva flow and decrease in exposure to caries protective factors.[40]

Caries Management

Management of active dental caries should be based on doing the minimum necessary to restore balance in the oral environment. Some traditional approaches have unsuccessfully attempted to prevent and manage dental caries by modifying every patient's habit that was outside the "ideal behavior" presented in textbooks. This lack of success is not surprising when considering that behavioral change is very difficult to accomplish. A more realistic and more evidence-based approach looks for a more personalized strategy that demands limited and pragmatic changes in behavior that could accomplish the goal of restoring the balance. Professional judgment when developing an appropriate caries management plan must take into consideration patient's risk level, reasons for this increased risk (i.e., predisposing risk factors), patient's readiness for change and the likelihood of compliance to the different possible therapies.

Numerous caries preventive therapies are available today. However, the level of evidence supporting each of the therapies is variable and clinicians should take that into consideration when developing the management plan. In the next few paragraphs we will present most of the options available today putting some emphasis on the level of evidence supporting them. The two preventive strategies with the highest level of supporting evidence are topical fluorides and pit and fissure sealants.

Fluorides

Topical fluorides have been shown to consistently reduce dental caries incidence not only in individual randomized clinical trials but also in multiple systematic reviews. Most evidence strongly suggests that its preventive effect is topical, affecting the demineralization-remineralization exchanges between tooth structure and the surrounding environment. Because of its demonstrated efficacy, relative safety, and wide spread use, multiple organizations and groups recommend the use of fluoridated dentifrices and the exposure to fluoridated water by the general population (e.g., ADA, CDC, etc.).

Several systematic reviews have shown that water fluoridation is effective in reducing caries in children and adults of all social classes,[50] and by 2010 73.9% of the US population was regularly exposed to fluoridated water. Toothbrushing with fluoride-containing dentifrices is probably the most common oral hygiene practice in the US and around the world. Dentifrices with fluoride concentrations of 1,000 ppm or above have been consistently shown to reduce dental caries in children and adolescents.[51,52]

For patients at increased risk for dental caries, additional fluoride exposure has been shown to reduce their caries incidence. Higher fluoride concentration dentifrices (1.1% or 5,000 ppm NaF) do not have the same level of supporting evidence as those at around 1,000 ppm, but because there is a dose-response preventive effect of fluoride dentifrices and the available clinical evidence in root surface caries[52] they should be considered for at risk patients. Adding a low strength fluoride (0.05% NaF) rinse after brushing has also been shown to be effective in reducing caries in at risk patients[53,54] and should be part of the armamentarium to manage some patients at risk.

Professionally applied fluoride products (varnishes, gels, and rinses) are also regularly recommended for caries risk patients. Fluoride varnish (5% NaF) is becoming the standard for topical fluoride applications because of its ease and short time of application, safety, and significant body of clinical evidence.[55]

Lastly, in some instances where fluoridated water is not available, prescription of fluoride supplements can be considered for young children. The use of fluoride supplements has been associated with a reduction in caries incidence. The effect is clear in permanent teeth; but the evidence is not as compelling for deciduous teeth.[56]

Dental Sealants

Sealing of pits and fissures is the other preventive strategy supported with large amounts of clinical data. Numerous studies have shown that resin-based dental sealants effectively prevent dental caries in pits and fissures of permanent molars.[57,12,13] Preventing caries development in pits and fissures is of upmost importance since most caries lesions originate at these anatomical locations. Furthermore, limited evidence suggests that sealants are more effective in preventing dental caries in pits and fissures than fluoride varnish.[58]

Glass ionomer-based dental sealants are also available and frequently used in teeth that are difficult to isolate. Data from clinical studies using glass ionomer materials as dental sealants suggest they might also be effective in preventing dental caries, but the evidence level at the moment is lower than that for resin based sealants, which affects our ability to provide definitive guidelines or rec-

ommendations about glass ionomer sealant use.[57,59]

Efficacy is not limited to preventing lesion formation in pits and fissures, dental sealants are also effective in managing non-cavitated caries lesions,[12,13] and thus have been recommended for this purpose by both the ADA[28] and CDC.[27] Developing a barrier between the biofilm and the caries lesion leads to the arrest of the lesion. As with professionally applied and prescribed fluoride products, dental sealants are recommended for teeth at risk for dental caries.[57]

Antimicrobials

Considering that dental caries requires the presence of a cariogenic biofilm (i.e., dental plaque able to produce dental caries), antimicrobial strategies to manage dental caries have been developed. Most of the research about the caries preventive properties potential of antimicrobials has been conducted on chlorhexidine or sugar alcohol based products. Chlorhexidine rinse (0.12%) has been shown to reduce dental plaque[60] and particularly mutans streptococci in saliva.[61] However, as suggested by a recent ADA evidence based review, the limited number of good quality studies that are available show no beneficial effect of chlorhexidine rinse in reducing dental caries.[62] Results from a recent clinical study showed a preventive effect of chlorhexidine rinse when used as part of a preventive regimen that included a fluoride mouthrinse.[63] Unfortunately, this study did not demonstrate an independent effect of the chlorhexidine rinse. In addition, chlorhexidine/thymol varnishes to be applied professionally have recently become available in the United States. Up to now, the available evidence supports their use only for elderly adults for the prevention of root caries.[62]

Numerous studies have shown the anticaries effects of polyols, particularly xylitol because of its antimicrobial properties. In these studies, xylitol has been delivered in a wide variety of vehicles such as chewing gums, lozenges/candies, toothpastes, etc. Available evidence clearly shows that xylitol is non-cariogenic and has an antimicrobial effect that is dose and frequency dependent. Furthermore, recent systematic reviews have consistently concluded that the regular use of xylitol or polyol-combinations in chewing gum and lozenges is an effective adjunct in coronal caries prevention. Subsequently, most health organizations worldwide recommend the use of it for patients at high risk of dental caries.[64] According to a recent ADA evidence based review,[62] daily use of xylitol-containing lozenges/hard candies that are dissolved slowly in the mouth after meals may reduce the incidence of coronal caries in children 5 or older (5-8 grams/day divided into 2-3 doses).

Lastly, experimental data have shown that triclosan and iodine have antimicrobial properties. However, as stated recently by the ADA, there is insufficient evidence available to support that either one is able to reduce dental caries.[62]

The main objective of restoring cavitated lesions, from a disease management perspective, is to stop the caries activity of the lesion and restore a cleansable and functional tooth surface.

Calcium Based Strategies

A variety of products containing calcium in different forms (e.g., calcium attached to casein derivates, calcium sodium phosphosilicate, etc.) have been recently introduced to the market to prevent dental caries, mainly via remineralization. The rationale for this approach is that while saliva is supersaturated with respect to enamel and dentin, precipitation of its minerals is severely limited by the presence of proteins. Therefore, providing calcium ions that could become available during a cariogenic challenge would shift the balance in favor of remineralization.[65]

While the idea remains interesting, the evidence supporting its clinical efficacy is still very limited. Recent systematic reviews have concluded that although there are some clinical studies supporting the remineralization potential of some of these formulations, there is yet no sufficient evidence from clinical trials demonstrating that any of these products prevent dental caries.[62,66]

Management of Cavitated Lesions

Cavitated caries lesions that limit regular dental plaque removal are likely to progress and require restorative treatment as part of the caries management for that patient.[67] The main objective of restoring cavitated lesions, from a disease management perspective, is to stop the caries activity of the lesion and restore a cleansable and functional tooth surface. The introduction of adhesive materials with mechanical and physical properties has revolutionized the design of cavity preparations allowing for much more conservative restorative dentistry. Cavitated caries lesions should be restored using minimally invasive principles minimizing the removal of tissue, with the goal of preserving as much tooth structure as possible.

Conclusions

Patient-centered "personalized" prevention and management of dental caries should be based on restoring the balance in the oral environment, with the goal of preserving tooth structure, using best evidence available and taking into consideration the dentist's expertise and the individual needs of the patient. Accurate detection of cavitated and non-cavitated lesions, determination of lesion activity, and a patient's risk of future disease are the cornerstones of modern patient-centered caries management. Classical preventive approaches such as dental sealants, fluorides, and restorative treatment, and recognizing their limitations, remain the strategies with the best

level of evidence supporting their efficacy and should be considered as the first line of treatment for patients at risk of dental caries. Antimicrobials and calcium-based products that have shown promise should be considered as adjunct therapies, not replacement, to the first line of defense treatments. Lastly, regular dental plaque removal and reduction of fermentable carbohydrate consumption should be encouraged, recognizing that this recommendation is based mainly on expert opinions and anecdotal evidence most likely due to the lack of compliance commonly found in at risk patients. ✧

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