Minimal Intervention Dentistry in General Practice

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Abstract

Minimal Intervention Dentistry (MID) is a modern approach to the management of caries, which emphasizes prevention and early interception of disease, underpinned by an understanding of the role of the dental plaque biofilm in disease initiation and progression, and how this is affected by lifestyle and behavioral factors. The MID approach should be the standard of care in modern restorative dentistry, as it avoids over-zealous restorative interventions as well as supervised neglect.

Incorporating the principles of MID into general dental practice for the management of dental caries involves using Caries Risk Assessment (CRA), as well as a minimally invasive restorative approach utilizing conservative caries removal methods, minimal cavity designs and the use of adhesive restorative materials. A range of methods now exist for measuring the contribution of risk factors to dental caries risk, allowing the clinician to target their interventions at the factors operating in the individual patient, by applying the concepts of ecological change to modify the biofilm, and motivational interviewing to alter patient lifestyle and dietary behaviour. This review discusses how the principles of MID are used for individual patient care, and suggests methods for implementation of MID into general dental practice.

Key Words: Minimal intervention dentistry, Dental caries, Caries risk assessment, Dental practice implementation, Patient behavioral change, Oral health team, Minimal invasive operative dentistry

Abbreviations: CPP-ACP: Casein Phosphopeptide-Amorphous Calcium Phosphate; MID: Minimum Intervention Dentistry

Introduction

When first introduced, the term 'Minimal Intervention Dentistry' (MID) referred to the use of smaller and more conservative cavity preparations. Today, the concept is much broader, being a philosophy of care related to risk assessment of individual patients, the early detection of oral disease, targeted preventively orientated strategies and limited surgical intervention appropriate to the level of disease. For dental caries, this involves unmoving away from an approach based only on restorative treatment of cavitated lesions (surgical care) to fully embrace the MID model (medical care), which stresses both behavioural and bacterial components.

While the concept of MID has been stressed in the literature for more than 10 years, uptake of this philosophy has not been at the global level. MID should be the standard of care in modern restorative dentistry, as it avoids over-zealous restorative interventions as well as supervised neglect. As the dental profession worldwide grapples with the challenges of dealing with high rates of dental caries in socially disadvantaged and medically complex patients, it is even more important to incorporate these concepts into practice [1,2].

Thematically, MID for dental caries can be divided into two main areas, the first being Caries Risk Assessment (CRA) [3], which focuses on disease causing factors, and a restorative component which focusses on conserving and preserving tooth structure, in order to minimize the irreversible consequences of caries in terms of breakdown of tooth structure. Using the principles of CRA encourages the dental clinician to concentrate on disease assessment in the patient examination, allowing individual patient targeting of risk factors so that disease activity is reduced and lesion remineralisation can occur. Based on a medical model of disease prevention and treatment, MID is underpinned by new developments in the understanding of the behaviour of the dental plaque microflora. The second component has a minimally invasive focus, and employs a conservative restorative approach, using small cavity designs and adhesive restorative materials. This is in direct contrast to the older cavity designs based on non-adhesive materials.

Sustained Changes in Dental Plaque Microflora Using Ecological Concepts

The ecological catastrophe concept of dental caries, as originally proposed by Marsh in 1995, is based on the view that a catastrophic change in the normal plaque biofilm is responsible for dental caries, through the emergence of acid producing and acid tolerant microorganisms [4-6]. The low pH environment generated from carbohydrate metabolism is the major factor responsible for the shifts observed in the oral microflora with high carbohydrate diets. When the plaque fluid pH falls, the relative proportions of mutans streptococci, lactobacilli, and other acid tolerant species increases. This is accompanied by a fall in the proportions of acid-sensitive species which prefer neutral or alkaline pH conditions, (such as *Fusobacterium nucleatum*, *Streptococcus gordonii* and *Streptococcus oralis*). A fall in pH to between 5.5 and 4.5 enriches the plaque biofilm for potentially cariogenic species whilst permitting many species associated with health to remain relatively unaffected. However, a further reduction in pH (<pH 4.5), will not only enhance the competitiveness of cariogenic organisms, but will inhibit the growth and metabolism of non-caries-associated species [7].

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The ecological approach recognizes that caries is a lifestyle-related disease which results from the interplay of host, microbial, lifestyle and behavioral factors (*Figure 1*). The notion that the composition and behavior of dental plaque can be altered and thereby its caries-causing potential links to the view that caries risk must be managed throughout all parts of the lifespan. This understanding of "lifetime" caries risk and the complex interplay of caries risk factors empowers the clinician to inform, educate and guide the patient so that they can enact a healthy lifestyle and diet. Understanding the effects of sustained changes in dental plaque microflora allows the clinician to select and prescribe the appropriate chemotherapeutic treatments.

Patient Caries Risk Assessment (CRA)

Oral disease, especially dental caries and periodontal disease are largely preventable. As understanding of these diseases has increased, management and treatment has progressed from being mostly surgical to becoming more preventively focused. MID is the philosophy of care related to risk assessment of individual patients; the early detection of oral disease, targeted preventively orientated strategies and limited surgical intervention appropriate to the level of disease [8]. For example, while many adolescents and young adults enjoy good oral health, particular groups in the community such as those from low socio-economic groups experience a high burden of oral diseases, and are less likely to access available dental care [9,10]. Young adults are in transition to the point of accepting responsibility for their own oral health, yet at the same time they must cope with greater oral health risks arising from a multitude of factors including changed living arrangements, including leaving family support structures and homelessness; poor lifestyle choices, such as excessive consumption of alcohol, use of tobacco, and misuse of drugs; and deleterious dietary patterns, including grazing, snacking, and frequent consumption of cariogenic foods and drinks with high sugar and acid content [11,12].

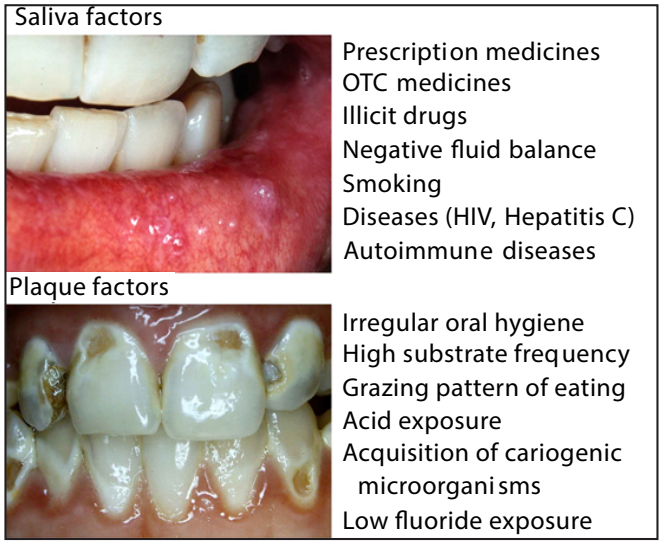

Figure 1. *A simple approach to assessing the major attack and protecting factors in dental caries, based on the System for Total Environmental Management (STEM). The upper panel lists common factors that influence the properties of resting saliva (such as its pH, buffering capacity, thickness and flow rate), and the lower panel factors that increase the cariogenic potential of the dental plaque biofilm. This list stresses common factors and is not meant to be exhaustive since any other factors can influence the degree of protection afforded by resting and stimulated saliva. The upper clinical image shows the visual assessment of resting salivary flow based on droplets forming from the labial minor glands, while the lower clinical image shows an aggressive caries pattern in a teenage patient.*

A patient risk assessment aims to identify and quantify the factors that initiate disease and cause its progression, i.e. what factors affect plaque biofilm pathogenicity or impair host defense from salivary systems in the particular individual [3]. For CRA to be an important part of minimal intervention strategy, early diagnosis of the disease is of particular importance, as most studies accept that early lesions are reversible [13,14]. Because the development of surface cavitation is a late stage in the caries process, there are opportunities to intervene in the process to arrest and reverse the lesion before committing to restorative procedures (*Figure 2*). The number of early carious lesions typically exceeds the number of clinically detectable cavitated lesions by a considerable margin, so one needs to have a high index of suspicion when discovering a frank cavitation, as it often represents the "tip of the iceberg" in terms of sites with disease present [15].

Patients with early carious lesions should undergo a structured caries risk assessment, for which a range of chairside tools are available, such as those assessing salivary parameters, plaque maturity and acid production, and levels of cariogenic bacteria. The use of chairside tests can provide information in a 5-minute time period so that advice to the patient can be personalized based on the data obtained. Therefore, as an essential part of caries management, CRA should identify and help manage the primary caries aetiological factors from the diet and lifestyle to allow early lesion and disease interception. Recognizing that past patterns

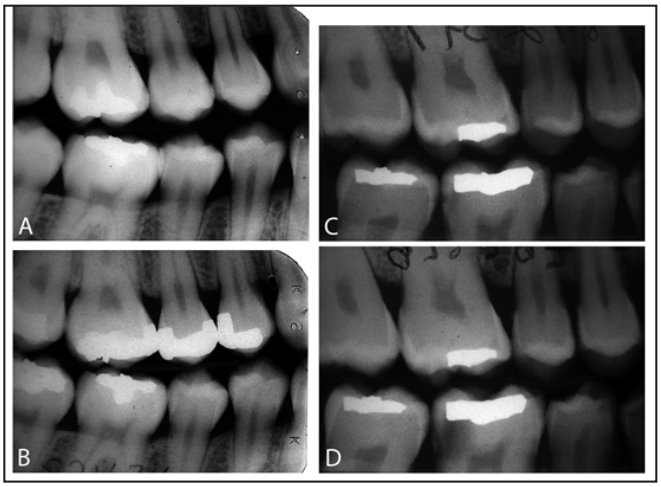

Figure 2. *Two clinical cases demonstrating errors in diagnosing and managing caries on approximal enamel surfaces. The left side shows a case where the radiographic appearance shows initial lesions within enamel on the maxillary premolars and first molar (A), which have been restored with amalgam using traditional cavity preparation outlines (B), resulting in unnecessary interventions with the start of a cycle of repeat restorations over the patient's lifetime. The right side shows a case where the diagnosis a carious lesion half way into dentine on 36 distal has been missed (C), and the resulting caries progression over the following year (D) has led to destruction of much of the distal tooth structure and exposure of the distal pulp horn.*

of disease often predict future disease, knowing the primary etiological factors can aid the patient in changing their lifestyle and behavior to address these.

Risk assessment should be used to try and predict an individual's expected caries experience over a period of time, and the likelihood of new caries activity. A further benefit would be to predict the progression of existing early carious lesions, enabling better treatment planning and intervention. Simple general practitioner guides for risk assessment are available, such as the 'STEM' guide written by one of the authors, to encourage the practitioner to develop appropriate patient questions concerning risk factors (*Figure 1*) [16]. Since intended principally as a guide and a demonstration of a risk analysis process, these methods are intended for use at the level of an individual patient. Scientific outcomes from following STEM and similar approaches remain un-validated, largely because the tools to map risk factors site by site in a given patient's mouth themselves lack the necessary refinement or precision.

At the present time, the standard of care is to identify and then arrest and reverse White Spot carious Lesions (WSL). These are typically found beneath mature deposits of dental plaque, which produce organic acids through fermentation. Plaque fermentation tests can be useful for assessing plaque cariogenicity at a particular site, and using this to educate and inform the patient regarding diet, lifestyle factors and oral hygiene. Oral hygiene at those sites can be reinforced and the patient instructed to use chemical plaque control agents such as chlorhexidine mouthrinses, which can also suppress levels of mutans streptococci [17-19]. White spots and pre-white spots (seen with fluorescence but not visible under normal lighting conditions) can be screened for, paying particular attention to known risk sites, such as sites adjacent to brackets in patients with fixed orthodontic appliances. These areas can then be treated with topical applications of CPP-ACP, using products such as Tooth Mousse™/MI Paste™ or Tooth Mousse Plus™/MI Paste Plus™ (GC Corporation, Japan) to reverse the subsurface mineral loss, and achieve a normal enamel translucency. Preventive care of this type is indicated for all non-cavitated enamel lesions on smooth surfaces.

Problems occur with most of the published caries prediction models which use generalized mathematical analysis to support final explanatory models [20]. Fortunately for dental clinicians, the literature does support a relatively good predictive value for a dentist's subjective opinion for caries risk assessment [21]. Although indicators can give a good idea of risk level, until now, they have not necessarily helped a clinician to understand why a particular patient has developed caries disease [22,23]. Recently a model originally proposed in 2002, and now established as the CaMBRA risk assessment tool, is showing considerable success. Utilizing the CaMBRA tool of pathological and protective risk factors criteria, patient data from teaching clinics at the University of California-San Francisco School of Dentistry were assessed after 6 years [23]. The recently published validation study showed that the list of risk factors used and the manner, in which they were used, successfully identified 69% of those at high risk and 88% of those at extreme risk (high risk plus salivary dysfunction) of presenting with new cavities at subsequent follow-up examinations. Furthermore, 76% of those assessed at low risk did not progress to cavities. This shows that good progress is being achieved in risk-based model development, and consequently it is likely that in the near future clinicians will have access to a range of valid assessment tools allowing accurate patient risk profiling [3].

The initial caries risk assessment should be carried out for each patient at the routine examination or recall appointment. The primary benefit of using patient risk assessment is that this approach enables the dentist to specifically focus on disease status and on early lesion diagnosis during the patient examination. Following accepted MID principles, the clinician can now develop and implement targeted and individualized MID treatment plans involving non-operative therapies, and minimal surgical operative intervention.

Mid Practice Implementation

The Caries Risk Assessment Appointment

It is of considerable benefit in terms of time management to arrange for specific risk assessment activities to be done within the one appointment. The clinician can carry out the plaque and saliva tests (using resting and stimulated saliva) and interpret a detailed 5-day diet assessment sheet (number of sugar and acid exposures outside of main meals) in a relatively short time frame. The results of these tests in conjunction with utilizing the motivational interviewing techniques described below, will allow the clinician to prescribe use of appropriate chemotherapeutic agents such as fluoride dentrifices, professionally applied fluoride varnishes, CPP-ACP products, chlorhexidine rinses or varnishes, and additional appropriate therapies such as use of alkalizing sodium bicarbonate rinses and peroxide therapies (rinses or carbamide peroxide bleaching trays) [8,17-19].

Patients may be reluctant to attend a specific risk assessment appointment when no other dental work is done, as they often come to a dental appointment with the expectation of some procedural work being undertaken. There is a risk that patients can fail to perceive the considerable value of the MID treatment approach. Rather than using a separate appointment, some elements of the risk assessment can be included within the time allocated for other established appointments, such as those already booked for restorations or prophylaxis and cleaning. Based on the authors' experience in private practice settings, this 'under- the radar' approach seems to result in greater patient acceptance and compliance.

At these opportunities, a structured approach to assessing and monitoring changes in caries risk would include the following:

• Exploring medical, social and dental history, identifying medical conditions and medications (prescribed, over-the counter, natural or otherwise) related to salivary dysfunction; past use of home care products; and past dental treatments.

• Clearly identifying the patient's awareness of their caries problem and their motivation for adopting long term solutions rather than a short term treatment which could result in long term failure.

• Analyzing current symptoms which may be indicative of underlying salivary dysfunction, including oral dryness at various times of the day and night; lack of salivary lubrication

during eating, talking and swallowing; salivary web formation during swallowing [24].

• Analyzing lifestyle factors which can increase caries risk, e.g. by reducing the protection afforded by saliva, or by sequestering calcium from the saliva (e.g. foods with citric acids) Key parameters to explore are dietary patterns involving acidic beverages of any type, because frequent intake of acidic floods and drinks can cause an aciduric oral flora to emerge due to ecological pressures [25-27].

Systematic Personalized Advice

A key component of the MID approach is a personalized oral health home care plan. This is designed from the lifestyle analysis, which explores the major risk factors which are driving the patient's caries risk. The advice should include additions to and deletions from the diet, focusing on food choice and lifestyle modifications which lower exposure to acidic foods and drinks as well as those containing fermentable substrates or high concentrations of caffeine. Lifestyle additions can include the use of sugar-free chewing gum to elevate stimulated (and resting) salivary outputs [28,29], non-fermentable snacks sweetened with stevia or Isomalt®, and low fat cheese between meal snacks to raise the plaque fluid pH and provide bio-available calcium ions. Increasing water intake to address issues with fluid balance will help ensure resting salivary flow is adequate. This can be done by drinking reticulated water which has optimal levels of fluoride, and avoiding bottle water which is often deficient in terms the level of fluoride.

Looking at the site distribution of disease at the non-cavitation and cavitation levels across the dentition, the practitioner can now give specific advice about plaque control and address issues such as daily toothbrushing routine; interdental cleaning methods, selection of the fluoride level in the dentifrice; use of other fluoride products such as gels or rinses; use of CPP-ACP remineralizing agents; use of antibacterial agents such as chlorhexidine; and the need for special devices or products, such as oral moisturizing gels [1,6,15,17,26-29]. They can also consider the use of other therapies for early enamel carious lesions such as resin infiltration, to prevent further mineral loss [30,31].

Achieving Patient Behavioral Change

Since dental caries is best thought of as a chronic multifactorial lifestyle disease, addressing the issue of disease management necessarily involves obtaining sufficient information to analyze the clinical and the behavioral causes of the disease [8]. The relevant clinical chair-side tests and their relevance with regard to caries disease have already been discussed, however it must be stressed that simply giving patients information will not in itself trigger meaningful or sustained behavior changes. Assuming that the patients have provided adequate (and truthful) information regarding their diet and lifestyle habits, the issue of accomplishing satisfactory behavioral change to reduce the caries risk factors remains the dominant problem.

In a busy general dental practice situation, the dentist or dental hygienist should arrange a structured interview appointment with the objective of helping the patient to understand his or her own specific caries risk factors and their role in the observed disease activity. With experience, the clinician can begin this process with some questions early in a typical examination appointment or prophylaxis cleaning appointment, and follow this with more expansive discussion at a detailed caries risk assessment appointment.

Achieving behavioral change in patients usually requires clinicians to have an understanding that aggressive force-feeding of information to the patient will not obtain the desired result, and that improving communications skills and understanding best practice in motivational interviewing techniques will greatly enhance results [32,33]. By asking the patient introspective questions to aid their own recognition of dietary and lifestyle behaviors might be causing the caries disease, the patient can become part of the overall discovery and diagnosis process, from which discussion and observation can achieve self-ownership of the disease problem. For successful disease management, a key objective for dental clinicians, as with medical physicians, is establishing patient empowerment and autonomy with improvements in patient motivation to address the causes of their disease [34].

Patient Recall Intervals for At-Risk Patients

Fixed recall periods have been customary in dental practice, the most common interval being 6 months for most patients [35,36]. The new MID model of caries risk assessment allows for individual targeted care with recall periods reflecting risk. Clinician education and training should reflect this change based on individual disease risk assessment, age of the patient and necessarily, patient compliance. Recall intervals should be customized to fit a patient's individual needs, based on this risk assessment. It is now considered that the setting of fixed recall periods is meaningless, given that there are many different reasons for having a dental examination [37]. Sufficiently rigorous evidence-based studies comparing individualized risk-based recall intervals with traditional fixed-interval recall periods are not yet available, but a well-designed multicenter U.K. based study is underway [38].

As a suggested practical measure, the authors recommend and utilize a specific 3-tone plaque-staining product (Tri Plaque ID gel™ from GC Corporation, Japan) to help determine an endpoint to current treatment required. The inclusion of a readily fermented substrate to this plaque-staining product allows recognition of highly acidogenic plaque because of the pH response of the dyes used – in this case a light-blue/aqua colour develops, whilst mature non-fermenting plaque is violet/blue and thin immature health-associated plaque is pink/red (*Figure 3*).

Being able to see the metabolic activity of the plaque biofilm in individual sites empowers the dental professional and motivates the patient, as both can now converse about the issues shown by a 'real-time' assessment of fermentation. By the patient then demonstrating adequate plaque removal and compliance, a suitable recall period can be set to allow timely monitoring of the patient.

Regular monitoring of high-risk patients by dental hygienists or oral health therapists is a cost-effective and efficient method of assessing patient compliance. In the authors' experience, the first such recall should be at 4 weeks after completion of treatment, where the focus will be oral hygiene, lifestyle and dietary change compliance. This visit also sets the period for the subsequent recall visits with the dental hygienist or oral health therapist. At these later sessions, monitoring of the status of early white spot lesions

Figure 3. *Use of Tri-Plaque ID three tone disclosing gel, showing acid producing cariogenic plaque as a light blue stained area on 43 buccal, positioned directly over an active white spot lesion. Mature non-fermenting plaque is shown as a dark purple-blue stain, and thin plaque as a pink-red stain. The inset shows the pH response of the blue dye from the stain, which is dark blue at neutral pH (left), and light blue at a pH of 5 and below (right).*

(WSL), the standard of mechanical plaque control and the level of plaque acid production after carbohydrate challenge (using the same 3 tone disclosing gel), and reviewing gingival soft tissue inflammatory changes will give a good indication of patient compliance. A cohort study using telephone calls to monitor patient compliance at 3-month intervals has also been demonstrated to aid oral hygiene, reducing early childhood caries [39], whilst demonstrating significant cost effectiveness in a large socially disadvantaged population group [40].

An Oral Health Team Approach

In terms of achieving MID outcomes, an important part of oral health care delivery in general practice is to follow a unified oral health team approach. The oral health team is composed of dentists, dental hygienists and oral health therapists, as well as chairside dental assistants and front-desk staff, all of whom should be involved in reinforcing the key messages. Front-desk staff can play an important role in improving patient attendance for caries risk assessment appointments and answering patient's queries. Establishing clear MID objectives, and then following up with regular staff discussions is the key in successfully implementing MID practice protocols using a team approach. Allowing other staff to observe chairside testing, documentation and patient motivational interviewing can successfully upgrade communication skills in the less skilled members of the team. An investment in the training of team members as oral health promoters not only improves practice efficiency but enhances job satisfaction because of the personal satisfaction gained from seeing patient behaviour changes [41]. Creation of standardized messages delivered by the dentist and reinforced by other clinical staff, helps to create value in the mind of the patient and improves their understanding of the disease from which they suffer.

In the examination of high caries risk patients, clinicians should always deliver a dual message:

1. "You have a bacterial disease" (or deficiency, as in xerostomic patients).

2. "We will restore the holes in your teeth" (to meet the 'Drill and fill' expectations of the patient).

Examples of standardized messages to justify carrying out further chairside tests are:

1. "We can help you avoid future cavities, by carrying out some simple tests".

2. "Like medical doctors, we need to carry out simple tests to find out the causes of your disease".

There are particular issues when dealing with the parents of young children, the disabled or elderly patients with carers. It is beneficial for clinicians to recognize that following the "train the trainers" approach will make these individuals oral health promoters themselves, which can help improve oral health outcomes [42].

Tooth Conserving Operative Principles

The surgical or restorative operative component of treatment should focus on preserving or conserving tooth structure. The use of smaller cavity designs which reflect the biological shape of the cavitated carious lesion and account for the requirements of using adhesive restorative materials should be the standard for everyday clinical practice. The timing of restorative interventions is critical, since once the enamel surface has cavitated; the plaque biofilm accumulates in a protected area from attempts at mechanical oral hygiene.

The advent of bonded composite and glass ionomer (GIC) adhesive restorations has allowed the development of modified cavity designs to take advantage of the benefits of the adhesive nature of these dental restorative materials. Common advantages to restoring cavitated carious lesions using minimal adhesive restorations include maximizing retention of tooth integrity and strength, and improving the opportunity to maintain pulp vitality. Minimal invasive principles should ensure minimizing unnecessary destruction of sound tooth structure, as well as achieving sufficient access for adequate vision and tactile sense for adequate caries removal.

Restoration Outlines

Following pre-conceived cavity outlines unnecessarily sacrificed sound tooth structure to follow set rules of "Extension for Prevention" and cavity extension into "self-cleansing" areas. This came at the expense of increasing cavity width and size, with corresponding reductions in fracture strength and an increased likelihood tooth fracture, respectively [43]. Excessively wide cavity forms contribute to the higher frequency of cusp fracture seen in older adults [44,45]. It is now recognized that the cavity design and outline should follow the three-dimensional shape of the lesion itself, to allow for maximum tooth conservation [46,47].

The clinician should limit the depth and extent of preparation, regardless of whether the final direct restorative material is resin composite, dental amalgam or another material, so that as much of the strength of the tooth is retained as possible. Amalgam should not be entirely discarded as an option because it has greater strength than both glass ionomer and resin composite and is still useful for the restoration of extensive cavities and for protection and retention of weakened cusps [48].

Minimal cavity designs can be used with dental amalgam as well as with adhesive materials, and designs for minimal preparations to retain the surrounding enamel and maximize

the area of enamel available for bonding. Achieving clean cavity margins that are free of caries during cavity preparation, will help ensure the integrity of the adhesive restorative seal, and is a key clinical objective [47].

Significant challenges arise in retaining tooth structure can arise when replacing failed restorations; hence it is essential that the removal technique not enlarge the cavity width, so that further loss of tooth structure is prevented. The same principles of minimal extension allowing maximum preservation of natural tooth structure apply for very large lesions [46]. As the cavity becomes larger, the remaining cusps will have become weakened and microfractures may be present, so the need to protect the weakened cusps must be considered within the final cavity design, once gain aiming to avoid sacrificing remaining tooth structure as much as possible. The bulk restorative materials used for larger cavities must have sufficient strength to avoid bulk fracture, and this is where lamination techniques can be useful, combining the advantages of both glass ionomer as a base, and resin composite as the overlying material.46 There is some evidence supporting use of resin reinforced glass ionomer cements as bulk restoratives in situations where occlusal load is limited, as an intermediate treatment modality [49,50].

Making the correct clinical decision to intervene

Following from this, the importance of developing the appropriate clinical skills necessary for early diagnosis of carious tooth lesions allows for appropriate treatment decisions. If surgical intervention and restoration is required, smaller restorations can be placed with the obvious benefits to restoration and tooth longevity. As a general rule, cavitated lesions require restoration to restore aesthetics or function and enable adequate plaque removal by the patient. Even these clinical decisions are not always clear-cut, and decisions can vary depending on the age of the patient, location of the lesion, and aesthetic considerations. For example an elderly patient with a shallow cavitated smooth surface lesion in the aesthetic zone who can successfully maintain effective plaque removal, is likely to be able to harden and remineralize these lesions over time with consistent topical use of fluoride and CPP-ACP products. Educating the patient so that they can achieve adequate plaque/ biofilm control in the area of the lesion is important in ensuring the maximal probability of remineralization. Lesion treatment decisions are particularly dictated by the position/location on the tooth, since non-cavitated smooth surface lesions can be remineralized, but occlusal lesions cannot, due to anatomical considerations [51]. The relatively poor access of deeper parts of occlusal fissures to saliva makes these areas unlikely to remineralize spontaneously. Fissure sealants have been shown in reviews and systematic reviews of clinical trials, to be effective in the prevention of occlusal caries, particularly for permanent molars [52,53]. Resin based sealants demonstrate superior retention rates when compared to glass ionomer alternatives, although their abilities to successfully prevent occlusal caries appears similar [54,55]. A key proviso of successful fissure sealant therapy remains the monitoring and maintenance of the fissure sealants over time [50,51].

Occlusal anatomical complexity complicates treatment decisions due to a change in the typical occlusal caries presentation. The majority of children and young adults now present with occlusal non-cavitated lesions rather than with cavitated lesions, and these are more difficult to diagnose compared to the traditional cavitated lesions [56]. Occlusal surfaces are often obscured by plaque and extrinsic stains. The enamel can be damaged by forceful probing with sharp sickle probes, so probes used to examine occlusal surfaces should be blunt and the probing forces light [57]. It may be necessary to use a powder abrasive cleaner to remove stains in order to see the surface details adequately. The presence of opacity at the entrance to a fissure or pit (i.e., extending into the lateral fissure walls) is the anatomical equivalent to a white spot lesion on a smooth surface, but this feature cannot be seen unless the occlusal surface is clean and dry.

It has been shown that visual diagnosis in a dry field with good lighting allows diagnosis of early to moderate depth non-cavitated occlusal lesions (with a higher sensitivity and specificity), compared to the use of a dental explorer or radiographs [58-60]. Use of magnification, usually via the use of dental loupes, remains a vital and necessary aid for the diagnosis of early lesions and practicing minimal invasive treatment. By improving their visual acuity, dental practitioners can more readily distinguish features of enamel lesions which indicate their active or arrested state [61]. The enhanced visibility provided by dental loupes gives not only an elevated level of awareness at the diagnostic level, but also an improved quality of treatment as the practitioner is better able to assess their cavity preparation for remaining caries, irregular margins, microfractures and other defects. Use of dental loupes has also been shown to significantly improve the performance of dental students [62].

In detecting lesions on accessible smooth surfaces at the white spot lesion stage, gently drying the area will increase the contrast with the adjacent normal enamel and make these easier to display to the patient. Light induced fluorescence is an additional powerful tool for aiding clinical diagnosis of white spot lesions [63,64]. Green and blue visible light elicit yellow fluorescence from healthy dental enamel, which can be seen if a composite curing light (LED, plasma arc or quartz tungsten halogen) is used to irradiate the tooth, and it is viewed through an orange protective filter.

Unlike accessible smooth surfaces, proximal smooth surface lesions present considerable diagnostic difficulties as studies have shown that radiographs of these lesions rarely demonstrate whether cavitation has occurred, particularly where the caries appears to have progressed just into the dentine [65]. Effective diagnosis has been elusive and is particularly important due to the inherently irreversible nature of restorative intervention. As people now enjoy longer lives and have higher expectations of keeping their teeth, the principles of minimal restoration in conjunction with disease risk awareness and understanding the underlying biological factors can help to avoid the lifetime restoration and re-restoration cycle, and so lessen the possibility of tooth loss.

Effective caries prevention for proximal smooth surfaces presents several unique challenges–the plaque biofilm environment ecologically is more amenable to the development of caries than for other smooth surfaces, because of low pH, low oxygen tension, and poor access to saliva. It is difficult to access proximal surfaces for mechanical oral hygiene, and

for visual examination or tactile exploration. Augmentation of clinical mirror/blunt probe examinations with bitewing radiographs is routine, however one must remember that the correlation between radiographic appearance and the histological extent of caries on proximal surfaces is imperfect (*Figure 2*).

Whilst the probability of cavitation increases with the depth of the radiolucency, not all proximal lesions visible on a radiograph reaching the dento-enamel junction will be cavitated, so the clinician faces a diagnostic dilemma if they are relying on bitewings radiographs alone for assessing such lesions and deciding whether or not to intervene restoratively. In asymptomatic teeth, restorative intervention is indicated when clinical cavitation has occurred. Whilst bitewing radiographs have a consistently high specificity for cavitated approximal caries detection, their sensitivity is lower. In other words, they are excellent in determining when restoration is not required, but less useful in determining when restoration is required [65].

Partial caries removal –How much is enough?

The traditional approach to caries removal relied on removing all softened and discoloured tooth structure, judged on a visual and tactile basis, with the objective being complete removal of all microorganisms to avoid any possible caries recurrence.

A new approach began in the 1960's with Fusayama's use of disclosing dyes, allowing identification of two distinct layers within carious dentine, namely an outer "infected" layer with bacterial infiltration and a disrupted structure, and an inner layer of "affected" dentine which retained a tubular dentinal structure, with no appreciable bacterial infiltration [66]. Fusayama accepted that the main purpose of carious dentine removal was to remove the bacterially infected dentine, but his studies showed that removing carious dentine based upon the parameter of hardness alone was problematic as there was a gradient of increasing hardness between the softened infected dentine and the underlying affected dentine which had been influenced by the diffusion of acids. He concluded that using either hardness or colour as endpoints for caries removal, was an unreliable method for discriminating between infected dentine and affected dentine.

Some early work questioning the traditional caries removal approach was demonstrated in an *in vivo* 10 year study by Mertz-Fairhurst et al. [67] and confirmed by later work from Edwina Kidd [68,69]. In the Mertz-Fairhurst study, frank cavitated occlusal lesions extending half the distance into dentine (between the dento-enamel junction and the pulp) were selected for restoration with composites or sealed amalgams. Before the resin composite restorations were placed, an occlusally divergent bevel of at least 1 mm wide was placed in sound enamel, but no instrumentation was carried out below the enamel bevel, leaving both the infected and affected carious dentine untouched. These studies demonstrated that leaving carious dentine under sealed restorations did not result in caries progression, pulpitis nor pulp death, and suggested that the successful restoration was more dependent on the integrity of the peripheral seal.

Since internal remineralization and healing of carious dentine remains an obvious objective of minimal invasive dentistry, it is always preferable to remove the infected carious dentine and maximize the retention of the affected dentine caries. This affected dentine layer retains its normal dentinal tubular structure, and has the potential to remineralize, possibly from calcium and phosphate ions delivered from the pulp, or from an external chemical source overlying the caries. Mount and Ngo [70] in 2000 demonstrated that GIC had the necessary properties of calcium, phosphate and fluoride release in a water-based environment to allow for remineralization and healing of the affected dentine. In a significant demonstration of this potential, a 2006 clinical trial using a strontium-based GIC demonstrated that a substantial amount of both strontium (a chemical analogue of calcium in remineralization) and fluoride crossed from the GIC into the dentine to create a hyper-mineralized zone.

In deep cavities, where the longevity of a direct restoration may be in question due to the depth of the margins, i.e. with concerns of a failure of the seal, a chemical treatment of the remaining dentinal caries using silver fluoride may be considered. This treatment may help to protect against future dentine reinfection. Silver fluoride (SF) itself, or in the stabilized form as silver diamine fluoride (SDF), has been used in a number of countries to arrest dental caries in young children [71,72]. A systematic review published in 2009 supports the effectiveness of silver fluoride solution as a topical agent for both caries lesion prevention and for arresting dentine caries within cavities, prior to restorations being placed [73]. The mechanism of action is postulated to be the deposition of silver salts and the antibacterial effect of silver ions deposited into the dentine.

For patients requiring aesthetic tooth colored restorations, a major disadvantage of use of silver fluoride has been dark discoloration of the final composite restoration due to the free silver ions and silver salts remaining. The recent development of a dual application system of silver fluoride followed by the application of potassium iodide (Riva Star, SDI, Melbourne, Australia), removes the free silver ions causing the discoloration, leaving a silver-dosed antibacterial dentine layer. Reassuringly, diamine silver fluoride is free of adverse side effects after applications over extended periods [72,73]. Topical application of silver or fluoride ions has also been shown to increase the mineral density of demineralized enamel and dentine lesions during remineralization in an *in vitro* study, but further studies will be required to determine if true remineralization is occurring [74].

The consequences of incomplete caries removal compared to complete caries removal in symptomless vital teeth, were examined in a 2006 Cochrane review [75], which confirmed the benefits of minimizing pulpal exposures, retaining pulpal vitality, with no difference in restoration longevity, nor further progression of the disease. A recent 2013 multicenter trial [76], has also found that the procedure of re-opening the cavity at a later date to remove residual dentine caries is unnecessary. It is now considered that incomplete caries removal is preferable to complete or aggressive caries removal in deep cavities in asymptomatic vital teeth as it will reduce the risk of iatrogenic pulpal exposure.

In summary, incomplete dentine caries removal has shown to be a valid treatment strategy, as it helps retain tooth vitality, structure and strength, with no apparent compromises in restoration longevity. Furthermore the use of GIC applied

onto dentine promotes self-healing mechanisms with dentine remineralization. Minimally invasive preparations which retain surrounding enamel will maximize the adhesive bonding surface area for the final resin composite restoration. Moreover, placing enamel cavity margins within sound enamel will help ensure the integrity of the adhesive marginal seal [47]. Maintaining this seal ensures that recurrent caries is less likely to occur, a key point given that recurrent caries is the dominant reason for restoration failure. It should also be stressed, that as yet, no current restorative material can adequately replace the natural form, strength, or anatomy of the natural tooth [77].

Conclusions

The use of MID principles to enhance the standard of dental care may seem obvious to many clinicians, yet the practical incorporation of these principles into routine dental practice has not yet been fully realized. Many dental practitioners originally trained in a restoration-centric mode of caries management may require some persuasion to trial and institute new dental protocols, whilst at the same time being pressured by their patients whose expectations remain with a traditional 'drill and fill' approach. A unified dental team approach utilizing MID principles of patient care, has demonstrated many advantages and is an efficient and productive strategy for modern general dental practice.

Disclosures

AM Brostek declares no conflicts.

LJ Walsh declares he is a co-inventor of salivary test kits and 3-tone plaque disclosing materials.

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