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Conservative Operative Management Strategies

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The dramatic changes in dental caries prevalence for the post-fluoride population over the latter part of the twentieth century necessitate a critical analysis of conventional restorative care. Fluoride-era dentitions (Fig. 1) require a different approach to prevent possible repetition of the challenging clinical scenarios currently occurring in the heavily restored and weakened dentitions of the older pre-fluoride generations (Fig. 2). Restorations are vulnerable to recurrent caries, technical deficiencies, and material failures, generating an unfavorable cycle of increasing tooth destruction. Caries management today requires a change from the practice of wholesale operative treatment of all detected "lesions" to a more discerning diagnostic approach, with the adoption of nonoperative strategies for early caries focusing on effective patient education and preventive disease control. Delaying operative intervention for early lesions and using effective conservative operative intervention strategies for active dentinal disease are expected to result in greater tooth conservation and longevity over the lifetime of the patient. This approach is a common teaching practice in North America, Europe, and, particularly, in Scandinavia. The cumulative scientific evidence [1–3] provides considerable support for these concepts.

Minimally invasive operative dentistry

A new paradigm of operative conservatism, sometimes referred to as "minimally invasive dentistry," is designed to promote maximum preservation of healthy dental structures over a lifetime [4]. It has evolved owing to greater knowledge of the significant stages involved in the caries disease continuum, increased understanding of the substantial uncertainties

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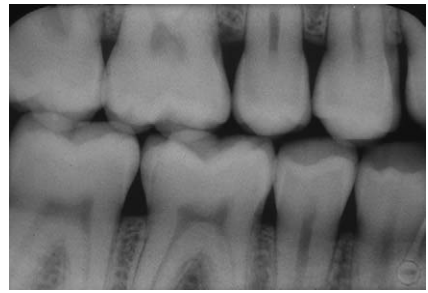

Fig. 1. Radiograph of a typical unrestored fluoride-era dentition. This 21-year old patient shows early proximal caries on the distal surface of the mandibular first molar that is amenable to noninvasive preventive management.

involved in caries diagnosis, and increased awareness of the limitations and problems associated with conventional restorative treatment. The fact that dentists currently spend more operative time replacing restorations, largely owing to recurrent caries [5], reveals the inability of traditional restorative therapy to cure or prevent this disease. The operative decision is a significant one given the potential for restoration failure. Such a decision using the current paradigm assumes that an active dentinal caries lesion is present and that no other more conservative therapy is possible to affect a successful outcome. Minimally invasive operative dentistry is a conservative philosophy based on sound science that spans the breadth of the disease continuum, including nonsurgical management of early noncavitated carious lesions [6], the use of effective conservative operative interventions for dentinal caries [7], two-stage conservative management of deep caries [8], and repair strategies for otherwise sound restorations with localized recurrent disease [9]. The overall long-term objectives of minimally invasive operative dentistry are conservation of sound tooth structure and long-term maintenance of pulp vitality.

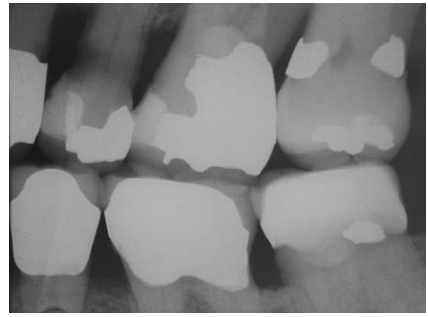

Fig. 2. Radiograph of a typical heavily restored and failing, pre-fluoride–era dentition with active recurrent disease (root caries) in both maxillary bicuspids.

It is also pertinent to define what minimally invasive dentistry is not. It is not intended to encourage earlier caries detection by new technology to provide early operative intervention, and it does not promote early irreversible treatment modalities before "the arsenal of biological preventive measures" is exhausted [4]. It does not support the provision of routine "minimally invasive" procedures in the name of diagnosis or prevention. A recent Fèdèration Dentaire Internationale Commission Project review of minimal intervention dentistry [1] concluded that the most important principles include (1) a delay of surgical intervention as long as possible, (2) the recognition that caries is an infection to be controlled by altering the oral environment, and (3) maximal preservation of tooth structure when operative intervention is required.

The scientific rationale for conservatism in operative dentistry

The early caries process

Caries is a complex multifactorial disease that is present in all populations but varies highly within and between groups. Carious lesions are indisputably the result of microbial metabolism involving a shift in the composition and metabolic activity of the biofilm on the tooth surface [10]. Dietary sugars, metabolized by plaque bacteria, produce organic acids and a pH sufficiently low for the occurrence of enamel demineralization. The net loss of mineral from the tooth surface results in the earliest clinical manifestation of caries—the "white spot" lesion. Even full-depth enamel lesions are not "cavitated" because the outer contour of the tooth is intact, and the lesions are potentially reversible with appropriate interception. Established noncavitated lesions present as proximal enamel radiolucencies on bite-wing radiographs (Fig. 3) or as marked opacity along the walls of occlusal grooves and fissures (Fig. 4). The occurrence, repair, or progress of the carious lesion into dentin will depend on the tooth resistance, environmental factors, and the caries risk behavior of the patient. Disease arrest requires a change in the oral environment and, because of the multifactorial etiology, thoughtful preventive management.

The presence of cavitation with associated significant dentinal infection is increasingly the minimum stage recommended for operative intervention. The time taken from surface caries initiation to the level of dentinal involvement is generally defined in years, even in moderate-risk and high-risk patients, according to the summarized literature from 1959 to 1988 [11]. Progression through enamel in permanent teeth may take from 6 to 8 years. Many detected lesions may be inactive and remain unchanged.

Accurate interpretation of disease presence, extent, and activity in relation to individual caries risk is an extremely important and challenging aspect of discerning diagnosis and disease management [12]. Patient-specific caries management strategies are necessary to control high-caries risk

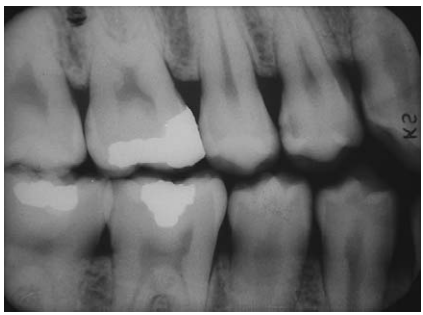

Fig. 3. Radiograph of a high-caries risk patient showing different stages of proximal caries progression. Early enamel caries is present tooth no. 3, noncavitated early dentinal caries on tooth no. 4, and cavitated active dentinal caries on tooth no. 5. The lesions in teeth no. 3 and 4 are amenable to a nonoperative preventive approach.

patients and may involve measures to reduce dental plaque and oral microbial levels, dietary investigation and modification, fissure sealants, and measures to remineralize or increase tooth caries resistance.

Uncertainties in clinical caries diagnosis

Caries diagnosis is an inexact procedure, and clinicians should be aware of the uncertainties involved and the considerable potential for diagnostic inaccuracy. The inherent errors affect the quality of treatment decisions and are a major factor in treatment variability. The performance of a diagnostic test can be measured in terms of sensitivity (the ability to detect true disease correctly) in conjunction with specificity (the ability to detect the absence of disease correctly). Incorrect diagnostic decisions lead to over- and under-treatment, of which unnecessary treatment is considered to be of most concern. A false-positive decision submits a sound tooth to unnecessary operative intervention and the cumulative risks associated with continuing re-

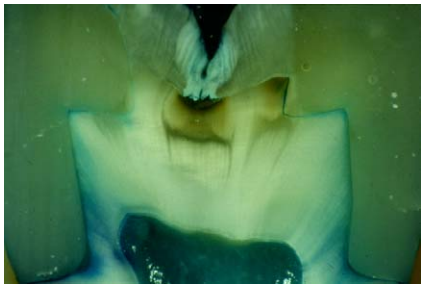

Fig. 4. Vertical section of a tooth with occlusal caries (from a composite microleakage study). Note the pronounced full-depth enamel, fissure wall demineralization that would be clearly visible clinically as highly opaque fissure walls before air drying. Early dentinal caries is also present, demonstrating a maximum visual ranking score of 2.

restoration for life. This issue requires reconciling the need for a diagnostic test providing high sensitivity with an understanding of the requirement for high diagnostic specificity to ensure that sound teeth are not misclassified. It also requires substantive knowledge of the variable nature of the caries process and the concept of individual caries risk. For this reason, current recommendations suggest that irreversible operative decisions be reserved for unequivocally present and progressing dentinal caries. Caries in the fluoride era is a disease of relatively slow progression, and it is unlikely that a missed borderline dentinal lesion will result in an early threat to the viability of the tooth [13]. Periodic recall health maintenance visits provide the opportunity to monitor the progress of questionable proximal lesions.

The following factors are required for optimal conservative caries management: (1) accurate diagnosis and risk assessment of caries presence, extent, and activity; (2) patient-specific primary prevention for remineralization and disease control; (3) minimum cavity design for cavitated lesions; (4) secondary preventive care; and (5) repair rather than replacement of restorations [1].

The re-restoration cycle

Restorations have a finite life span depending on various operator, patient, and material factors. A short re-restoration cycle has a weakening effect on the tooth and increases the risk of adverse pulpal consequences [14]. Operative treatment is also not without risk to adjacent teeth. During 60% to 70% of proximal preparations, the adjacent tooth may be damaged and will develop caries more frequently [15]. Technical restorative difficulties may also result in less than ideal proximal contacts or contour that can impact negatively on the health of the periodontium and affect restoration longevity. Even in vitro occlusal micropreparations are difficult to restore with composite without the inclusion of porosities and voids that could lead to early failure in patients [16].

In current practice, the major volume of restorative work is the replacement of restorations, and one of the most common reasons for replacement is recurrent caries [17]. Clearly, restorations, including those with "extension for prevention," are unable to provide any treatment or cure for the underlying oral disease. Traditionally, technical factors have been overemphasized with respect to restoration longevity, whereas measures to help the patient manage the microbial disease process have been underemphasized [18]. Both of these factors deserve equal consideration when operative intervention is warranted.

Operative intervention thresholds

The academic consensus from the scientific evidence suggests that (1) enamel lesions with intact surfaces do not require immediate restoration,

and (2) established dentinal disease and the presence of cavitation define the need for restorative intervention [11,12]. Optimal diagnostic procedures to define the true presence, extent, and activity of the lesion are required. These challenges are demanding, especially given the disparate incidence and presentation of disease, the expanded range of diagnostic technologies available, and the conflicting advice offered in the general dental literature.

Proximal caries

For a radiographic criterion implying that all radiolucencies are positive signs of disease, true-positive and true-negative rates of 90% and 78% have been found [19]; therefore, 10% of all cavities may be overlooked and 22% erroneously misinterpreted as caries. Many enamel "lesions" on radiographs may be artifacts or nonprogressing arrested caries. Radiographic caries diagnosis is associated with uncertainty. The best approach for a questionable lesion is to inform the patient, initiate basic prevention, and monitor the lesion at future recall visits. With respect to the relationship between the radiographic depth and point of proximal cavitation, the literature reports rates of cavitation ranging from as low as 40% to as high as 79% for lesions visible within the outer half of dentin on radiographs [20,21]. Lesions that extend radiographically between 0.5 and 1.0 mm into dentin have been shown to be significantly more likely to progress over a 3-year period (92%) than shallower lesions (50%) [22]; therefore, this criterion is a useful threshold for proximal operative consideration [11]. The teaching programs of 64% of North American dental schools do not recommend operative intervention until a lesion has reached the outer third of dentin, and monitoring of early lesion progression is currently taught by most schools [23].

Occlusal caries

Fissure caries continues to be a significant clinical problem despite overall reductions in caries prevalence. The diagnosis of occlusal caries is particularly challenging, and the inherent uncertainties lead to widely differing treatment decisions. The lack of diagnostic accuracy can lead to occasional instances of substantial hidden disease being discovered, resulting in an overcompensatory tendency to provide routine operative intervention for all questionable sites. The best method for prevention of occlusal caries is to identify caries-susceptible situations and initiate sealants before a significant level of disease occurs. Although there is some consensus that the minimum stage at which surgical intervention is necessary is that of definite dentinal disease, diagnosis of dentinal involvement in the absence of overt signs of disease is challenging.

Radiographs cannot detect early occlusal caries confined to enamel, and radiographic diagnosis of dentinal occlusal caries by determination of radiolucency into dentin has particularly low sensitivity. In a summation of

the 15 best-rated radiologic studies of caries into dentin on the occlusal surfaces of permanent teeth, the mean sensitivity was 0.51% (49% of true disease not detected) and the mean specificity 0.86% (14% falsely diagnosed as carious) [24]. It is somewhat reassuring that, when related to levels of infection, bite-wing radiographic analysis was more reliable than visual or electronic caries monitoring in predicting heavily infected dentin. Dentin bacterial counts obtained from radiologically sound fissures were low and increased significantly when lesions were radiographically visible in dentin [25]. This finding supports the use of fissure sealants as an appropriate management of susceptible fissures that are minimally affected visually and that appear sound radiographically.

A recent systematic review of the literature demonstrated that although visual and visual/tactile methods give low sensitivity, they provide the highest and least variable diagnostic specificity [26]. The use of improved visual detection techniques can differentiate the different stages, depth, and activity of occlusal lesions [27]. These visual ranking criteria represent increasing levels of disease as related to the optical behavior of affected enamel and include the knowledge that the initial white spot lesion occurs on the fissure walls, and that there is always surface evidence of carious attack before any dentinal involvement [28]. The criteria are defined as follows: 0, when no opacity or discoloration is evident along the fissure wall; 1, when opacity or discoloration is only visible after air drying; 2, when wall opacity or discoloration is visible without air drying (see Fig. 4); 3, when the presence of localized areas of enamel breakdown occurs within the opaque enamel (Fig. 5); and 4, when cavitation exposes the dentin. Training in the technique is required, and the teeth must be clean. The use of a sharp probe for diagnosis of occlusal caries does not seem to increase diagnostic acuity and may cause iatrogenic damage [29]. Although visual occlusal cavitation is highly suggestive of dentinal involvement [30], care is required to distinguish the microcavitation of grade 3 from normal pit or fissure anatomy. Diagnostic accuracy has been shown to be improved significantly when

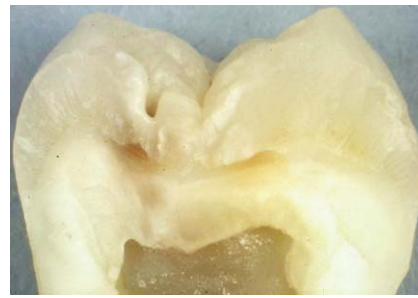

Fig. 5. Vertical section of tooth with visible localized enamel breakdown (microcavitation) and dentinal caries. The minimum visual ranking score is 3.

criteria-based visual and radiographic diagnoses are combined. In a sample of teeth with questionable caries without any evidence of cavitation, a combination of radiographic and visual examination produced a sensitivity of 0.75 and specificity of 0.90 for first permanent molars [31].

The development of even more accurate diagnostic methods would contribute significantly to appropriate management decisions for occlusal surfaces. Although a new commercial laser fluorescence caries detection device increases diagnostic sensitivity, it is unable to provide an accurate determination of the extent and activity of the caries present [32]. This new technology is also associated with lower diagnostic specificity, increasing the potential for false-positive diagnoses, particularly in a low-risk patient population [26]. This observation is a cause for concern regarding the speed of acceptance of this technology into general practice given the changing paradigm of contemporary caries management that is aimed at minimizing operative intervention.

Use of dyes in cariology

Colored dyes have been suggested as a clinical diagnostic aid by providing qualitative assessment of affected dental tissues by visual staining. The major objective of any diagnostic test is the discrimination of the presence of disease from the absence of disease. Nonspecific dyes used in dentistry are somewhat problematic because they tend to stain a wide variety of substrates and lack discriminative diagnostic action. Clinical use of dyes began with the suggested use of basic fuchsin, and later acid red solution, during cavity preparation to differentiate infected from affected carious dentin [33]. Since that time, various protein dyes have been marketed as dentinal caries detection agents. Intended to enhance complete removal of infected carious dentin without overreduction of sound dentin, the dyes were originally purported to stain only infected tissues.

Accuracy of dentinal caries detector dyes

When the level of infection of dye-stained and unstained dentin at the amelodentinal junction was measured at the completion of cavity preparation, it was discovered that not all dye-stainable dentin was infected [34]. The absence of stain does not ensure elimination of bacteria [35]. The dyes stain the organic matrix of less well-mineralized dentin [36,37]. The lack of specificity of caries detector dyes has been confirmed [38]. The dyes neither stain bacteria nor delineate the bacterial front but stain the collagen associated with less mineralized organic matrix. When used on caries-free, freshly extracted human primary and permanent teeth, it was discovered that sound circum-pulpal dentin and sound dentin at the amelodentinal junction took up the stain owing to the higher proportion of organic matrix normally present in these sites. The routine use of these dyes without an understanding

of their distinct limitations could result in excessive removal of sound tooth structure and an increased likelihood of mechanical pulp exposures. Dye staining and bacterial penetration are independent phenomena, and dye staining lacks the necessary specificity for the accurate detection of carious dentin. The fact that nonspecific dyes stain normal dentin at the amelodentinal junction negates the use of dye subsequent to fissure opening as a method of confirmation of a diagnosis of the presence of caries.

Accuracy of caries detector dyes for occlusal caries

The use of dyes for diagnosis of carious enamel has proved even more elusive than for dentin. Many dyes, such as procion dyes, produce irreversible staining that is clinically unacceptable. Although fluorescent dyes, such as sodium fluorescein, can enhance laser fluorescence methods for the detection and quantification of early mineral loss from enamel surfaces [39], the use of simple protein dyes as a clinical visual aid does not improve diagnostic acuity over the careful use of visual diagnostic criteria.

Although a perfect correlation of fissure dye stain with dentinal caries has been reported for occlusal surfaces [40], a later study revealed that dye solutions could significantly increase the incidence of misclassification [41]. Detection solutions found "caries" in 11 of 17 noncarious teeth (64%) as determined by bur verification. Visual and caries detection solutions were 53% and 43% correct, respectively. Caries detector dye staining has also been shown to provide little correlation with the presence of caries around amalgam restorations [42]. In an in vitro study, approximately 70% of dye-stained margins were microscopically caries free, and approximately 53% of unstained margins showed microscopic evidence of caries. There was a distinct lack of correlation between staining and enamel demineralization. It was hypothesized that the erroneous marginal staining observed most likely occurred owing to the presence of denatured proteins derived from plaque, pellicle, saliva, or food. The diagnosis of caries based on dye staining around restorations was not recommended because it would lead to significant unnecessary re-treatment.

Dye application to unprepared fissures was not able to influence positively dentinal caries detection by visual inspection [43]. Although sequential invasive fissure opening using small burs considerably improved (70%) the sensitivity of visual inspection for dentinal caries, the use of dye application after each stage of fissure opening did not improve diagnostic accuracy and was not advocated. Perfect sensitivity at the site and surface level could be achieved with visual inspection after dye application, but the respective specificities were 0.37 and 0.17. The biologic price for this degree of sensitivity was that 63% to 83% of sound surfaces would be restored unnecessarily. Perfect sensitivity for dentinal caries was also achieved with the DIAGNodent (KaVo America, Lake Zurich, Illinois) device in this study. The price for this degree of sensitivity was a specificity of 0.13,

suggesting that 87% of sound surfaces would undergo unnecessary invasive fissure opening.

There is a lack of substantive scientific literature to support the use of dyes on apparently sound or questionable occlusal fissures to improve the diagnostic information gained over the use of visual ranking criteria alone. The use of dyes on occlusal surfaces is generally associated with high sensitivity but unacceptably low specificity given their propensity to stain indiscriminately many different types of surfaces and substrates. False-positive findings are a significant concern. When balanced against the largely insignificant consequences of false-negative findings in the diagnosis of incipient occlusal dentinal caries, which can be sealed successfully, the use of an unsubstantiated diagnostic procedure is of serious concern.

Conservative operative management strategies

Conventional operative dentistry involves standardized preparations that use differing degrees of outline form and extension for prevention. Recently, more conservative forms of operative intervention have been recommended that concentrate on the removal of carious dentin and the preservation of as much sound tooth structure as possible. A systematic review of clinical studies pertaining to three specific conservative operative techniques was published in 2001, including a review of proximal-only, ''tunnel,'' and preventive resin restorations (PRRs) [7].

The permanent dentition

The proximal tunnel restoration

The tunnel technique aims to remove and restore proximal dentinal caries via an occlusal access and has the theoretical potential to preserve the overlying proximal marginal ridge. A systematic literature review of tunnel restorations revealed a total of nine clinical trials in permanent teeth and two in primary teeth, all using glass-ionomer restorative materials. ''Partial'' or ''total'' tunnels were described depending on the extent of proximal external perforation and the presence of residual demineralized enamel. Because external cavitation is increasingly accepted as the earliest stage necessitating operative intervention, the partial tunnel technique currently has limited application.

The early small clinical trials with dedicated operators indicated that this approach was promising; however, larger clinical studies resulted in high early failure rates. The longest clinical study (7 years) reported a 50% survival time of 6 years [44], but recent multi-operator trials provide evidence of high rates of associated caries (41% to 45%) as early as 3 years [45–47]. Residual caries, recurrent caries, and the progression of residual demineralized enamel are factors cited in failure, emphasizing the high-caries milieu of the interproximal area in the general population. The

presence of a glass ionomer was unable to overcome this degree of caries challenge in most studies.

A more recent study has confirmed these findings, with only 35% of restorations surviving 5 years [48]. Patient caries activity and operator skills affected survival. Baseline posttreatment radiographs revealed the difficulties associated with the blind operator access and showed evidence of poor location and removal of caries. The technique is difficult to execute, the extent of residual demineralized proximal enamel is not appreciated, and low restoration survival is associated with the limited preparation extension. The low effectiveness results in a high incidence of early re-restoration, supporting the use of a more direct initial approach that includes judicious removal of adjacent demineralized tooth structure in the proximal contact area.

The proximal-only restoration

Proximal "box-only" or "slot" preparations include no occlusal dovetail or extension for prevention. Although only three clinical studies pertaining to proximal-only preparations in permanent teeth were found in a recent systematic literature search, they were long-term studies (5–10 years), and the results were favorable [49–51]. Two of the studies involved adhesive proximal-only restorations with resin composite. No failures were recorded for 68 composite box-only restorations over 5 years, despite the presence of technical deficiencies noted on baseline radiographs [49]. These deficiencies included common composite technical problems such as cervical deficiencies (13%), voids (9%), and dentinal radiolucencies (1.5%). The 10-year success rate for composite proximal "saucer" preparations was 68.6% [50]. Half of the failures recorded were caused by recurrent decay, and half were considered technique related. Recurrent caries, when present, occurred only at the gingival margin and not buccolingually, justifying the minimal lateral and occlusal extension. Loss of retention did not occur. One clinical trial of tunnel restorations included a small number of control silver amalgam proximal-only restorations. No failures were recorded for these restorations over a period of 5 to 7 years [51].

Available clinical trials support the proximal-only restoration as a viable treatment option that provides similar or better longevity when compared with conventional class 2 restorations combined with greater tooth preservation. The technique is superior to tunnel restorations, most likely owing to improved operator visibility and removal of all associated demineralized enamel (Figs. 6–10). Proximal-only restorations are a common teaching practice in many dental schools. The preparation eliminates the significant tooth weakening resulting from automatic inclusion of the occlusal surface. An accurate diagnosis of the occlusal fissure condition is required.

An in vitro comparison of proximal tunnel and slot preparations revealed residual caries in 25% of tunnel preparations compared with 7% of proximal box preparations, no significant difference in the amount of tooth structure removed, and a mean distance from the pulp that was slightly

Fig. 6. Clinical example of conservative proximal-only composite restoration. This preoperative photograph shows cavitation. (*From* McComb D. Part 4. Minimally invasive dentistry—concepts and techniques in cariology. Reviewing the evidence on tunnel and slot restorations. Oral Health Prev Dent 2003;1(1):69; with permission.)

greater for the proximal slot preparation [52]. The morphology of the proximal preparations produced by the 14 different dentists varied considerably, and the frequency of discrepancies was high, indicating that precise knowledge of effective preparation form is lacking. Recent in vitro evidence suggests that the integrity of the proximal box restoration is improved when retentive elements (proximal grooves) are included and unsupported proximal enamel is eliminated [53]. Preparation of wall and floor definition or, alternatively, internal proximal or gingival retention will help secure the bonded interface. Total reliance on the bonding procedure for retention against long-term occlusal function in nonretentive "saucer-shaped" preparations may lead to dislodgement or microleakage.

Gingival margin location. Gingival extension of class 2 restorations, whether traditional or box-only design, is of particular interest because the vast

Fig. 7. Initial proximal-only slot preparation. (*From* McComb D. Part 4. Minimally invasive dentistry—concepts and techniques in cariology. Reviewing the evidence on tunnel and slot restorations. Oral Health Prev Dent 2003;1(1):69; with permission.)

Fig. 8. Preparation showing gingival floor demineralization and need for further proximal contact clearance. (*From* McComb D. Part 4. Minimally invasive dentistry—concepts and techniques in cariology. Reviewing the evidence on tunnel and slot restorations. Oral Health Prev Dent 2003;1(1):69; with permission.)

majority of recurrent decay occurs in the gingival proximal location [54]. An analysis of short-length proximal restorations with gingival margins ending close to the contact area showed a significantly higher rate of recurrent caries over a 2-year period [55]. Narrow gingival extension has also been associated with increased recurrent caries over an 8- to 10-year study period [56]. There is evidence that overly conservative gingival extension increases the risk of recurrent caries. Because a ''self-cleansing'' location for the gingival margin of proximal restorations is impossible, good patient home care is essential.

The preventive resin restoration

The PRR is a conservative occlusal restoration that involves replacement of discrete areas of carious tooth structure with resin composite followed by

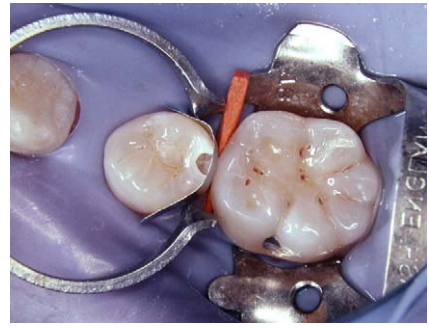

Fig. 9. Matricing. (*From* McComb D. Part 4. Minimally invasive dentistry—concepts and techniques in cariology. Reviewing the evidence on tunnel and slot restorations. Oral Health Prev Dent 2003;1(1):69; with permission.)

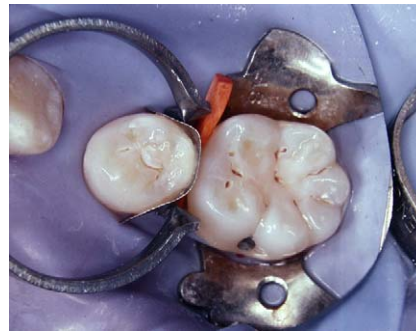

Fig. 10. Restoration. (*From* McComb D. Part 4. Minimally invasive dentistry—concepts and techniques in cariology. Reviewing the evidence on tunnel and slot restorations. Oral Health Prev Dent 2003;1(1):69; with permission.)

the use of an overlying fissure sealant instead of traditional extension for prevention. A systematic review [7] found 18 published clinical studies, of which 15 were prospective and 3 retrospective investigations. All of the clinical studies showed generally favorable outcomes; however, all reported partial or total loss of the sealant as a major problem (13% to 70%). Deficient areas of fissure sealant were periodically replaced during the trial period in some studies, which improved the clinical success. Three studies performed a direct comparison with occlusal class I silver amalgam restorations [57–59]. The PRR was at least as successful as amalgam in two of the trials at up to 5 years, with the added advantage of greater preservation of sound tooth structure. Sealant failure was a significant problem in the third study, which led to an occurrence of 8% recurrent caries. No class I amalgam failures were recorded over the 3 years. All cases of occlusal caries, up to 24% at 9 years, were associated with sealant failure, although the incidence of sealant failure was significantly higher than the occurrence of caries [60]. No occlusal caries was reported with intact sealants in any of the clinical studies. Loss of sealant was increased over glass-ionomer restorative materials and larger areas of composite restoration. In a different but related study, sealed composite restorations placed over substantial carious dentin appeared to halt the progress of the caries when observed radiographically over a period of 10 years [61]. This finding provides reassurance concerning inadvertent sealing of early dentinal caries under fissure sealants and has positive implications for the conservative removal of deep affected carious dentin near the pulp.

The PRR is an effective conservative treatment for localized areas of occlusal dentinal decay. The weak link is the overlying fissure sealant. Because the sealant replaces extension for prevention, it is an integral part of the restoration. Patients must be informed that this restoration requires regular monitoring and maintenance.

The primary dentition

The longevity of restorations is low in the primary dentition [62], and the earlier the age at restoration, the lower the longevity [63,64]. The predicted life span of replacement restorations is even shorter [63]. The major reasons for replacement of restorations in the primary dentition are restoration fracture or total loss [65]. The search continues for improved materials as a restorative solution to caries management in the primary dentition. The vast majority of clinical research on the primary dentition involves relatively short-term comparisons of new commercial restorative materials as they enter the marketplace.

Conservative proximal-only primary molar restorations

A systematic review of proximal-only restorations in primary teeth found 12 clinical studies, 8 involving different types of glass ionomers and 4 using polyacid-modified composites or "compomers" [7]. No clinical studies involving proximal-only silver amalgam or composite restorations were reported, and few of the reviewed studies included conventional control restorations. Material effects dominated the performance of primary molar restorations, with conventional and silver-cermet glass ionomers providing consistently poor results in traditional and box-only restorations, generally owing to their strength limitations. These materials are not suitable for restorations in occlusal function, particularly where an occlusal isthmus is present. The failures largely involved restoration fracture and bond breakdown, with total loss of the restoration. Recurrent caries was recorded in association with a significant proportion of these broken conservative restorations, which needed early re-restoration. Deleterious material effects overwhelmed any possible assessment of preparation conservatism on tooth longevity, pulpal response, and recurrent caries. It is likely that the conservative preparations contributed to the higher failure rates with these low-strength materials owing to dimensional and technical limitations.

Success rates for proximal-only preparations in primary teeth show some potential for improvement with better materials [7]. Failure rates ranging from as low as 2% to as high as 40% were reported for proximal-only resin-modified glass-ionomer restorations in three studies over a period of 3 years. Much improved but still variable (0% to 20%) failure rates were reported in four clinical trials using polyacid-modified composite materials or compomers over 2 years. Failures most frequently occurred owing to a loss of retention, often in combination with caries, suggesting inadequate box preparation retention. The restorations in the more successful studies included proximal grooves to prevent proximal displacement forces during function. Extremely poor performance has been documented for tunnel restorations in primary teeth, with a 35% failure rate at 1 year for composite restorations [66] and a 90% failure rate for conventional glass ionomer restorations over 3.5 years [67].

Conservative operative procedures have not been particularly successful for the primary dentition and may not be warranted. Traditional and conservative operative management strategies show similar highly variable success rates, emphasizing the many different disease, operator, and patient factors involved in treatment of children. Regardless of whether conventional or conservative restorative procedures are used, optimal retention and resistance form features are advisable for the primary dentition. Concomitant and future caries control is essential for the high-risk child and should include providing cogent information and advice to parents.

Summary

The goal of minimally invasive operative dentistry is to achieve maximum conservation of sound tooth structure to maintain a healthy dentition over a lifetime. The concept requires awareness of the potential for diagnostic inaccuracy and involves thoughtful treatment decisions, including delayed operative intervention strategies. The initial operative decision is a significant one given the potential for restoration failure and the negative effects of the re-restoration cycle. A correct operative decision assumes that an active dentinal carious lesion has been diagnosed accurately, and that no other more conservative therapy is possible to affect a successful outcome. Effective and well-executed conservative strategies for the permanent dentition, such as the PRR and proximal-only restorations, have the potential to preserve tooth strength and enhance dentition longevity. Conservative operative management strategies for the primary dentition have proved less successful and may not be warranted. Successful conservatism demands effective disease management and technical excellence.

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