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Treatment Decisions and Conservation of Tooth Structure

Joseph B. Dennison, DDS, MS*,
James C. Hamilton, DDS

Department of Cariology, Restorative Sciences and Endodontics, School of Dentistry, University of Michigan, 1011 North University, Ann Arbor, MI 48109, USA

The discipline of operative dentistry has been synonymous with caries prevention and the conservation of tooth structure since the days of Black, but the context of that conservation has changed significantly over the years. The principle that a natural unrestored tooth is stronger than a restored tooth is discussed in the earliest operative textbooks. Nevertheless, the early restoration designs used greatly undermined cuspal support and advocated the removal of sound tooth structure along all occlusal grooves [1]. The life cycle of a restored tooth from natural eruption to extraction via multiple restorative procedures has been described for many years (Fig. 1) [2]. This cycle has not changed much, except that newer materials and more conservative philosophies have lengthened the time span for each stage. As a result, most elderly people have at least a majority of their natural teeth. This phenomenon is expected to improve more significantly in the ‘‘baby boomer’’ generation that is now approaching retirement age. This segment of the population, as well as persons who are younger, have benefited from a lifetime of preventive measures (eg, systemic fluoride, topical fluoride, oral hygiene education, sealants) that have significantly reduced the incidence of dental caries. Recent data comparing the National Health and Nutrition Examination Surveys I and III indicate that the total caries experience in children aged 6 to 18 years has been reduced by approximately 58% (reduction of 4.44 to 1.90 decayed, missing, or filled [DMF] teeth) from 1974 to 1994 [3]. Even though occlusal morphology retains cariogenic foodstuffs, the enamel is more resistant to demineralization and early caries development. Caries progresses more slowly into the adjacent dentin when

* Corresponding author.
E-mail address: dennison@umich.edu (J.B. Dennison).

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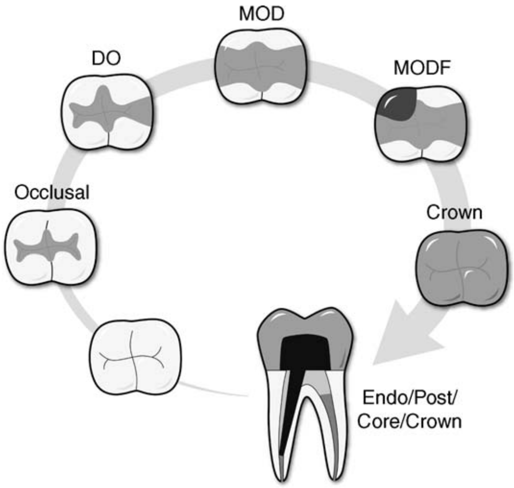

Fig. 1. The life cycle of a molar tooth from eruption to complete restoration.

enamel is well fluoridated [4]. This delay allows time for the clinical initiation of appropriate preventive regimens.

The work of Markley in the early 1950s [5] focusing on the placement of conservative amalgam restorations to eliminate carious or precarious pits and fissures was the most significant move away from the standard cavity preparation with a wide isthmus that weakened the tooth. His philosophy of minimizing operative procedures in favor of retaining sound tooth structure preceded the era of adhesive dentistry but actually laid the foundation for it. His cavity designs were truly fissurotomies, and his class I restorations were deep preventive resin restorations (PRRs) (Fig. 2). As a result of his pioneering work, many textbooks emphasized more conservative cavity preparation designs and less fissure extensions. As another example of this movement, the dovetail design, standard for a class II preparation, has been

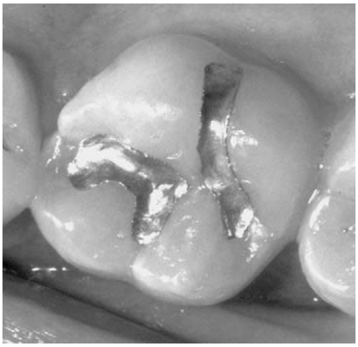

Fig. 2. Conservative occlusal amalgam restorations as proposed by Markley.

removed from current textbooks. The introduction of acid-etching enamel by Buonocore in 1978 [6] and the advent of adhesive operative procedures were other significant steps in prolonging the life cycle of a molar tooth and conserving vital structure.

Currently, dental students are trained to consider restorative intervention as the last alternative in an active oral health care program. Patients are being presented with more preventive options and conservative treatment plans than ever before. Nevertheless, the goal of getting the conscientious patient from natural eruption through old age without losing any teeth is ever present. All of the major textbooks on operative dentistry have at least one chapter dedicated to prevention, and all have modified the criteria for caries diagnosis and the modes for intervention with conservation of tooth structure as the ultimate goal [7,8]. The suggestion of a prophylactic odontotomy (ie, ‘‘the elimination of a precarious pit or fissure by a standard cavity preparation and the filling thereof to prevent decay’’) [7–9] is replaced with the proposal for preventive chemotherapy, a sealant placement, or a preventive restoration. All of these alternatives conserve tooth structure and delay the first stage (small occlusal restoration) of the life cycle of a molar for many years in a compliant patient. In the presentation of cavity designs, emphasis is placed on minimizing isthmus widths, extensions into contiguous fissures, and proximal flare, especially with adhesive restorations. The concept of ‘‘extension for prevention’’ as developed in Black’s early cavity designs is not promoted, and minimal intervention is substituted.

Minimal intervention and the concepts of microdentistry

Minimally invasive dentistry, sometimes referred to as ‘‘microdentistry,’’ is a logical extension of conservation of tooth structure. With the advent of resin-based composites [10] and acid-etching of enamel [11], smaller preparations minimize the destruction of tooth structure required to provide amalgam the necessary bulk for strength. In 1977, Simonsen [12] described sealant-restorations in which only the carious tooth structure was removed, and the small preparation was filled with unfilled resin or a combination of unfilled resin and filled resin depending on its size. In 1980, Simonsen [13] presented the 3-year results from a clinical study that used the concept described in 1977 as a PRR. Ninety-eight percent to 100% of the restorations had preformed adequately based on the size of the carious lesions. At the end of 3 years, some of the restorations had reached the stage at which additional resin material would soon need to be added. The concept of PRRs led directly to what is now known as minimally invasive dentistry, without the sealing of radiating pits and fissures.

New technology in the form of instruments and devices has aided this minimally invasive trend to remove just the carious tooth structure. In 1992, air abrasion was reintroduced to the profession. The use of 27-μm aluminum oxide powder propelled through narrow 0.4-mm orifices at pressures ranging from 40 to 160 psi gave dentists the capability to abrade small preparations with rounded internal line angles and beveled cavosurface margins, which were well suited for restoration with bonded resin-based composite. Air abrasion is a technology that is often associated with minimal intervention because it easily creates narrow preparations less expensively and more efficiently than lasers [14]. Special bur sets such as the Fissurotomy (S.S. White Burs Inc., Lakewood, New Jersey) and the Micro Diamond-Prep System (Brasseler USA, Savannah, Georgia) are marketed specifically for minimally invasive dentistry (Fig. 3).

Given the small size of minimally invasive preparations as the first restorative procedure for many carious teeth, a low-viscosity resin-based composite, sometimes referred to as flowable composite, is recommended for two reasons. Low-viscosity materials can be injected into a preparation by inserting a 22-gauge needle to the bottom of the preparation, allowing the restorative material to fill the preparation from the bottom up and reducing the chance of entrapping air. Second, flowable composites conform

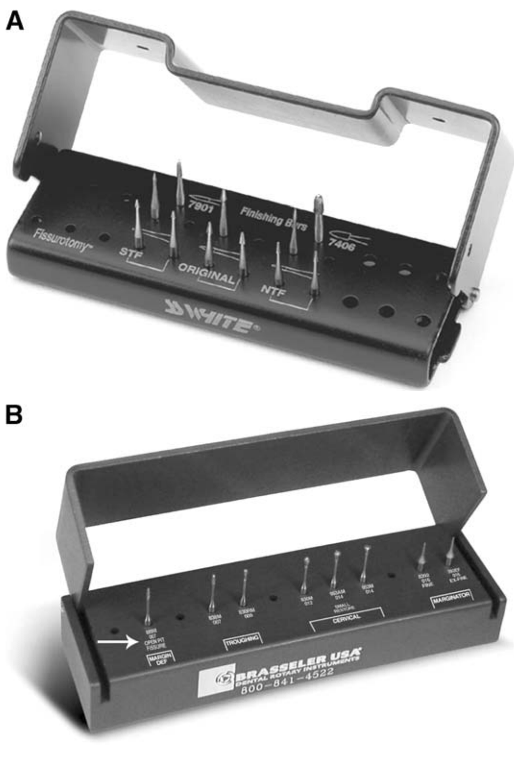

Fig. 3. Bur sets specifically advocated for microdentistry preparation techniques. (*A*) Fissurotomy kit. (Courtesy of S.S. White Burs Inc., Lakewood, New Jersey; with permission.) (*B*) Micro Diamond-Prep System. (Courtesy of Brasseler USA, Savannah, Georgia; with permission.)

to the preparation walls more easily. A benefit for the practitioner is that these materials accept and retain a polish similar to enamel.

Benefits of conserving tooth structure

The potential benefits of conserving tooth structure by delaying intervention or minimizing the operative procedure, if intervention is required, have already been alluded to as prolonging the life cycle of a tooth. The direct benefits are fourfold: (1) the opportunity for recurrent caries to develop along a restoration margin is minimized, (2) the incidence of early restoration failure is reduced, (3) the incidence of tooth fracture related to weakened cusps resulting from larger restorations is decreased, and (4) pulpal vitality is retained throughout life.

Minimizing recurrent caries

Once a restorative material is placed on or into a tooth, an interface is created between an artificial substance and a biologic substrate. Every such interface, whether adhesive or nonadhesive, is subject to the same stresses from occlusal function, thermal cycling, and chemical environmental influences through factors such as saliva [15]. Margin debonding or microstructural material failure can occur in the best of restorations and may eventually lead to catastrophic failure or the development of recurrent caries (Fig. 4). When this occurs, the restoration must be repaired or replaced, usually requiring the loss of additional tooth structure and the insertion of a larger restoration. As a result, the tooth enters the next stage of its life cycle, and the new restoration is subjected to additional stresses related to the increased area of coverage. All of this can be prevented or

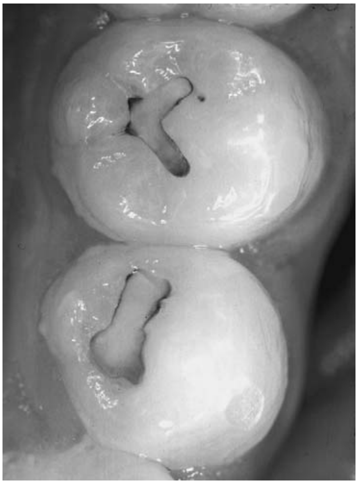

Fig. 4. Margin discoloration associated with debonding in a composite resin restoration.

minimized if the first restoration is never placed, or, if it is adhesive, if minimal extension is performed.

Reducing early restoration failure

Restoration failure occurs in response to functional stresses placed on restorative materials that are inadequately anchored or supported by underlying tooth structure. Adhesive procedures are technique sensitive, and any contamination of a bonding site can compromise the conservative nature of the procedure. The larger a restoration is, the more surface that is exposed to such forces, and the less tooth structure that is available to provide retention or resistance (Fig. 5). As a result, larger direct placement restorations in amalgam or composite resin fail more frequently than smaller ones, and the life cycle is again accelerated. Conservation of tooth structure early in the restorative phase will delay this process.

Decreasing the incidence of tooth fracture

Small cavity preparations, even before the minimal intervention model, were associated with less cuspal fracture. Since the advent of bonding, investigators have noted the reinforcing aspects of bonded resin-based composite [16] and, to a lesser degree, bonded amalgam [17]. In vitro evidence suggests that a bonded composite in a class II preparation will help reinforce cusps to prevent cusp fracture [16]. A clinical study in a university setting indicated that bonding amalgam did not improve the long-term clinical performance or initial postoperative sensitivity [18]. It is clear empirically and from a case-control study that the larger the proportion of a tooth is occupied by a restoration, the more likely it will fracture [19]. As weakened cusps are fatigued with shearing occlusal forces, enamel fractures are initiated, and entire cusps can fail (Fig. 6). The loss of an entire cusp

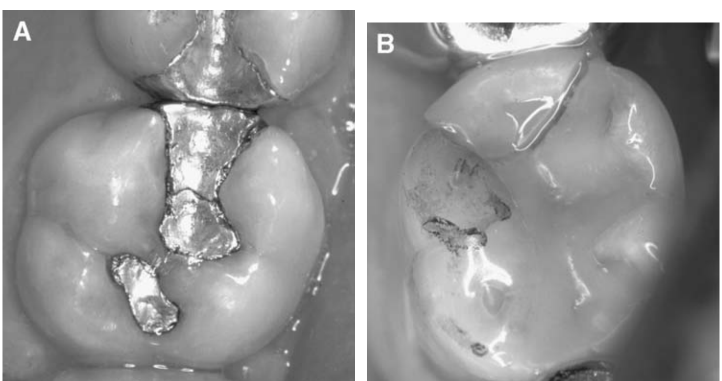

Fig. 5. Major material failure in large direct restorations. (*A*) Isthmus fracture in an amalgam restoration. (*B*) Box fracture in a posterior composite restoration.

Fig. 6. Cuspal fracture associated with loss of support in placing a large amalgam restoration.

requires the placement of a full crown, and, again, the life cycle is accelerated to the next stage, with a possible threat to vitality in the process. Given the inconsistent success of tooth reinforcement via bonding with a resin-based composite, the best recommendation is to keep preparations as small as possible and to delay the placement of the first restoration. Measures should also be taken to improve oral hygiene and to apply preventive agents such as topical fluoride and sealants.

Preserving pulp vitality

The basic design of a class II Black preparation was structured to retain as much tooth structure over the pulpal chamber as possible. Every modification in cavity design has promoted this concept to an even greater degree. A PRR in composite resin does not even necessitate that the dentinoenamel junction be penetrated. Any effort to preserve pulpal vitality in cavity designs and material management is a step toward preserving the natural dentition.

Treatment decisions for incipient and hidden pit and fissure caries

Clinical diagnosis

Several factors must be evaluated in the analysis of diagnostic data before a treatment/no treatment decision can be made clinically. The first step is to estimate whether the enamel defect being studied is active or represents potential caries. In the patient who has incipient or hidden caries, the initial diagnosis is based on whether the lesion remains in enamel or extends into dentin. At this decision point, a simple diagnosis becomes more complex, and current criteria and instrumentation are inadequate to provide consistent results. From the criteria standpoint, there are two schools of thought. One group (largely in the United States) uses visual and tactile criteria combined; the other group (largely European) uses only visual criteria. The standard combined criteria were developed at a conference on the Clinical Testing of Cariostatic Agents in 1968 [20]. They include the following:

1. Based on an explorer catch with minimal pressure, a determination is made as to whether the morphology represents an intact fissure or softness at the base of the fissure, which is indicative of active caries.
2. An undermining discoloration or opacity along the base of the fissure is a visual factor that is strongly indicative of active caries, usually penetrating into dentin.
3. Decalcification on surface enamel along the sides of the fissure is a positive criterion for a caries diagnosis, although, if caught in the early noncavitated white lesion stage, it may be remineralized with conservative therapy or effectively covered by a sealant.

When used exclusively, these criteria have a tendency to yield more false-positive decisions than when the European visual criteria are used alone [21,22]. Although attempts have been made to discredit these criteria, and to show an iatrogenic effect from strong tactile exploration [23,24], they are still actively taught in dental schools and used exclusively by American practitioners. European cariologists propose a visual only evaluation with slightly different criteria (Table 1), which have the potential to allow early caries to develop more extensively before diagnosis is confirmed. When used exclusively, these visual criteria have the potential to yield more false-negative decisions than the combined criteria. A later diagnosis, although possibly more reliable, may result in the loss of additional tooth tissue when the initial restoration is placed. The visual criteria are rather subjective and left to the opinion of the examiner, other than those for cavitation or an undermining halo, which lead to a decision to restore. Although they are

Table 1
Criteria used in visual examination for pit and fissure caries

Rating	Criteria
0	No or slight change in enamel translucency after prolonged air drying (>5 s)
1	Opacity (white) hardly visible on the wet surface but distinctly visible after air drying
1a	Opacity (brown) hardly visible on the wet surface but distinctly visible after air drying
2	Opacity (white) distinctly visible without air drying
2a	Opacity (brown) distinctly visible without air drying
3	Localized enamel breakdown in opaque or discolored enamel with or without grayish discoloration from the underlying dentine
4	Cavitation in opaque or discolored enamel exposing the dentine beneath

From Ekstrand KR, Ricketts DNJ, Kidd EAM, et al. Detection, diagnosing, monitoring and logical treatment of occlusal caries in relation to lesion activity and severity: an in vivo examination with histological validation. Caries Res 1998;32(4):249; with permission.

perceived visually as signs of possible fissure involvement, color, stains, and morphology have generally proved to be lesser contributors to treatment decisions.

Radiography specific to hidden caries

The person most associated with the study of hidden caries is Weerheijm [25–28]. Hidden caries is defined by Weerheijm and others as "occlusal dentine caries which are missed on a visual examination while a radiograph of the tooth shows caries clearly into dentine" [29]. By this definition, radiographs are required to make the diagnosis of hidden caries. Many dental practitioners find hidden caries when they start to intervene operatively into what they suspect is a small carious lesion, revealing instead an extended carious lesion that is well into dentin.

It has been postulated that the incidence of hidden caries is increasing owing to the influence of fluoride, which reduces the rate of enamel cavitation, hiding the caries progression into dentin [30]. Some studies suggest that the number of occlusal carious lesions in children not diagnosed clinically, qualifying as hidden caries, is between 2% and 12% depending on the arch and the study [31,32]. Concern about hidden caries extends back to articles by Hyatt and McCall in 1931, indicating that occlusal caries into dentin that is not visible during a clinical examination is not a recent occurrence [33,34].

The question remains whether the occurrence of hidden caries is associated with fluoride [35,36], and whether there has been a recent increase in its occurrence owing to the increase of fluoride. The case for fluoride increasing the incidence of hidden caries does seem to be the most plausible explanation.

New technology for the diagnosis of caries

Diagnosing caries is a basic function of dentistry. Recently, devices have been introduced to aid dentists in accomplishing this task. One of the more popular is a laser fluorescence based device, the DIAGNOdent (KaVo, Biberach, Germany), which emits a red laser light beam into the tooth and quantifies the fluorescence given off from the surface. The greater the amount of fluorescence detected, the higher the reading. Although this device is widely used, stained pits and fissures alone may lead to higher DIAGNOdent values [37]. Composite restorations, sealants, and polishing pastes can also interfere with the DIAGNOdent performance [38], and angulations of the tip of the DIAGNOdent can result in different values at the same spot on the tooth. Consequently, reproducing readings in a clinical situation can be problematic [39]. The DIAGNOdent is convenient to use owing to its small size, battery power, and relative ease in calibration, which is necessary for each patient. Because of its small footprint, it can be placed on a bracket table or on the counter behind the patient. The most experienced dentists use the

DIAGNOdent as an aid to diagnosing caries, but it is not the gold standard for determining whether to intervene operatively into a carious lesion.

Fiberoptic transillumination (FOTI) has been available for many years and has been most widely used in Europe [40]. This technology uses a narrow fiberoptic bundle to transmit visible white light through tooth structure, allowing the dentist to visualize in a darkened operatory any areas of the tooth that do not transmit the light uniformly. These dark shadows in the tooth are evidence of a carious lesion. As is true for the DIAGNOdent and digital image fiberoptic transillumination (DIFOTI) devices, the performance of the FOTI has been shown to be affected by fissure staining. Nevertheless, it is particularly useful in detecting proximal smooth surface caries. Clinicians trained to use FOTI technology have found it to be a useful adjunct in clinical diagnosis [41].

A more expensive and more recent aid to caries diagnosis is the DIFOTI (Electro-Optic Sciences, Irvington, New York) [42]. This device sends a visible light beam through the tooth and in real time transmits a digital image to a computer monitor that can be captured, stored, or printed. Areas of the tooth that do not transmit light well are suspected carious lesions. This two-dimensional image can give a realistic view of the size and position of carious lesions; however, metallic restorations or dark surface stains can interfere with interpretation of the image.

Because the DIFOTI requires a computer, monitor, and printer to visualize the image, as well as to store and print the image, a mobile cart is necessary if the office environment is not networked. Transilluminated digital pictures are then stored and retrieved for any tooth. Accompanying software automatically stamps the date and time on each image and presents the images in the sequence taken for each tooth. Contrast and brightness of the image are automatically controlled by the software but can be adjusted manually.

One of the newest technologies to assist dentists in diagnosing caries is quantitative light-induced fluorescence (QLF). The QLF-Vision unit (Inspektor Research Systems BV, Amsterdam, Netherlands) will be introduced into the United States in early 2005. This device allows enhanced visualization of early carious lesions owing to their reduced fluorescence intensity when compared with healthy tooth structure [43]. There is a positive relationship between the mineral content of tooth structure and tooth fluorescence [44]. The unit is currently designed to be moved within the dental practice and consists of a xenon light source, filter system, digital camera, computer, and software. The light illuminating the tooth is transmitted through a liquid-filled light guide. The fluorescence images are captured in color and digitized in real time. The images can be stored, retrieved, and analyzed with custom software. This system allows the earliest detection of carious lesions.

Because new technology allows dentists to locate incipient carious lesions earlier than ever before, it is incumbent upon the profession to use this information to support the remineralization of tooth structure when indicated and not to intervene operatively at the earliest sign. Remineralization will maintain the strength of the tooth. If hydroxyapatite is replaced with fluorapatite, the tooth will be more resistant to the demineralization that initiates early caries.

Discriminating active caries from arrested caries

Despite the importance of determining the activity of a carious lesion, dentistry has not developed a reliable method to accomplish this task in a clinical situation. The standard diagnosis is based on the tactile discrimination of the surface texture after the lesion is exposed. A discolored surface that is hard and smooth to explorer touch is an arrested lesion and may not require any treatment. A softer surface is indicative of active caries, and at least preventive measures should be instituted.

Risk analysis as a factor in determining treatment

In all treatment/no treatment decisions, consideration must be given to the environment around the tooth and the potential for the tooth to become carious in the near future. The potential for an initial or precarious lesion to progress is based on the presence of risk factors conducive to the development or support of the carious process. Some of these factors affect the resistance of the tooth to demineralization, such as the genetic background of the patient (family history), fluoride exposure (systemic and topical), occlusal morphology (the degree to which fissure morphology is conducive to plaque and food material retention), and the tooth position in the arch. Another set of factors relate to the oral environment surrounding the tooth, such as the saliva composition, a dietary pattern high in sugars and carbohydrates, oral hygiene effectiveness, and systemic medications. Demographic factors include the age of the patient, gender, education, income, occupation, living environment, smoking status, and dental priorities that are involved in estimating caries activity. Although practitioners have shown an appreciation for these factors, office programs need to be established and reimbursed more effectively if prevention is actually going to supercede intervention [45,46].

Evidence supporting or not supporting early treatment

Early operative treatment of incipient carious lesions made sense in the past before fluoride and other preventive procedures were available to reduce caries risk and enhance remineralization. Few lesions could remineralize or arrest owing to the high caries rate. Today, the progression of a carious lesion has changed owing to the amount of fluoride available to patients in the form of toothpaste, mouth rinses, and community water supplies. Consequently, how dentists treat carious lesions should also change.

Fluoride is most often cited for the decreasing rate of caries in the United States [3]. Fluoride is believed to have reduced the rate of progression of carious lesions. Besides allowing more time for the tooth to remineralize, it provides an opportunity for dentists to evaluate the success or failure of remineralization treatments. By intervening operatively too soon, the opportunity to remineralize the tooth owing to improved oral hygiene or the application of preventive therapies is lost, and the re-restoration cycle is started. The dentist should use the time granted by the slower caries progression rate to institute preventive treatments. Often, dentists prefer operative intervention. The treatment for early carious lesions should be therapies that encourage remineralization. Operative intervention starts a cycle of re-restoration that progressively leads to more lost tooth structure [47].

Empirically, it would seem that operative intervention into early carious lesions versus waiting to restore would reduce the size of the resultant restoration. What is not appreciated is that small lesions can remineralize if given the right conditions, especially with higher levels of fluoride or other preventive therapies. If the lesion does progress, it is at a slower rate, and the resultant size of the preparation does not seem to be significantly different [48]. This observation may seem counterintuitive; however, with very small carious lesions and early intervention, proportionally more healthy tooth structure will be removed during preparation than if the tooth is treated later after attempting remineralization therapy, even with minimally invasive procedures. In the long run, the patient will conserve more tooth structure, have fewer restorations that will eventually need repair or re-restoration, and retain stronger teeth because of questions regarding the reinforcing of tooth structure by adhesive restorations [18].

Experts in evidence-based dentistry and medicine believe that the best evidence to support the clinical management of patients is obtained from a randomized clinical trial [49]. Surprisingly, only one randomized clinical trial gives any guidance as to when to intervene operatively in a carious lesion to conserve the most tooth structure, a question that is basic to operative dentistry [48]. This randomized clinical trial examined the benefits of early operative treatment of questionable carious lesions versus later treatment after the lesion had progressed to a diagnosed carious lesion. The outcomes for this study were assessed by comparing how many teeth were treated in the control and experimental groups that had caries extending into dentin and the size of the cavity preparations in each group.

The clinical trial enrolled 93 patients between the ages of 12 and 36 years (mean, 24 years). Each patient had from one to three questionable occlusal pit and fissure caries, for a total of 223 teeth. The teeth were randomized into an early treatment group and a control group. A tooth in the control group was treated only if the questionable pit and fissure lesion progressed to a carious lesion based on any of the following criteria: (1) a soft stick with a standardized explorer, (2) signs of radiographic caries on a bite-wing radiograph, or (3) decalcification associated with a pit or fissure [20].

The 113 teeth randomized into the early treatment group were treated at baseline with air abrasion and minimally invasive techniques. The investigators were surprised to discover that 44% of the teeth in the early treatment group already had caries that had progressed into dentin. Because of the randomization, approximately 44% of the teeth in the control group were assumed to also have caries that had progressed into dentin. This assumption led to the concern that there would be many teeth requiring treatment and larger cavity preparations as the teeth in the control group were examined at 6-month intervals. After the 12-month recall, nine teeth in the control group were diagnosed and treated for caries, and the mean size of the preparations was not significantly different from that in the early treatment group. In the following 4 years, five, five, three, and three control teeth, respectively, were diagnosed with caries and treated. There continued to be no significant difference between the volume of the cavity preparations in the early treatment group and the control group (Table 2). The cumulative number of teeth treated in the control group with caries into dentin was significantly less than in the early treatment group until the fifth year. The mean index of decayed, missing, or filled surfaces (DMFS) [50] was 8.36, which ranged from 0 to 57 at baseline for the 93 patients. This finding indicated that the patients had an average caries rate for their age. The mean plaque index [51] was 0.53, showing that little to no plaque was associated with the teeth in the study.

There was a restriction in enrolling patients with five or more actively carious teeth (cavitated lesions). Nevertheless, this restriction was never a factor, because only one patient in the study had one grossly carious tooth at baseline. This observation suggests that patients with questionable carious lesions in pits and fissures of posterior teeth do not have many grossly carious teeth. It can be assumed that patients with a high-caries rate have carious lesions that do not stay questionable for long, progressing to diagnosed caries in a short time; therefore, the patients in this clinical study were not thought to have a high-caries rate. Any caries that was present was progressing slowly or had arrested. Because of the slow progression of

Table 2
Cavity volume comparisons in early and late treatment groups

Evaluation time	Control group diagnosed with caries (teeth)	Early treatment group with caries (teeth)	Mean volume of preparations control group (mm^3)	Mean volume of preparations early treatment (mm^3)	Probability of significant difference in size of preparations (P)
Baseline	—	50	—	20.5	—
Year 1	9	—	15.2[a]	—	.279
Year 2	5	—	21.2[a]	—	.390
Year 3	5	—	18.6[a]	—	.865
Year 4 and 5	6	—	19.2[a]	—	.939

[a] Volume values are cumulative with each year.

caries, lesions were not significantly larger when diagnosed using a combination of a dental explorer to probe the pits and fissures, bite-wing radiographs, and visual detection of decalcification in pits or fissures. The findings suggest that, for patients 12 years of age and older without many active carious teeth, it is prudent to watch questionable carious lesions in the pits and fissures of posterior teeth, the major area for primary caries.

Sealant therapy in low-risk populations to conserve tooth structure

There are two approaches to evaluate the efficacy of sealant therapy on the occlusal fissures of posterior teeth. The first approach is to evaluate the absolute efficacy of the procedure and the materials under ideal conditions and to document the merits of using sealants to inhibit caries and conserve tooth structure. These effects have been well documented many times in clinical studies over the past two decades, and there is no question that the procedure has sound scientific merit [52–55]. The efficacy of sealant use is discussed in detail elsewhere in this issue. The second aspect of sealant therapy deals with treatment selection and the general clinical experience when dealing with small potential lesions. This aspect of practical clinical application is the focus of the discussion herein, because it relates to the conservation of tooth structure on a population basis. Despite the volume of scientific evidence in the literature that sealant application is a sound preventive treatment, the actual use of sealants in the United States in a generally low-risk private practice population is low. The reasons for this phenomenon are multi-factorial, highly philosophical, and largely economically based, and general resolution of these issues must continue to be a long-term oral health goal.

Sealant treatment versus no treatment

Early studies on sealant efficacy were conducted using a half-mouth design so that teeth could be paired and patients could serve as their own control. One such study was conducted in Chelsea, Michigan in the late 1970s [53]. The population used was a low-risk group of children with a family history of geographic stability and a sound family, blue-collar background. First molars on one side of the arch were randomly treated without an effort at risk assessment other than to confirm a diagnosis of “no active caries” based on the visual/tactile criteria described previously. Five years following a single application of a filled sealant, the efficacy of treatment was 39.7%, and the complete sealant retention was 31% (Table 3). There was a strong correlation between the partial loss of a sealant and a decrease in the caries protective effect of the treatment, as noted with the drop in efficacy. In the analysis, only a small group of children (18%) progressed through 5 years without any sign of caries in the untreated molar controls. Although the treatment was deemed successful, there was no

Table 3
Effectiveness of sealant in paired permanent first molars

Evaluation period (mo)	Treated sound and control sound	Treated decayed and control decayed	Treated sound and control decayed	Treated decayed and control sound	Net gain	Effectiveness (%)
12	104	11	82	5	77	82.8
24	53	29	100	4	96	74.4
36	45	47	96	5	91	63.6
48	37	64	81	3	78	53.8
60	26	83	63	5	58	39.7

Adapted from Charbeneau GT, Dennison JB. Clinical success and potential failure after a single application of a pit and fissure sealant: a four-year report. J Am Dent Assoc 1979; 98(4):561.

disease present in these patients' mouths, and the treatment was essentially unnecessary (representing overtreatment). There was also a small group in which the treated tooth became carious and the control remained disease free (3%). This finding indicates the small but potential negative effect of treating when not indicated and causing a localized lesion to develop (Fig. 7). Although minimal, this response is often not reported in clinical studies, and the positive efficacy is overstressed in low-risk populations. In the long term, this population was re-evaluated after 10 years while Simonsen evaluated a similar population after 15 years (55), and there was still a positive treatment effect present (Table 4 and Fig. 8).

Sealant treatment versus restoration

Handleman and coworkers [56] and Going and coworkers [57] have documented the decrease in the viability of caries-producing bacteria after

Fig. 7. A tooth previously treated with sealant showing partial loss of sealant material and the initiation of new caries (*white arrow*).

Table 4
Decayed, missing, or filled score per 100 test and control teeth at yearly recalls

Recall (mo)	Pairs examined	Test	Control
12	202	7.9	46.0
24	186	17.7	69.4
36	193	26.9	74.1
48	185	36.2	78.4
120	88	49.8	76.1

Adapted from Charbeneau GT, Dennison JB. Clinical success and potential failure after a single application of a pit and fissure sealant: a four-year report. J Am Dent Assoc 1979; 98(4):561.

placing a pit and fissure sealant and maintaining a full peripheral margin seal. A problem arises when this seal is broken owing to debonding stresses and complete or partial sealant loss occurs. In an attempt to evaluate the severity of this situation, a comparative study was performed in the pediatric dentistry clinic at the University of Michigan. Sealant treatment was maintained at full retention and compared with amalgam restoration over a 7-year period [58]. In this pilot study population, only 56% of the sealants survived the full 7 years with complete retention, whereas 28% required one reapplication, 8% required two reapplications, and 8% required three reapplications (Table 5). With proper maintenance (6-month recall and reapplication to full coverage when necessary), the molars were maintained caries free. On the other hand, three contralateral amalgam restorations exhibited margins that fractured, formed crevices, and were replaced owing to a clinical diagnosis of secondary caries. The other amalgam restorations were all clinically acceptable, but 15% exhibited noncarious crevice

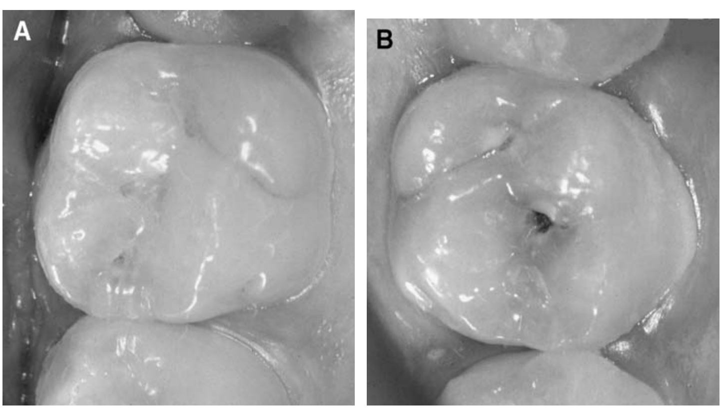

Fig. 8. Contralateral maxillary molars in the same patient 5 years after half-mouth sealant treatment in a clinical study. (*A*) Full sealant retention. (*B*) Cavitated carious lesions in the central and distal pits without treatment.

Table 5
Sealant retreatment over a 7-year period

		No. of retreatments/surface (%)			
Years	Surfaces evaluated	0	1	2	3
4	41	22 (54)	13 (32)	4 (10)	2 (5)
5	30	14 (47)	10 (33)	3 (10)	3 (10)
7	25	14 (56)	7 (28)	2 (8)	2 (8)

Data from Straffon LH, Dennison JB. Clinical evaluation comparing sealant and amalgam after 7 years: final report. J Am Dent Assoc 1988;117(6):754.

formation along the margins. Although there is no doubt as to which treatment is more conservative of tooth structure, the cost of treatment plus maintenance needs to be re-evaluated in light of practical treatment decisions. Newer restorative materials that release fluoride in low concentrations and more conservative adhesive treatments could be compared with sealants, but all of these restorations would be less conserving of tooth structure if used to treat early caries in place of observation or sealants.

Sealant treatment followed by restoration

A more recent study was conducted retrospectively to evaluate the treatment cycle of a sealed tooth using a large insurance database involving generally low-risk children and adolescents [59]. All patients in specific age ranges for newly erupting first or second molars who were seen during a 1-year period and who had sealant placed or were eligible for placement according to their dental coverage were followed up by their claim history for a 5-year period. Data for the first molars in years 3, 4, and 5 showed that sealed surfaces were later restored in 3.3% of cases after 3 years, in 5.1% after 4 years, and in 7.2% after 5 years. In contrast, unsealed first molars were restored at the rate of 9.5% after 3 years, 11.7% after 4 years, and 13.7% after 5 years. Data for the second molars in years 3, 4, and 5 showed that sealed surfaces were later restored in 6.2% of cases after 3 years, 8.0% of cases after 4 years, and 10.4% after 5 years. Unsealed second molars were restored at the rate of 14.9% after 3 years, 18.1% after 4 years, and 20.8% after 5 years. A graphic illustration of this failure rate shows a steady increase in failure per year for both molars, with the second molar always at a higher incidence rate (Fig. 9). This parallel but straight-line incremental increase suggests that the protective effect of sealant treatment decreases over time, with little effect left in the fifth year (relative risk, 0.96) (Table 6). With an overall cumulative protective effect of 50% after 5 years, based on a usage rate of 6% to 8% in 1991, the effect on the burden of dental care through sealant treatment in this insured population was only minimal. For sealant treatment to be meaningfully effective in a large segment of the population, a way must be found to increase the selective use of the treatment at a time of documented risk for early occlusal caries.

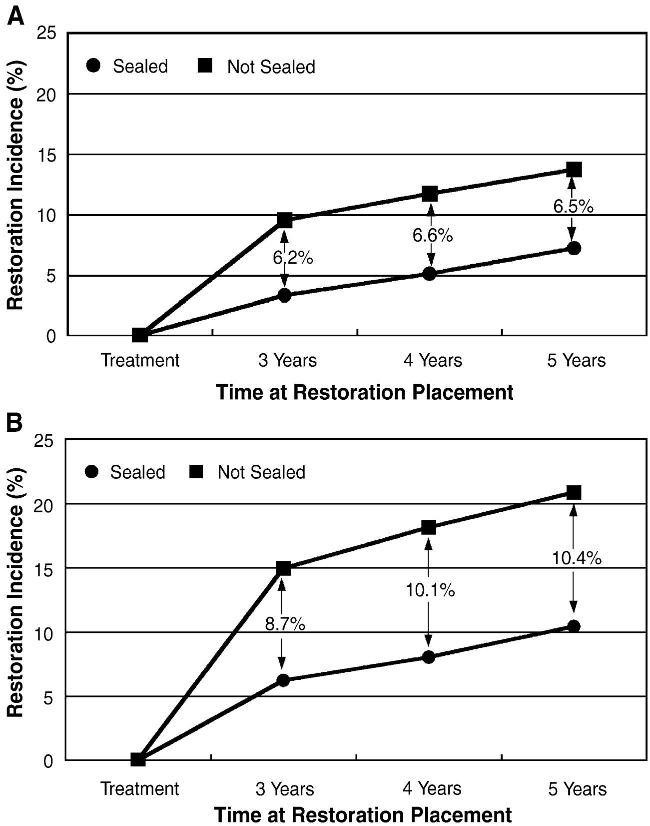

Fig. 9. Graphs of the incidence of restoration placement 3, 4, and 5 years after sealant placement in comparison with an untreated control group of children. (*A*) First molars in children aged 5.5 to 7 years at sealant placement. (*B*) Second molars in children aged 11.5 to 14 years at sealant placement. (*From* Dennison JB, Straffon LH, Smith RC. Effectiveness of sealant treatment over five years in an insured population. J Am Dent Assoc 2000;131(5):602; with permission.)

Table 6
Relative risk of restoration in teeth that received sealant

Tooth type	After three years	During fourth year	During fifth year
First molars			
Cumulative	0.34	0.44	0.53
Yearly	0.34	0.79	0.96
Second molars			
Cumulative	0.41	0.44	0.50
Yearly	0.41	0.50	0.79

Relative risk = $I_{Restored}$ (with prior sealant)/$I_{Restored}$ (without prior sealant), where $I_{Restored}$ is the incidence of restoration.

Data from Dennison JB, Straffon LH, Smith RC. Effectiveness of sealant treatment over five years in an insured population. J Am Dent Assoc 2000;131(5):603.

Summary

Final decisions for treatment/no treatment in low-risk populations must be made considering the opportunities available for remineralization, the arrest of incipient caries, or sealant protection, which are the ultimate in tissue conservation. New technology to aid in the diagnosis of caries is available and can be helpful as an adjunct in making these decisions. The consistent application of defined criteria and the full consideration of a patient's risk factors will lead to more conservative decisions than if purely subjective judgments and past clinical experience form the basis for a customary practice routine. When patients are at a higher risk and intervention is the most appropriate decision, the program for minimal intervention using microdentistry techniques will preserve tooth structure and allow preventive therapy to be applied to reduce future risk and slow caries progression. The life cycle of a molar can be delayed significantly if therapeutic measures are instituted early within the framework of an active oral health care maintenance program.

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