ARTICLE 1

RATIONALE AND TREATMENT APPROACH IN MINIMALLY INVASIVE DENTISTRY

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A B S T R A C T

Background. Current methods of detecting caries, especially fissure caries, are inaccurate, causing some caries to go undetected until it has reached more advanced stages. Minimally invasive dentistry is a philosophy in which the goal of intervention to conserve healthy tooth structure. The authors review the rationale and role of air abrasion in successful practice in the 21st century that includes the philosophy of minimal intervention.

Clinical Implications. This objective encompasses a range of clinical procedures that includes assessment of caries risk to reinforce patient self-help, early detection of the disease before lesion cavitation to fortify the oral environment, restoration of fissure caries with maximum retention of sound tooth structure and sealant placement in unaffected areas. This conservative approach minimizes the restoration/re-restoration cycle, thus benefiting the patient over a lifetime.

Minimally invasive dentistry adopts a philosophy that integrates prevention, remineralization and minimal intervention for the placement and replacement of restorations.[1] Minimally invasive dentistry reaches the treatment objective using the least invasive surgical approach, with the removal of the minimal amount of healthy tissues. A carious dental lesion is the result of bacterial infection. Restoration of the tooth does not cure the disease. Acids produced by bacteria as metabolized sugars and cooked starches continue to demineralize tooth structure. Initial lesions occur beneath the enamel surface and can be repaired largely by ingress of salivary calcium, phosphate and fluoride ions. A balance between demineralization and remineralization inhibits progression of the lesion. Measurements of cariogenic bacterial levels with simple in-office saliva tests, determination of salivary flow rates and buffering capacity and analysis of dietary intake are needed. Patients who have active caries or who are at high risk of caries should be put on a regimen that attacks each part of the caries process: antibacterials (for example, chlorhexidine), buffering agents such as baking soda products, sugarless gum for increased salivary flow, office and home fluoride applications, diet counseling to explain the role of sugars and cooked starch in the caries development process, and use of sealants. When it has been determined that a lesion needs to be restored, removal of decay with maximal conservation of healthy tooth structure should be the main consideration. Since our "permanent" restorations are seldom that, we need to minimize the restoration's size and the restoration cycle that often leads to tooth fracture, endodontic treatment and crown, and occasionally root fracture and extraction of the tooth.

This article discusses the philosophy and treatment involved in performing minimally invasive dentistry.

EARLY CARIES DETECTION

Fluoride has contributed to a dramatic reduction in the caries rate among children. Smooth surfaces have received the greatest reduction in caries incidence; however, almost 90 percent of the caries occurs in pits and fissures.[2] Pits and fissures do not respond to remineralization as effectively as smooth surfaces, and caries progression in dentin is more rapid than in enamel. Pitts and Lond[3] discussed the changing character of fissure caries, with its tendency to cavitate at a much later stage than seen in years past so that detection with the explorer occurs much later in the development of the lesion. Weerheijm and colleagues[4] discussed the "hidden occlusal

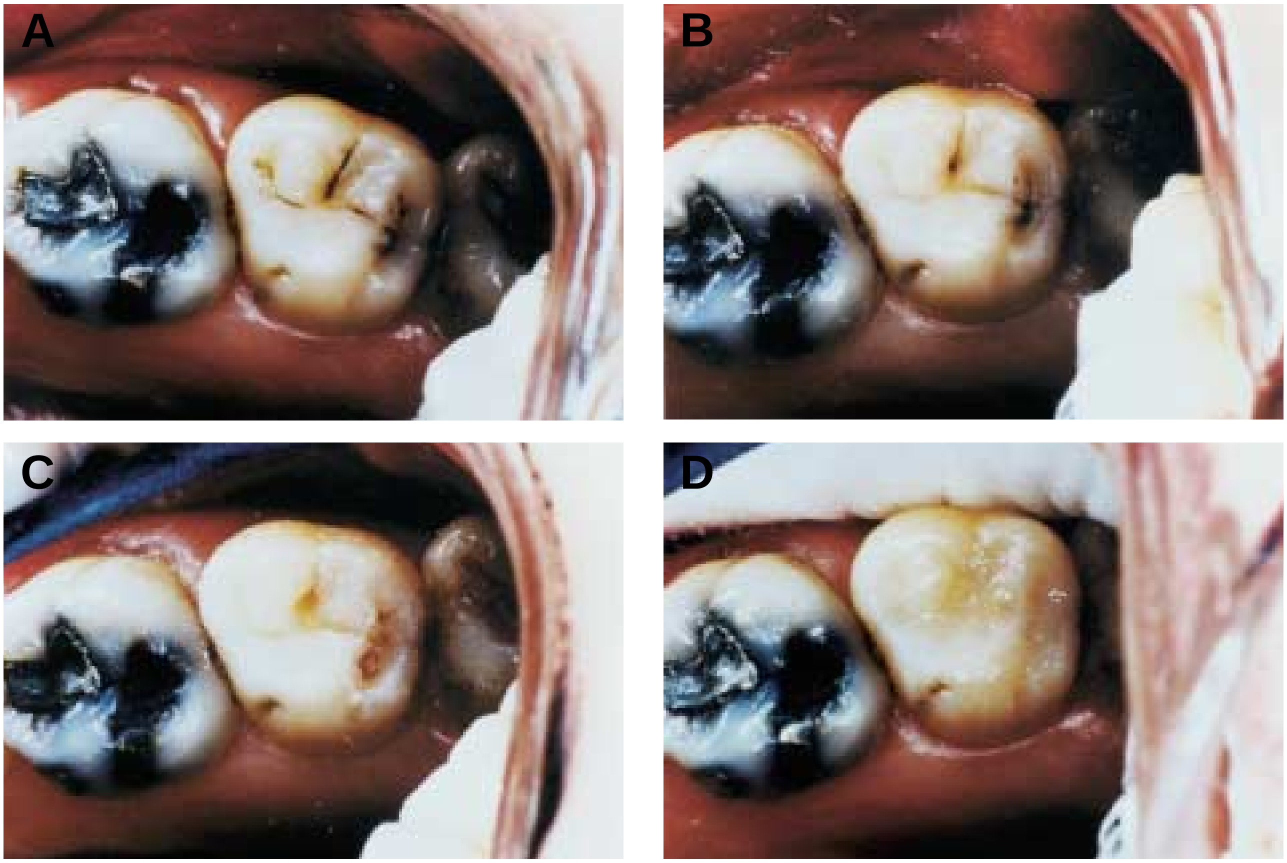

Figure 1. A. A middle-aged patient had heavily stained fissures and a "catch" with an explorer in the distal pit of tooth no. 2. Air abrasion was selected for conservative caries removal without the use of local anesthetic. B. Initial cleaning of the fissures indicated areas needing further caries removal. C. Caries has been removed with minimal removal of sound tooth structure and no discomfort to the patient. D. The preventive resin restoration placed with composite in the deepest areas and sealed uninvolved fissures.

caries" that is difficult to detect on clinical examination but is advanced enough into dentin to be detectable on bitewing radiographs. In their study, they found that 15 percent of teeth judged to be completely clinically sound had distinct radiolucencies seen on radiographs.

Many investigators speculate that the enamel cavitates at a later stage of the caries because of the widespread use of fluoride that has made the overlying enamel more resistant to dissolution by bacterial acids. Penning and colleagues[5] found that the explorer detected fissure caries accurately only 24 percent of the time. Inadequacy of detection methods (both visual and tactile) and the necessity of removing sound tooth structure render the choice either to "watch or wait" or to treat a perplexing clinical decision.

Another option is the minimally invasive approach that allows the clinician to take a look in the fissures to detect caries with minimal loss of sound tooth structure. Should decay be discovered, this approach involves minimal tooth preparations.

MINIMAL TOOTH PREPARATIONS

Many conventional preparations are based upon a philosophy of extension for prevention and the needs of the restorative material rather than the health of the tooth. Minimally invasive dentistry utilizes techniques and materials to access caries that cannot be remineralized and to restore the tooth with minimal loss of healthy structure. Sealants are used as a preventive measure for pits and fissures likely to become carious. When caries is present, small composite restorations referred to as "preventive resin restorations" offer a more conservative preparation than the large amalgam preparation, which requires more healthy tooth structure be removed. Pits and fissures are minimally prepared to remove demineralized enamel and dentin, and then restored with resin-based composite. Unaffected fissures are cleaned of organic debris and sealed (Figure 1).

Bonding with adhesive resins retains the restorations rather than mechanical retention from undercuts and dovetails. Extensions into embrasures are not made unless dictated by the caries.

Osborne and Summitt[6] reviewed the literature that supports abandonment of the principle of extension for prevention and cited numerous studies that refute extending margins into "self-cleansing areas." They concluded that noncarious fissures should be sealed for prevention rather than eradicated, that proximal margins need not be placed into embrasures and any occlusal isthmuses should be narrow, not wide. Undermined enamel is not removed unless it is very thin, as it will be supported by bonded composite resin.

Sixty percent of approximal caries with radiographic evidence of penetration into the outermost portion of the dentin have not yet cavitated on the enamel surface.[7] Attempts at remineralization of these lesions should be done prior to restorative approaches. However, when it has been determined that intervention is needed, conservative preparation designs such as facial and lingual slots, occlusal boxes and tunnel preparations should be the preparations of choice. Management of noncarious cervical lesions (abrasion, abfraction and erosion) also mandates minimal preparation to preserve remaining tooth structure.

The capacity to remove caries in its early stages with minimal intervention does not necessarily dictate that every pit and fissure should be treated in search of hidden caries. Examination for fissure caries includes a careful inspection with magnification (×2.5 glasses to ×10 microscope), good illumination and well-dried teeth. Loss of natural enamel translucency, color changes in enamel and dark discolorations in dentin are possible signs of caries. Considering the patient's risk for caries, past caries experience, and age combined with the clinical findings all determine whether or not fissures should be left untreated, sealed or minimally invaded. Ideally, removal of decay is preferred; however, if a good seal is achieved with a composite resin or sealant, the caries process stops.[8-10]

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AIR ABRASION

In the 1940s, Dr. Robert Black began studying the use of air abrasion technology for dental applications. The S.S. White Company introduced the Airdent air abrasion unit in 1951. It was popular for a short while since it eliminated the heat, vibration and noise of the belt-driven handpiece. Three factors, however, led to the demise of air abrasion at that time. First, air abrasion was not able to prepare cavities with well-defined walls and margins, and the materials of that time (mostly amalgam and direct or indirect gold) demanded such preparations since bonding was not available. Second, the Borden air turbine handpiece was introduced in the late 1950s and many dentists found it faster and capable of doing all preparations. Third, high-velocity suction had not been developed yet, so there was not adequate evacuation of the powder, which was rather messy in the operatory.

Recently, air abrasion has had a resurgence in clinical practice with 18 percent of general practitioners now using the devices, 50 percent of whom have purchased the devices in the past year.[11] This renewed interest in air abrasion is attributed to its ability to conserve tooth structure, our ability to bond tooth-colored restorations to enamel and dentin, and advances in technology that permit us to use less powder when preparing teeth and to adequately evacuate that powder.

Air abrasion techniques provide for minimally invasive caries removal and tooth preparation. With the wide range of bonded materials (including flowable composite resins) now available, these smaller preparations can be restored effectively.

Air abrasion for restoration preparation removes tooth structure using a stream of aluminum oxide particles generated from compressed air or bottled carbon dioxide or nitrogen gas. The abrasive particles strike the tooth with high velocity and remove small amounts of tooth structure. Efficiency of removal is relative to the hardness of the tissue or material being removed and the operating parameters of the air abrasion device. Generally, gas pressures range from 40 to 160 pounds per square inch. The most common particle sizes are either 27 or 50 micrometers in diameter. Particle flow rates range widely, depending on the type of device. The speed of the abrasive particles when they hit the tooth depends upon the gas pressure, nozzle diameter, particle size and distance from the surface. Typical operating distances from the tooth range from 0.5 to 2 millimeters. Farther distances produce a more diffuse stream that results in a diminished cutting ability.

Clinical applications. Specific indications for use of air abrasion are caries removal; restoration preparation; cutting and etching tooth structure for the placement of composites, porcelain and ceramics; and as an adjunct to the dental drill and handpiece bur. These indications support a wide range of clinical procedures that include

- removal of superficial enamel defect;
- cleaning fissures and surface preparation for sealants;
- preparation for preventive resin restorations;
- removal and repair of composites, glass ionomers and porcelain restorations;
- small Class I through V preparations;
- surface preparation of abfractions and abrasions;
- removal of pit and fissure surface stain on enamel before placement of a resin-based composite restoration or porcelain veneers;
- cleaning and preparation of tooth structure and castings for cementation or rebonding.

Air abrasion is an excellent tool for detection of pit and fissure caries. When clinical, radiographic and patient risk factors make pit and fissure caries suspect, air abrasion can be used to remove the organic debris and determine if caries is present. Use of burs for this procedure would remove far more sound enamel than the few micrometers removed with air abrasion. If caries is not found, the enamel surface has been cleaned and suitably textured before etching and bonding of sealants. Air abrasion has been shown to enhance enamel bonding.[12-14]

Any caries can be removed conservatively with air abrasion, which minimally opens the pits and fissures to allow for visualization and access to caries with much less loss of sound enamel and dentin than when burs are used. If caries is limited to enamel, then a sealant or flowable resin-based composite can be placed. If caries penetrates into dentin, then the preventive restoration can be used with a heavily filled resin in deep or wide areas subjected to forces of mastication. Sealant material is used to cover noncarious pits and fissures. Extension for prevention is replaced with "seal for prevention."

A caries detector dye may be used to aid in visualizing areas suspicious for caries. Early work by Fusayama[15] showed a basic fuchsin dye to selectively stain the infected carious layer (which is heavily bacteria-laden, soft, amorphic dentin with the collagen matrix denatured and no potential to remineralize). The infected layer is removed and affected dentin (which has far fewer bacteria, is partially demineralized but has an intact collagen matrix and the potential to remineralize) is left.

Air abrasion is also well-suited for small preparations of Class I through V restorations. Air abrasion is well-suited for preparing the root surface for bonding to restore abrasion or abfraction lesions without cutting the tooth for mechanical retention of the restorative material. Air abrasion breaks the glaze of the highly polished surface that is not suitable for bonding and produces a highly textured surface that is excellent for the wet dentin-bonding technique. Servicing existing restorations by removing accessible recurrent caries at the tooth/restoration interface increases longevity of existing restorations. This technique is particularly important for treating extensively restored teeth where there is increased risk of weakening the tooth by further extension of the restoration.

Air abrasion preparations that extend into dentin usually can be done without use of local anesthesia. Patients can forego the injection and the prolonged numbness after the procedure is complete. Sensations of discomfort during air abrasion is usually at low levels and can be managed by reducing air pressure and powder flow or using shorter bursts of powder. Practitioners indicate that 85 to 90 percent of patients do not request anesthesia, resulting in more efficient use of treatment time, and allowing for treatment of teeth in multiple quadrants in a single visit. Patients are less anxious with the quieter sound of air abrasion as opposed to the high-pitched whine of the high-speed drill. Additionally, with air abrasion, there is none of the vibration that patients feel with high- or low-speed drilling.

Clinical limitations. Air abrasion is not well-suited for removal of amalgam and gross caries. Air abrasion is not an efficient means of removing large amalgams especially, and there is concern for the levels of mercury released when amalgam is abraded. Air abrasion of amalgam for one minute releases mercury vapor four times in excess of the OSHA standard.[16] However, brief, incidental surface abrasion of amalgam should not produce significant mercury vapor release.

Air abrasion is also not effective for removal of gross caries because it does not cut substances that are soft or resilient well.

Care must be taken when working near soft tissues due to risk of laceration, air dissection and emboli. An inadvertent spray to soft tissues is not likely to cause damage, but a prolonged direct spray could potentially cause injury. When used properly, risk of adverse events is extremely low.

Air abrasion produces a rounded textured cavosurface margin and thus is not suitable for restorative preparations requiring definitive walls and sharp, well-defined cavosurface margins such as those needed for conventional amalgam and gold restorations, or composite inlays or porcelain inlays. It is also not suitable for crown preparations and removal of large gold semiprecious and non-precious metal restorations.

Air abrasion does not obviate the need for acid conditioning of enamel prior to sealant placement or composite resin restorations.[17,18]

Systems and features. Air abrasion devices include cart, table top and handheld models. Handheld devices are generally not suitable for restoration preparation but are used to prepare tooth, metal, composite or porcelain surfaces for bonding. Some models have built-in features and accessories such as additional compressor, evacuation and high-intensity curing lights. Operator controls are either mechanical or digital. Mechanical control is standard in lower cost devices, and their control of powder flow rate (the primary determinant of overspray and consequent mess to be evacuated, washed or otherwise removed) is more tenuous than with digital control, which provides a consistent and minimal amount of powder while maintaining high efficiency. In selected devices digital control also allows for pulsed mode of operation, providing an interrupted air abrasive stream at settings from 0.5 to 2.0 seconds.

Air abrasion handpieces and nozzles are removable to facilitate sterilization, and have working angles ranging from 0 to 120 degrees. For pit and fissure caries, a slight angulation from 90 degrees to the occlusal surface is the most efficient cutting angle, producing a narrow preparation with minimal reflected spray. For facial and lingual preparations, a 60-degree angle produces a shallower preparation and allows for evacuation of reflected spray. Generally, less than 10 grams of aluminum oxide is used in pit and fissure caries removal for one preparation. Nozzle orifice diameters range from 200 to 800 µm. Larger nozzle orifices require higher powder flow rates and gas pressures to maintain cutting efficiency. High-volume evacuation removes the bulk of used aluminum oxide particles and can be supplemented with extraoral evacuation systems that are designed to remove dry particles (but not any liquids).

Aluminum oxide is the most commonly used industrial abrasive, and is classified by the U.S. government as a "nuisance dust" rather than a "toxic dust." The acceptable exposure limits are much higher than the amount of aluminum oxide typically found in an operatory using air abrasion as long as proper technique and evacuation is used.

Aluminum oxide contains no silica. If inhaled, particle sizes larger than 10 µm cannot enter the alveoli and are swept from the bronchial tree by the respiratory cilia. Aluminum oxide has low potential for causing respiratory problems. However, caution should be used with patients with known respiratory diseases, including asthma. Good suction and a rubber dam that extends over the nostrils will help to minimize inhalation of particles by the patient. If not using a rubber dam, place a nonwoven pad in the mouth as a throat drape. Some practitioners will place the nitrous oxide nosepiece on the patient and administer low levels of nitrous oxide and oxygen or oxygen alone.

Learning and clinical technique. Clinicians learn the air abrasion technique using clinical simulation materials such as glass slides and simulated teeth and extracted teeth before treating patients. When learning, the clinician should use the lowest pressure achieving enamel and dentin removal

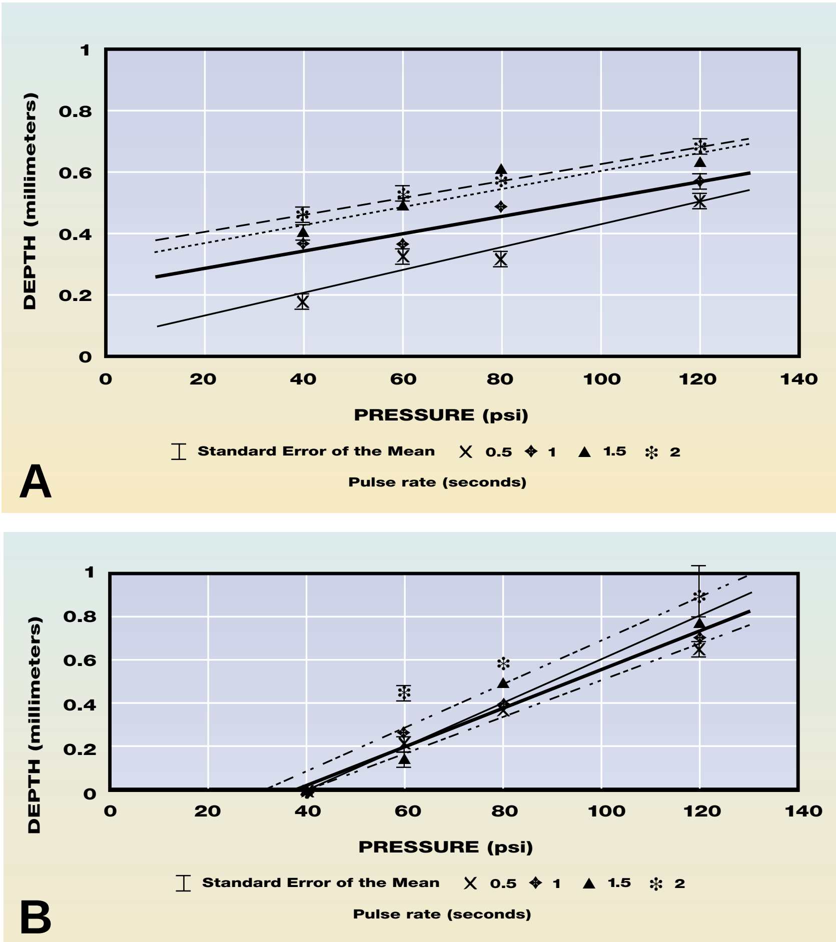

Figure 2. A. Air abrasion of enamel as a function of pressure (pounds per square inch, or psi) and pulse rate (seconds) for 27-micrometer particle size and 0.12 gram/second particle flow rate. B. Air abrasion of enamel as a function of pressure (psi) and pulse rate (seconds) for 50-µm particle size and 0.44 g/sec particle flow rate.

and a small particle size. A larger particle size has more mass, hits the tooth with more impact, induces more pain and creates more overspray due to the particles traveling farther. The handpiece is positioned with the nozzle tip about 2 mm from the tooth surface and at a slight angle from the perpendicular to allow an exit path for air particles that will not inhibit the incoming abrasive stream. It is kept in motion and inspected frequently to prevent excessively deep cutting. The access to the lateral extent of the decay should be prepared before deeper dentin decay is attempted. Soft, deep decay is best removed by a low-speed handpiece and large round bur or spoon excavator.

Drill and air abrasion comparison. Where caries is present, clinicians can use a number of minimally invasive treatment options that include smaller burs, air abrasion or lasers. In deciding which modality to use, factors to consider include amount of tooth to remove, ease of use, speed, need for anesthesia and patient management. Applied research has demonstrated that air abrasion removes less tooth structure than drilling.

Our laboratory measured the amount of healthy enamel and dentin removed using air abrasion in comparison to drilling and is described as follows.

Noncarious molars were treated with air abrasion at various air pressures to determine treatment times using either 27- or 50-µm particles. The rate of removal of tooth structure was compared at identical times of application to the high-speed drill using a no. 245 carbide bur and the low-speed drill using a no. 1/2 carbide bur. The range of enamel removed was 923 ± 92 to 2,108 ± 354 µm for the high-speed drill and 186 ± 53 µm to 914 ± 221 µm for air abrasion; the low-speed drill did not remove enamel. The range of dentin removed was 1,524 ± 51 to 2,672 ± 436 µm for the high-speed drill; 59 ± 15 to 892 ± 15 µm for air abrasion; and 213 ± 33 to 602 ± 104 µm for the low-speed drill.

The results showed that air abrasion removed less tooth structure than the drill. With air abrasion, higher air pressures caused a linear increase in tooth structure removal, and 50-µm particles removed more tooth structure than 27-µm particles at higher air pressures (Figure 2).

Air abrasion and the drill were also compared for speed of caries removal in fissure caries, shallow dentin caries and deep dentin caries.

Results indicated that air abrasion and the drill are comparable in speed in fissure caries, air abrasion is faster in shallow dentin caries and the drill is the preferred method in deep caries removal owing to the inability of air abrasion to remove soft carious dentin.[19]

Users of some types of lasers report similar conservative preparations, efficiencies of time and reduced need for local anesthesia.

CONCLUSION

Minimally invasive dentistry requires a change in philosophy in our approach to managing dental caries. Dental caries needs to be viewed as a bacterial disease rather than the end product of that disease—a hole in the tooth. Patients should be assessed for their caries risk.[20] The practitioner can then help patients prevent caries or reverse it in its early stage by interrupting the disease process prior to cavitation of the lesion. This requires suppressing the bacteria, limiting the substrate upon which they survive and its duration in the mouth, enhancing the oral environment (increasing saliva and its minerals), and protecting the teeth with fluoride and sealants in addition to the usual oral hygiene methods that we teach our patients.

When the caries process cannot be reversed, minimally invasive techniques and materials should be used to conserve sound tooth structure. Air abrasion is one such treatment modality that allows us to minimize loss of sound tooth structure during caries removal. The changing nature of fissure caries with later cavitation and our inability to accurately detect fissure caries with the dental explorer and radiographs can leave us perplexed as to whether to "watch and wait" or invade the fissures. With air abrasion we can remove debris from suspicious fissures and take a look to determine whether caries is present or not. When debris is removed, if caries is not present we need proceed no further. We can then "seal for prevention" and abandon antiquated principles of extension for prevention.

Conservative approaches should help patients maintain their dentition for their lifetimes. ■

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