

# The Evidence Supporting Alternative Management Strategies For Early Occlusal Caries and Suspected Occlusal Dentinal Caries

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**Objective** To assess the strength of the evidence describing the effectiveness of alternative strategies to the detection and management of early occlusal caries and suspected occlusal dentinal caries.

**Methods** Nine detection and intervention decision points were identified as being central to the management of early occlusal caries and suspected occlusal dentinal caries, or suspicious areas. For each decision point, the evidence for effectiveness was assessed, using existing systematic reviews when available, and nonsystematic review methods when necessary.

**Results** For the 2 detection decisions (early occlusal caries and suspicious areas) the strength of the evidence was weak. Accuracy in detecting early occlusal caries was extremely variable within and across detection methods. Approximately 50% of suspicious areas identified had dentinal caries. The strength of the evidence for effectiveness of nonsurgical approaches for the management of early occlusal caries was weak for all 3 management strategies examined (doing nothing, sealants, remineralization). This evidence suggested that sealants were highly effective, with remineralization reflecting moderate effectiveness. For the management of suspicious areas, the strength of the evidence was still weaker and reflected the same relative effectiveness. For the surgical management strategy for suspicious areas, operative treatment, the evidence was strong and reflected high effectiveness for preventive resin restorations, but no evidence was available for minimally invasive techniques.

**Conclusion** Identification methods for early occlusal caries are not accurate. The strength of the evidence for effectiveness of nonsurgical management strategies for early occlusal caries is at best, weak. The available evidence suggests that sealing both enamel caries and suspected occlusal dentinal caries is the most effective management approach if subsequent maintenance of the sealed surfaces can be assured.

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## INTRODUCTION

The dental profession's approach to the treatment of caries has been evolving in recent years. A generation ago, it would have been fair to characterize the predominant treatment philosophy as being reactive and focusing on operative

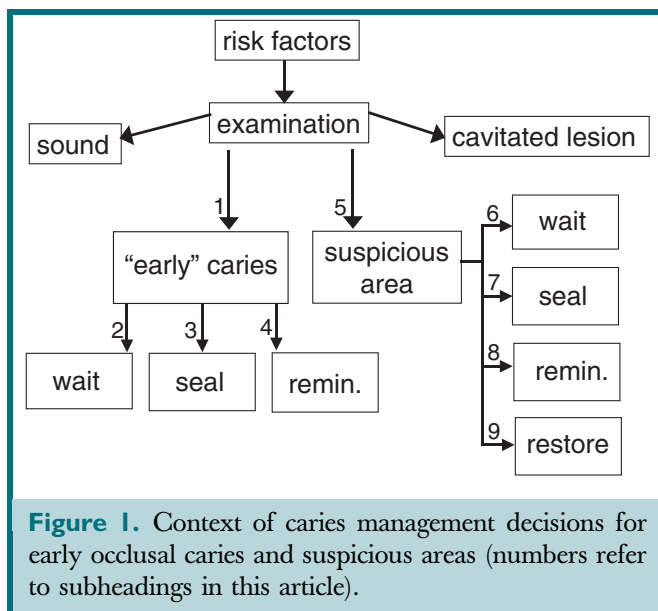
intervention. When lesions were detected, and often when they were suspected, they were restored, and the earlier the better. Prevention was important for children and "one size fit all." Over the past several decades, advances in materials and technology and changes in caries epidemiology have all contributed to the emergence of a more proactive, tailored preventive and conservative treatment philosophy characterized by greater attention to the individual and his or her disease, with reduced emphasis on universal immediate surgical intervention.

The profession is slowly progressing from “finding and filling” to “early detection and management.” Dentists adopting this treatment philosophy have fewer cavities to fill, and more surfaces to save. But, progress has not been rapid. This conservative approach first achieved wide visibility with the publication of a supplement to the *Journal of the American Dental Association* in 1995.<sup>1</sup> The 2001 NIH Consensus Development Conference on the Diagnosis and Management of Dental Caries Throughout Life adopted the caries management paradigm in structuring its Conference Statement,<sup>2</sup> and adoption by clinicians has been urged frequently.<sup>3-5</sup> Nevertheless, indirect evidence suggests that a large segment of the profession may not employ recommended caries management strategies in their practices.<sup>6-8</sup> The management of noncavitated lesions on occlusal surfaces seems in particular to attract recommendations for surgical intervention in the absence of evidence of caries progression into the dentin.<sup>9,10</sup>

In all likelihood there are several reasons why recommended conservative, noninvasive strategies to managing early occlusal lesions are not being adopted rapidly by clinicians. One of those possible reasons is that clinicians have found the strategies to be ineffective in actual practice. Thus, it is entirely appropriate to examine the strength of the evidence that underlies current recommendations for the management of early occlusal caries lesions.

Figure 1 illustrates the context within which decisions about early caries occur. First is a decision concerning whether an early caries lesion is present. An examination of any given occlusal surface can have 4 possible outcomes ordered in increasing severity of caries involvement: (a) the surface is sound, ie, no lesion is detected; (b) it has “early caries,” ie, a non-cavitated caries lesion that is assumed to be confined to the enamel is detected; (c) it has a “suspicious area” or suspected occlusal dentinal caries, ie, visual, tactile, and radiographic signs are insufficient to definitively indicate the presence of dentin caries but some of these signs are present—the area may or may not show definite signs of noncavitated enamel caries; or (d) it has a definitive cavitated caries lesion detected visually or radiographically. The following discussion will not address outcomes a and d because management strategies are straightforward in these instances. If a decision is made that the surface exhibits early occlusal caries or is suspicious, however, clinicians have a variety of management options. For early lesions these options include waiting (doing nothing), sealing the occlusal surface, and attempting to halt progression and remineralize the lesion through use of antimicrobials and fluorides. For suspicious areas these same 3 options are available, as well as a fourth, placing a restoration.

Thus there are a total of 9 decision points within the context of the management of early occlusal caries and suspected occlusal dentinal caries (2 concerning the identification of the condition, and 7 related to the treatment intervention) where the evidence can be assessed. This discussion does not present original systematic reviews of the



**Figure 1.** Context of caries management decisions for early occlusal caries and suspicious areas (numbers refer to subheadings in this article).

evidence for each of these decision points. Rather, existing systematic reviews are summarized, and when no such review is available, the readily available evidence, ie, relevant English language literature identified through MEDLINE searches, is surveyed. The purposes of this examination are to assess the strength of the readily available evidence and to summarize the conclusions that can be drawn from that evidence for each of the 9 decision points.

### I. Detection of Early Occlusal Caries

A systematic review of methods for the detection of dental caries was prepared for the 2001 NIH Consensus Development Conference on caries management.<sup>11</sup> The review included studies reporting the sensitivity and specificity of detection methods for occlusal enamel caries in permanent teeth as determined through comparison to a histological reference standard. Only 3 studies of the visual method of detection, and none of the visual-tactile methods were included. Four studies of radiographic methods, 2 of laser fluorescence, and 1 each of fiber-optic transillumination (FOTI) and electrical conductance were included. A subsequent systematic review of the DIAGNOdent laser fluorescence device included 5 studies, 2 of which also contributed observations for other methods.<sup>12</sup>

Table 1 summarizes the results reported in the 2 systematic reviews. Studies of visual identification methods show a striking diversity of performance, with 2 studies reporting very low sensitivity coupled with extremely high specificity, and the other 2 reporting moderate levels of both sensitivity and specificity. This difference is due to differences in the criteria used to identify the lesions, and neatly illustrates the tradeoff inherent in all diagnostic tests, where increasing the sensitivity of the test (the ability to correctly identify lesions that are present) results in degradation in the test’s ability to correctly rule out disease. When sensitivity is improved, the

rate of false positives increases, and when specificity is improved, the rate of false negatives (missed lesions) increases.

Studies of radiographic identification methods generally report low sensitivity and moderately high to very high specificity, with the 6 available studies showing a range of values within these general parameters. Studies of the laser fluorescence identification method show somewhat more consistent performance, with high specificity and moderate and more variable sensitivity. The limited information available suggests that the performance of electrical conductance identification resembles that of laser fluorescence, and FOTI identification performs at levels similar to radiographs.

The number of available studies is quite small, and within each method there is enough variation in performance that it is not possible to predict what an “average” clinician might expect to achieve. In the systematic reviews from which these results are summarized, no syntheses of results were attempted due extreme heterogeneity in both criteria for lesion identification and reported performance. At best, these studies can be considered as establishing broad ranges for

expected performance in dentists’ practices. Notably, no studies of the performance of combined methods have been reported where one of the methods is used as an initial detection method, with positive results followed up with a second method. In sum, the available evidence is weak, and it indicates that the diagnostic performances of available methods for detecting early occlusal caries tend to be variable across operators and are generally substantially less than perfect.

## 2. Doing Nothing for Early Occlusal Caries

The “wait and watch” approach to the management of early occlusal caries might be appropriate if there is substantial doubt surrounding the identification of the lesion, or if efficient and effective preventive treatments are unavailable. Any such decision to do nothing should be made with knowledge of the probability of progression of these lesions over time. Unfortunately, only a few studies are available that report on the progression of early caries on occlusal surfaces. Table 2 lists 6 such studies in which the information

**Table 1.** Performance of detection methods for enamel caries on occlusal surfaces

Study, First Author	Method*	No. of Sites	No. of Examiners	Lesion Prevalence, %	Sensitivity	Specificity
<b>Visual Examination</b>						
Wenzel 90 <sup>14</sup>	×10 photos	46	4	17	0.72	0.66
Ashley 98 <sup>13</sup>	direct visual	103	1	25	0.60	0.73
Fyffe 20 <sup>15</sup>	direct visual	421	20	35	0.10	0.98
Costa 02 <sup>16</sup>	direct visual	49	nr	35	0.19	1.00
<b>Radiographic Examination</b>						
Wenzel 90 <sup>14</sup>	D speed	46	4	17	0.44	0.70
Wenzel 90 <sup>14</sup>	Digitized D	46	2	17	0.31	0.72
Ashley 98 <sup>13</sup>	Digora	103	1	25	0.24	0.80
Ashley 98 <sup>13</sup>	E speed	103	1	25	0.19	0.80
Costa 02 <sup>16</sup>	D speed	49	nr	35	0.00	1.00
Costa 02 <sup>16</sup>	Sensor (digital)	49	nr	35	0.14	0.64
<b>Laser Fluorescence</b>						
Lussi 99 <sup>17</sup>	4-10, D2	105	nr	44	0.64	0.87
Shi 00 <sup>18</sup>	6.8-22.1, D1-D2	76	nr	35	0.42	0.95
Tonioli 02 <sup>19</sup>	6-20, D1-D2	143	4	35	0.38	0.82
Costa 02 <sup>16</sup>	6-20, D1-D2	49	nr	35	0.79	0.94
Başeren 03 <sup>20</sup>	>12, D2	31	2	19	0.67	0.80
<b>Electrical Conductance</b>						
Ashley 98 <sup>13</sup>	ECMII	103	1	24	0.65	0.73
Lussi 99 <sup>17</sup>	ECMII	105	nr	44	0.64	0.87
<b>FOTI</b>						
Ashley 98 <sup>13</sup>	—	103	1	25	0.21	0.95

\*For radiographs = type of film; for laser fluorescence = cut points for identification, type of lesion being identified; for electrical conductance = equipment type.  
nr = not reported.

**Table 2.** Progression of untreated enamel caries on occlusal surfaces

Study, First Author	No. of Teeth	Age	Duration	Exposure	Reversal	No Change	Progression
de Liefde 87 <sup>21</sup>	374	5 y	20-32 mo	NaF, 6 mo	nr	64%	36%
Heller 95 <sup>22</sup>	56	1 <sup>st</sup> grade	60 mo	no F	nr	48%	5%
Grindefjord 95 <sup>23</sup>	166	2.5y	12 mo	no F	17%	19%	64%
Autio-Gold 01 <sup>24</sup>	177	3-5 y*	9 mo	no F	36%	35%	27%
Florio 01 <sup>25</sup>	33	6 y	12 mo	NaF rinse	nr	94%	06%
Maltz 03 <sup>26</sup>	56	5-6 y	24 mo	no F	55%	20%	25%

\*Deciduous teeth.  
nr = not reported.

is obtained from the experience of the control groups in comparative trials.<sup>21-26</sup> The subjects in these groups were all young children, and 2 studies included only deciduous molars.<sup>23,24</sup> Observation periods range from 9 to 60 months, and 2 groups received fluoride therapy as a part of the trial. Preventive treatment from other sources was not examined in these studies. The percentage of lesions in permanent teeth that progressed (either to dentin caries or filled status) was loosely associated with the duration of the observation period, with 6% in 1 year, 25% and 35% in 2 to 3 years, and 52% in 5 years. The criteria for both early occlusal caries at baseline and for lesion progression were different across the studies. Thus the strength of evidence describing the progression of early occlusal caries must be considered weak. Although it would be presumptuous to assume that these results suggest a progression rate of approximately 10% per year in permanent teeth, the findings do suggest that the identification of early occlusal caries does not carry with it the implication of immediate, inevitable progression of all such lesions to identifiable dentinal caries, at least in permanent teeth.

### 3. Sealing Early Occlusal Caries

Despite the likelihood that among the many millions of occlusal sealants placed in the past decades some proportion were inadvertently placed over existing early caries lesions, the outcome of such treatment has not been closely examined. Seven studies report the results of intentional sealant placement over noncavitated enamel caries on occlusal surfaces evaluated after 1,<sup>25</sup> 2,<sup>27,28</sup> 3,<sup>29-31</sup> and 5

years.<sup>22</sup> No progression was observed in the 1-year and one of the 2-year studies,<sup>27</sup> which involved 29 and 12 teeth respectively. In another 2-year study,<sup>28</sup> 2% of 232 sealants “failed,” a category that included lost sealant and caries requiring restoration. In the 3-year studies, 8% of 392,<sup>29</sup> 4% of 95,<sup>30</sup> and 2% of 191<sup>31</sup> occlusal surfaces with early lesions had become cavitated after being sealed in field studies using glass ionomer sealant and a “press-finger” technique. In the 5-year study, 11% of 380 occlusal surfaces with early lesions that were sealed with glass ionomer sealants had become frankly carious (41%) or were filled (59%). In the 1-year and the 3-year studies no repairs were performed. Some but not all lost sealants were repaired in one of the 2-year studies<sup>27</sup>, and repairs were performed routinely in the 5-year study. The evidence from these studies must be considered weak due to small numbers of studies, small numbers of teeth within some studies, differences in criteria for enamel caries at baseline and for progression, the accuracy of these identifications, opportunities for bias in the assessments, and evaluation of infrequently used materials and techniques. Within these constraints, the results suggest that sealing enamel caries reduces the likelihood of lesion progression. Collateral evidence from an examination of sealants placed over dentinal caries (see section 7) adds some support for this necessarily tenuous conclusion.

### 4. Fluorides and Antimicrobials for Early Occlusal Caries

The evidence for the effectiveness of fluoride and other antimicrobials in halting the progression and promoting the

**Table 3.** Effectiveness of fluoride for halting progression of enamel caries on occlusal surfaces

Study	No. of Exp Teeth	Age	Duration	Fluoride Treatment	Experimental % progression	Control % progression
de Liefde 87 <sup>21</sup>	497	5 y	20-32 mo	NaF solution	33%	36% <sup>†</sup>
Autio-Gold 01 <sup>24</sup>	153	3-5 y*	9 mo	NaF varnish	17%	27%
Florio 01 <sup>25</sup>	36	6 y	12 mo	NaF varnish	6%	6% <sup>†</sup>
Maltz 03 <sup>26</sup>	64	5-6 y	24 mo	NaF gel	16%	25%

\*Deciduous teeth.  
†Control group received fluoride.

remineralization of early caries on occlusal surfaces is scant. Four studies have been reported, all assessing the effectiveness of fluorides (Table 3).<sup>21,24-26</sup> No studies of other agents were identified. Two of the studies assess fluoride varnish, with one each assessing NaF gel and NaF solution. The durations of the studies ranged from 9 months to 32 months, and all subjects were young children. One study examined lesion progression on primary molars, with the remainder using first permanent molars. All 4 studies had comparison groups, 2 of which were also exposed to fluoride treatment for ethical reasons.<sup>21,25</sup> Each study used different criteria for identifying enamel caries at baseline, and for determining lesion progression. Thus, the strength of the evidence is considered to be weak. The experimental group was favored in 3 of 4 studies, although statistical significance was achieved in only 1 study.<sup>25</sup> The prevented fractions ranged from 0% to 37%, but due to generally low progression proportions in the control groups, the clinical significance of these reductions is somewhat reduced.

### 5. Identification of Suspicious Areas

Occlusal surfaces with suspicious areas or suspected occlusal dentinal caries may also evince signs of enamel caries, but the emphasis is on the suspicion that caries has penetrated into the dentin in these areas, necessitating surgical intervention. The criteria for suspicious areas that have been reported in the extant literature typically include considerations of color, shadow, and “stickiness.” Consideration of suspicious areas is included in this discussion of early occlusal caries not only because outcomes associated with early dentinal caries need to be considered, but also because quite often, when the suspicion is not supported, the actual clinical situation is an enamel lesion. No systematic review of the accuracy of clinicians in detecting suspicious areas has appeared, and a search using the terms “suspicious,” “suspected,” “dubious,” “doubtful,” and “questionable,” crossed with “dental caries” identified only 3 pertinent studies.<sup>32-34</sup> Each used different criteria for what constituted a suspicious area. Two used histological examination to determine caries status,<sup>32,33</sup> and one used excision of the suspicious area.<sup>34</sup> The number of examiners and inter-rater agreement were not indicated in these reports.

The proportions of suspicious areas that actually involved caries extending into the dentin were 41%, 44%, and 51% for the 3 studies. The evidence, while not strong, is homogeneous despite the differences in criteria and in validation method. Presumably, when dentists identify areas as suspicious, they are indicating that they are unable to make a firm decision about the likelihood of dentin involvement. In fact, the available evidence shows that in these areas the likelihood of dentin involvement is approximately the same as the likelihood of no dentin involvement. Thus, within the limitations of the small number of dissimilar studies, when dentists express uncertainty about caries status on occlusal surfaces, they are correctly interpreting the odds of dentin involvement to be about “50/50.”

### 6. Doing Nothing for Suspicious Areas

One of the 3 studies cited above included a 2-year observation period during which one half ( $n = 89$ ) of the original sample of suspicious occlusal surfaces was followed with no intervention except when the suspicious area was deemed to have progressed to a definitive caries lesion with dentin involvement.<sup>34</sup> During this period 16% of the suspicious areas were deemed to have progressed. The volume of the cavity preparations for these lesions was reportedly not different than the volume of the cavity preparation for lesions treated immediately, suggesting that progression of these lesions was minimal.

No other recent studies of the progression of suspected occlusal dentinal lesions have appeared. However, a review of reports from an earlier era (when progression rates may have been higher) identified 4 studies reporting that between 47% and 77% of questionable occlusal fissures progressed to caries in periods ranging from 24 to 41 months.<sup>35</sup> Another study identified “doubtfully carious” areas in first permanent molars at public health clinic examinations in New Zealand, and found that 34% required surgical intervention at subsequent examinations, according to clinic protocols and criteria.<sup>36</sup> Unfortunately, the interval between examinations was not stated.

Thus the strength of the evidence describing progression of suspicious areas in the absence of any intervention is weak. It is characterized by a small number of older studies with relatively high proportions of lesions showing signs of progression in periods of 2 to 4 years, and one recent study identifying a far lower proportion in a similar time period. No conclusions can be reached from this evidence. It is disquieting to note that in the past 20 years, only 1 study has reported outcomes associated with areas deemed suspicious despite dentists’ frequent use of this designation.

### 7. Sealing Suspicious Areas

One study of the outcomes of placing occlusal sealants on suspicious areas has been reported.<sup>37</sup> Among 12 teeth, 2 (17%) were judged to have progressed upon removal of the sealant at the end of 5 years. There are several reports assessing clinical outcomes associated with the placement of sealants over “carious lesions” without overt cavitation. In these studies,<sup>37-43</sup> the criteria for caries was the presence of an occlusal “catch” or “sticky fissures,” and in those studies where baseline radiographs were available, the maximum extent of permissible progression for inclusion was one half of the distance to the pulp.<sup>41-43</sup> Thus, these studies probably examined outcomes of more advanced lesions than those comprising the 50% of suspicious areas that are assumed to be dentinal caries lesions. The results of these studies are summarized in Table 4. In the studies by Handelman et al<sup>42,43</sup> where progression was assessed only through radiographs and reported only as an aggregated assessment, there was either no change or a perceived decrease in the radiolucency when sealants remained intact, and an increase in the radiolucency when sealants were judged to

**Table 4.** Outcomes of sealing over suspicious areas or dentin caries

Study	No. of Surfaces	Age	Lesion Type*	Sealant Type <sup>†</sup>	Diagnostic Method	Progression/Regression		
						Duration	Sound Sealant	Defective Sealant
Handelman 76 <sup>39</sup>	19	n/r	catch	UV	clinical w/ final radiographic	1-2 y	15%/25%	—
Harris 76 <sup>38</sup>	113	6-14	stick	UV	clinical	3 y	0%/nr	66%/nr
Going 78 <sup>37</sup>	12	10-14	SS	UV	clinical	5 y	nr/83%	—
Going 78 <sup>37</sup>	18	10-14	stick	UV	clinical	5 y	nr/89%	—
Gibson 80 <sup>40</sup>	58	7-8	stick	auto	radiograph	2.5 y	19%/nr	—
Handelman 81 <sup>41</sup>	108	6-9	catch	UV	radiographic	1.5-4 y	14%/58%	47%/44%
Handelman 85 <sup>42‡</sup>	167	6-9	catch	UV	radiographic	3 y	decrease <sup>§</sup>	increase <sup>§</sup>
Handelman 86 <sup>43</sup>	113	12-15	catch	auto & UV	radiographic	2 y	decrease <sup>§</sup>	decrease <sup>§</sup>

\*Criteria for lesion identification. SS = suspicious area; stick = sticky fissure; catch = explorer catches on definite lesion; nr = not reported; — = no data available.

<sup>†</sup>Type of polymerization initiation.

<sup>‡</sup>Contains some observations from 1981 study.

<sup>§</sup>Overall summary, results not disaggregated to individual lesion.

be defective. A similar pattern of regression or low rates of progression associated with intact sealants and greater progression associated with defective sealants is also reflected in the remaining studies, where results were reported for individual lesions. The outcome assessments in these studies were subjective and nonquantitative, and criteria for caries at baseline and for progression and regression varied extensively among the studies. Thus the evidence must be considered as weak. Nevertheless, the available studies do reflect a general pattern suggesting that sealing suspicious areas may slow or halt progression for up to 5 years if the sealant remains intact.

**8. Fluorides and Antimicrobials for Suspicious Areas**

No studies of the effectiveness of fluorides or chemical antimicrobial treatments specifically for suspicious occlusal areas have been reported. The only treatment specifically touted to be effective in arresting dentinal caries on these surfaces is ozone therapy.<sup>44</sup> However, a recent systematic review of ozone therapy found “no good evidence” that ozone therapy was effective in arresting or reversing the progression of dental caries (including some cavitated lesions) in pits and fissures.<sup>45</sup>

**9. Operative Treatment for Suspicious Areas.**

The final alternative treatment approach to be considered for suspicious areas is surgical intervention with placement of a restoration. A variety of restorative techniques can be used ranging from traditional composite or amalgam restorations, through more conservative preventive resin restorations, which are now frequently recommended as the most appropriate conservative surgical approach for small occlusal lesions that extend into dentin,<sup>46</sup> to “minimally invasive” methods to enlarge and debride fissures using air abrasion and/or special burs with subsequent placement of sealant or resin-based flowable composite.<sup>47</sup> Clinical studies of the latter

approach have yet to be reported. A systematic review of preventive resin restorations found the evidence for effectiveness (survival) of preventive resin restorations to be strong.<sup>46</sup> The evidence indicated that preventive resin restorations have “generally favorable outcomes” at periods ranging from 2 to 9 years, with failures (caries) ranging from 0% to 24%, but the review authors also noted that all studies reported sealant loss to be a major problem.<sup>48</sup>

**DISCUSSION**

The general clinical issue that led to this assessment was why conservative, noninvasive management strategies for early occlusal caries and suspected dentinal occlusal caries were not being widely and rapidly adopted by US clinicians. It is immediately clear that one possible reason for the slow pace of adoption may be the lack of strong evidence supporting most of these management strategies. In fact, the only strategy shown to be effective by evidence that could be rated as strong is the strategy that features surgical intervention, which is an anathema to many proponents of conservative management.

However, it is not the purpose of this assessment to determine why practitioners have been slow to adopt conservative management strategies. Rather, its first purpose is to examine the strength of the evidence underlying the strategies, and as noted, for the most part, the formal evidence is weak. Its second purpose is to summarize the conclusions that can be drawn from the available evidence about the effectiveness of the strategies, if possible.

When clinicians examine for early occlusal caries, regardless of the method or methods they use, they will miss a substantial proportion of these lesions, and will also misidentify a smaller proportion of sites as being lesions when, in fact, they are not. Unfortunately, the evidence does not allow much more precise estimates of these inaccuracies. Even though there are some indications of general differences in the

relative performance of various methods for detecting lesions (sensitivity) and ruling them out (specificity), the available evidence makes it clear that enough opportunities for variation in the application of any given diagnostic method exist to render even these relative rankings of performance dependent on an individual clinician's behaviors.

The knowledge that the identification of early caries is subject to error heightens the need for accurate information about progression of these lesions, if only because the probability of false-positive identifications suggests that immediate surgical intervention will be inappropriate in some instances. This need is not fully met by the available evidence describing the probability of progression of early occlusal caries. The problem lies more with the strength of the evidence than it does with the lack of homogeneity of the evidence. There are only a few studies, as a group they do not define lesions or the progression of lesions similarly, and individually they have design weaknesses. The results of these studies do reflect a reasonably congruent general picture of progression of early occlusal caries; perhaps no more than 10% to 20% of these lesions will progress to dentinal caries in the course of a year in the absence of any intervention. Thus the majority of these lesions are either not progressing, or progressing only slowly.

The effectiveness of methods to arrest and/or reverse early occlusal lesions obviously bears on the overall success of the nonsurgical intervention strategy. Here again, the quantity of studies examining the effectiveness of sealant, fluorides, and other antimicrobials in preventing progression of enamel caries is disappointingly small, and the study quality is generally low, rendering the evidence weak. Again, however, the evidence tends to be homogeneous, suggesting that sealants are effective in the short term if they remain intact, while fluorides offer small reductions in the proportion of lesions progressing. It is important to note that no sealant studies assessed outcomes longer than 5 years. The longer-term effectiveness of intact sealants in halting the progression of enamel caries is unknown.

The results of the assessments of the strength of the evidence for the detection and management strategies of suspicious areas closely parallel the findings discussed for enamel caries. Again, within the limits of weak evidence, about one half of suspicious areas are actually dentinal caries, for which surgical intervention may be appropriate. The remainder are either enamel caries or sound sites, where nonsurgical interventions would seem indicated. The rate of progression of untreated suspicious areas simply cannot be estimated based on the weak existing evidence, which, with the exception of one recent study showing minimal progression over 2 years, suggests progression by more than one half of lesions over 2 to 4 years, based on a small number of older studies.

The only evidence for effectiveness of any approach to halting progression of suspicious areas involves sealants, and consists of a single study reporting results for 12 occlusal surfaces. Several other studies have examined effectiveness of

sealing noncavitated carious lesions in dentin, and the results are similar to those for sealing enamel caries, although the quality of the studies is lower. If sealants remained intact, progression was reported to be low to nonexistent.

There can be little argument that the evidence supporting conservative, nonsurgical management strategies for early occlusal caries and suspicious areas is weak. While it is less clear that further evidence will hasten clinicians' adoption of these strategies, such studies are needed simply to support the appropriateness of continued promotion of the strategies. The outcomes questions raised by these strategies do not all require clinical trials. Carefully constructed observational studies could contribute needed information about lesion progression under the various management strategies. The recently initiated National Institute for Dental and Craniofacial Research (NIDCR) Practice-Based Research Networks would seem to be an excellent venue within which to organize such studies, notwithstanding the expressed intent of these networks to conduct short-term studies.<sup>49</sup> Initial observation periods of at least 2 years will be necessary, but such durations should be achievable in these networks. Evaluation of longer-term outcomes is also important, and could also be accomplished among practices in the networks, but short-term studies must first be planned to gain support, with extensions envisioned if recruitment, retention, and reliability are all favorable.

Perhaps the most troublesome aspect of any proposed new studies, and certainly an Achilles' heel of most of the existing evidence, is the specification of criteria for "early occlusal caries." The variety of criteria for identification of "early lesions," "incipient lesions," "noncavitated lesions," "catches," and "slight sticks," all terms used to denote a condition that this assessment has assumed to be noncavitated caries lesions confined to enamel, is bewildering. A single standardized set of criteria for identifying and staging enamel caries is an essential prerequisite for progress in this area. Fortunately, such a criteria set, ICDAS, is currently reaching the final stage of development.<sup>50</sup> These criteria appear to be face valid, histologically accurate, and perhaps, most importantly, reasonably reliable following training and calibration. If development is ultimately successful, this set of criteria should be used in all further studies of early caries. Development of standardized criteria for suspicious areas is more problematic, if only because the condition is defined as an equal probability of the presence and absence of disease. Because individuals will vary in their degree of certainty, a reliable index of uncertainty will be difficult to define.

## CLINICAL IMPLICATIONS

If this, then, is the state of the science, what is the prudent clinician to do? It would seem appropriate that clinicians first reflect on the accuracy of identification of early lesions in their day-to-day practices. A critical message contained in the results assessed here is that no matter what method is used, the accuracy of identification of early caries is quite variable,

so attention to maximization of accuracy is a logical first step. Clinicians might reflect on how frequently they open occlusal pits or fissures and observe no sign of demineralization beyond the dentoenamel junction, as well as how frequently they observe demineralization well beyond what was expected based on clinical signs. If either occurrence is frequent, more diligent examinations, or perhaps recalibrations of examination criteria are probably indicated. Clinicians might also assess the extent they use radiographs to identify “hidden” dentinal caries, as well as the use of supplemental identification methods, such as DIAGNOdent, to ensure that they are being used as supplements, rather than replacements for visual methods. Additionally, clinicians might evaluate the appropriateness of using probes in caries examinations. There is no evidence demonstrating greater accuracy of visual-tactile examinations compared to visual examinations, while there is evidence to indicate that if probe is used forcefully, the effect is to collapse what were previously uncavitated demineralized areas at the bases of fissures, thereby creating catches.<sup>51-53</sup> Clinicians might wish to consider carefully whether the undocumented benefits of probing outweigh its potential to cause “progression.” Finally, when patients present with multiple early lesions or suspicious areas for which surgical intervention is planned, the clinician should consider sequencing treatment starting at the site with the highest likelihood for dentinal involvement, with decisions regarding opening of subsequent teeth predicated on the “biopsy” of the preceding tooth.

Attention to an individual clinician’s accuracy of identification of early occlusal caries is important because the clear suggestion from the available evidence is that the usual course for early caries lesions is slow, if any, progression to dentinal caries. Thus, as the certainty that a noncavitated enamel lesion has been detected increases, the need for immediate intervention to avoid rapid progression of more advanced lesions diminishes. For suspicious areas, the message is less clear. Older studies suggest substantial progression, while one recent study gives little indication that immediate operative intervention is necessary. Nevertheless, with respect to the necessity for immediate operative intervention, the key distinction would seem to lie between overt dentinal caries, and both enamel caries and suspicious areas. Of course, the individual clinical situation will invariably be more complex, because individual patients present additional information related to their caries risk status such as past and current caries experience, current dietary, oral, and caries preventive behaviors, and physiological factors that may signal an increased likelihood for departure from the usual course of progression.

A proposition raised in the introduction to this discussion was that conservative nonsurgical management strategies for early caries might be ineffective. From the evidence summarized here, that proposition must be considered invalid. The available evidence suggests that at least one of the strategies, sealants, is effective for enamel caries, and although the evidence is much weaker, for suspicious areas as

well. Thus, clinicians wishing to avoid surgical interventions in an effort to preserve tooth tissue and avoid the onset of the re-restoration cycle,<sup>54</sup> should consider applying sealants to occlusal surfaces with enamel lesions or suspicious areas. This is not a new recommendation, it has been advanced as early as 1984.<sup>55</sup> However, when weighing this intervention, the likelihood that the tooth will be evaluated periodically for the foreseeable future should be considered. The evidence is quite clear that only intact sealants confer maximum preventive effects, so decayed surfaces that are sealed will require periodic inspection and possible repair. Again, this application of “the evidence” must be tempered by consideration of individual circumstances, and perceived risk of progression may suggest either a more conservative or more aggressive alternative treatment selection. Indeed, the individualization of treatment based both on the evidence and a patient’s particular circumstances is the very core of evidence-based practice.<sup>56</sup>

These alternatives to sealing early caries and suspicious areas all present both comparative advantages and disadvantages. The chief advantage of doing nothing, or of using antimicrobial/fluoride remineralization treatments is that the pit or fissure of interest remains accessible for subsequent visual evaluations, whereas sealants interfere with such assessment. Thus, the clinician has to weigh the trade-off of uncertainty following sealant treatment with less-effective performance from the alternatives of waiting or antimicrobial treatment. The chief advantage of operative intervention is the certainty that carious tissue is removed, thus eliminating the possibility of progression. But the tradeoffs here include opening the tooth despite a general consensus on the inappropriateness of operative intervention for enamel caries, and the necessity for maintenance of the restored surface, which may be at elevated risk for secondary caries. Currently, there is no evidence that the long-term outcomes associated with minimally invasive operative procedures are any different than for more traditional restorations, where repair is necessary, and the re-restoration cycle is a concern.

These general observations drawn from the available evidence will not completely satisfy clinicians’ need for answers to questions for individual patients. The problem lies with the strength of the evidence, not the message that it conveys. With so few studies of any strategy, it is difficult to know the extent to which a given approach will be effective in all possible situations. The key question for many clinicians is not whether a given management strategy works in general, but how well it will work for specific individuals. To address that question, many more studies, incorporating subjects with a variety of sociodemographic and risk factors are needed. That is the power of evidence-based analysis, but it needs more evidence than is currently available for early occlusal caries management strategies. Currently, the evidence only suggests that sealants are the most effective noninvasive approach for the treatment of early occlusal lesions and suspicious areas in populations undifferentiated

by caries risk status. Clinicians must apply this evidence in light of specific information that a patient presents.

## REFERENCES

- American Dental Association, Council on Access, Prevention, and Interprofessional Relations. Caries diagnosis and risk assessment: a review of preventive strategies and management. *J Am Dent Assoc* 1995;126(Suppl):1S-24S.
- Diagnosis and Management of Dental Caries Throughout Life. National Institutes of Health. Consensus Development Conference Statement. March 26-28, 2001. *J Dent Educ* 2001;65:1162-8.
- Powell L. Caries risk assessment: relevance to the practitioner. *J Am Dent Assoc* 1998;129:349-53.
- Anusavice K. Present and future approaches for the control of caries. *J Dent Educ* 2005;69:538-54.
- Featherstone J. The caries balance: the basis for caries management by risk assessment. *Oral Health Prev Dent* 2004;2(Suppl 1):259-64.
- Fiset L, Grembowski D. Adoption of innovative caries-control services in dental practice: a survey of Washington state dentists. *J Am Dent Assoc* 1997;128:337-45.
- Eklund S, Pittman J, Heller K. Professionally applied topical fluoride and restorative care in insured children. *J Public Health Dent* 2000;60:33-8.
- Bader J, Shugars D, White B, Rindal D. Evaluation of audit-based performance measures for dental for dental care plans. *J Public Health Dent* 1999;59:150-7.
- Murdoch-Kinch C, McLean M. Minimally invasive dentistry. *J Am Dent Assoc* 2003;134:87-95.
- Brostek A. Early diagnosis and minimally invasive treatment of occlusal caries—a clinical approach. *Oral Health Prev Dent* 2004;2(Suppl 1):313-9.
- Bader J, Shugars D, Bonito A. A systematic review of the performance of methods for identifying carious lesions. *J Public Health Dent* 2002;62:2001-13.
- Bader J, Shugars D. A systematic review of the performance of a laser fluorescence device for detecting caries. *J Am Dent Assoc* 2004;135:1413-26.
- Ashley P, Blinkhorn A, Davies R. Occlusal caries diagnosis: an in vitro histological validation of the Electronic Caries Monitor (ECM) and other methods. *J Dent* 1998;26:83-8.
- Wenzel A, Fejerskov O, Kidd E, Joyston-Bechal S, Groeneveld A. Depth of occlusal caries assessed clinically, by conventional film radiographs, and by digitized, processed radiographs. *Caries Res* 1990;24:327-33.
- Fyffe H, Deery C, Nugent Z, Nuttall N, Pitts N. In vitro validity of the Dundee selectable threshold method for caries diagnosis (DSTM). *Community Dent Oral Epidemiol* 2000;28:52-8.
- Costa A, Yamaguti P, De Paula L, Bezerra A. In vitro study of laser diode 655 nm diagnosis of occlusal caries. *ASDC J Dent Child* 2002;69:249-53.
- Lussi A, Imwinkelried S, Pitts N, Longbottom C, Reich E. Performance and reproducibility of a laser fluorescence system for detection of occlusal caries in vitro. *Caries Res* 1999;33:261-6.
- Shi X, Welander U, Angmar-Månsson B. Occlusal caries detection with KaVo DIAGNOdent and radiography: an in vitro comparison. *Caries Res* 2000;34:151-8.
- Tonioli M, Bouschlicher M, Hillis S. Laser fluorescence detection of occlusal caries. *Am J Dent* 2002;15(4):268-73.
- Başeren N, Gokalp S. Validity of a laser fluorescence system (DIAGNOdent) for detection of occlusal caries in third molars: an in vitro study. *J Oral Rehabil* 2003;30:1190-4.
- de Liefde B. A study of the chemical treatment of early caries of occlusal pits and fissures. *N Z Dent J* 1987;83(371):10-2.
- Heller K, Reed S, Bruner F, Eklund S, Burt B. Longitudinal evaluation of sealing molars with and without incipient dental caries in a public program. *J Public Health Dent* 1995;55:148-53.
- Grindefjord M, Dahllof G, Modeer T. Caries development in children from 2.5 to 3.5 years of age: a longitudinal study. *Caries Res* 1995;29(6):449-54.
- Autio-Gold J, Courts F. Assessing the effect of fluoride varnish on early enamel carious lesions in the primary dentition. *J Am Dent Assoc* 2001;132:1247-53.
- Florio F, Pereira A, Meneghim M, Ramacciato J. Evaluation of non-invasive treatment applied to occlusal surfaces. *J Dent Child* 2001;68:326-31.
- Maltz M, Barbachan e Silva B, Carvalho D, Volkweis A. Results after two years of non-operative treatment of occlusal surfaces in children with high caries prevalence. *Braz Dent J* 2003;14:48-54.
- Gray G. An evaluation of sealant restorations after 2 years. *Br Dent J* 1999;186:569-75.
- Cooney P, Hardwick F. A fissure sealant pilot project in a third party insurance program in Manitoba. *J Canad Dent Assoc* 1994;60:140-5.
- Frencken J, Makoni F, Sithole W, Hackenitz E. Three-year survival of one-year ART restorations and glass ionomer sealants in a school oral health programme in Zimbabwe. *Caries Res* 1998;32:119-26.
- Frencken J, Makoni F, Sithole W. ART restorations and glass ionomer sealants in Zimbabwe: survival after 3 years. *Community Dent Oral Epidemiol* 1998;26:372-81.
- Holmgren C, Lo E, Hu D, Wan H. ART restorations and sealants placed in Chinese school-children—results after three years. *Community Dent Oral Epidemiol* 2000;28:314-20.
- Ketley C, Holt R. Visual and radiographic diagnosis of occlusal caries in first permanent molars and in second primary molars. *Br Dent J* 1993;174:364-70.
- Ouellet A, Hondrum S, Pietz D. Detection of occlusal carious lesions. *Gen Dent* 2002;50:346-50.
- Hamilton J, Dennison J, Stoffers K, Gregory W, Welch K. Early treatment of incipient carious lesions: a two-year clinical evaluation. *J Am Dent Assoc* 2002;133:1643-51.
- Meiers J, Jensen M. Management of the questionable carious fissure: invasive vs noninvasive techniques. *J Am Dent Assoc* 1984;108:64-8.
- Dooland M. The fate of first permanent molars recorded as “doubtfully carious” at a school dental clinic. *Aust Dent J* 1982;27:117-8.
- Going R, Loesche W, Grainger D, Syed S. The viability of microorganisms in carious lesions five years after covering with a fissure sealant. *J Am Dent Assoc* 1978;97:455-60.
- Harris N, Moolenaar L, Hornberger N, Knight G, Frew R. Adhesive sealant trial: effectiveness in a school population of the U.S. Virgin Islands. *J Prev Dent* 1976;3:27-37.
- Handelman S, Washburn F, Wopperer P. Two-year report of sealant effect on bacteria in dental caries. *J Am Dent Assoc* 1976;93:967-70.
- Gibson G, Richardson A. Sticky fissure management. *J Can Dent Assoc* 1980;46:255-8.
- Handelman S, Leverett D, Solomon E, Brenner C. Use of adhesive sealants over occlusal carious lesions: radiographic evaluation. *Community Dent Oral Epidemiol* 1981;9:256-9.
- Handelman S, Leverett D, Iker H. Longitudinal radiographic evaluation of the progress of caries under sealants. *J Pedod* 1985;9:119-26.
- Handelman S, Leverett D, Espeland M, Curzon J. Clinical radiographic evaluation of sealed carious and sound tooth surfaces. *J Am Dent Assoc* 1986;113:751-4.
- Baysan A, Lynch E. The use of ozone in dentistry and medicine. *Prim Dent Care* 2005;12:47-52.
- Rickard G, Richardson R, Johnson T, McColl D, Hooper L. Ozone therapy for the treatment of dental caries. *The Cochrane Database of Systematic Reviews* 2004;3:CD004153.
- Murdoch-Kinch C, McLean M. Minimally invasive dentistry. *J Am Dent Assoc* 2003;134:87-95.
- Hudson P. Conservative treatment of the class I lesion. A new paradigm for dentistry. *J Am Dent Assoc* 2004;135:760-4.
- McComb D. Systematic review of conservative operative caries management strategies. *J Dent Educ* 2001;65:1154-61.

49. National Institute for Dental and Craniofacial Research. Available at: <http://www.nidcr.nih.gov/NewsAndReports/NewsReleases/NewsRelease03312005.htm>. Accessed July 1, 2005.
50. Pitts N. "ICDAS"—an international system for caries detection and assessment being developed to facilitate caries epidemiology, research and appropriate clinical management. *Community Dent Health* 2004; 21:193-8.
51. Eckstrand K, Qvist V, Thylstrup A. Light microscope study of the effect of probing in occlusal surfaces. *Caries Res* 1987;21:368-74.
52. van Dorp C, Exterkate A, ten Cate J. The effect of dental probing on subsequent enamel demineralization. *J Dent Child* 1988;55:343-7.
53. Yassin O. In vitro studies of the effect of a dental explorer on the formation of an artificial carious lesion. *J Dent Child* 1995;62: 111-7.
54. Brantley F, Bader J, Shugars D, Nesbit S. Does the cycle of rerestitution lead to larger restorations? *J Am Dent Assoc* 1995;126:1407-13.
55. Meiers J, Jensen M. Management of the questionable carious fissure: invasive vs noninvasive techniques. *J Am Dent Assoc* 1984; 108:64-8.
56. Sackett D, Rosenberg W, Gray J, Haynes R, Richardson W. Evidence-based medicine: what it is and what it isn't. *BMJ* 1996;312: 71-2.