Caries-Detector Dyes — How Accurate and Useful Are They?

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Abstract

Commercially available caries-detector dyes are purported to aid the dentist in differentiation of infected dentin, yet research has established that these dyes are not specific for infected dentin. They are non-specific protein dyes that stain the organic matrix of less mineralized dentin, including normal circumpulpal dentin and sound dentin in the area of the amelo-dentinal junction. A considerable body of evidence indicates that conventional tactile and optical criteria provide satisfactory assessment of caries status during cavity preparation. There is reason for concern that subsequent use of a caries-detector dye would result in unnecessary removal of sound tooth structure. The use of caries-detector dyes has also been suggested as a diagnostic aid for occlusal caries. Although diagnosis of carious dentin beneath apparently sound enamel can be challenging, there is a lack of substantive evidence supporting the use of dyes for this purpose and false positives are a significant concern. Careful visual inspection combined with bitewing radiographic diagnosis has been shown to be the most reliable diagnostic method for the presence of infected dentin requiring operative treatment.

MeSH Key Words: *dental caries/diagnosis; dyes/diagnostic use*

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The prime treatment objective for carious teeth requiring operative intervention is complete removal of infected dentin followed by placement of a well-sealed, long-lasting restoration. Fundamental considerations in the process are the maintenance of pulp vitality and minimal destruction of sound tissue. Current biological principles of caries management stress concomitant disease control and operative conservatism. This emphasis recognizes that dentists currently spend more time retreating restored teeth (about 60% of adult treatments) than treating primary decay[1] and that the cycle of re-restoration significantly weakens teeth and involves additional pulpal insult.[2,3] Indeed, whether to provide operative treatment has become a significant judgement decision

Current Management of Dental Caries

Given a compliant patient, today's knowledgeable dentist has the ability to provide disease management and conservative operative techniques that can maintain the post-fluoride dentition for a lifetime. Modern management of caries stresses non-invasive techniques wherever possible and maximum protection of sound tooth structure. Conservative techniques are necessary from the initial treatment decision through to management of significant disease.

An important example is the recognition that proximal caries, evident on radiographs in enamel only, is invariably non-cavitated and is responsive to active prevention techniques. Only when there is definite evidence of dentinal involvement is operative treatment indicated.[3] At the other end of the spectrum, recognition of the evidence that dentinal demineralization, at the advancing front of dentinal caries, precedes bacterial invasion[4] has allowed conservative treatment of the deep carious lesion in appropriate clinical situations. Careful tactile and spatial judgment to differentiate between heavily infected outer carious dentin, which must be removed, and uninfected, demineralized, inner affected dentin, which may be left, reduces the risk of direct pulpal exposure, allows continuing pulp vitality and maximizes the known reparative potential of the dental pulp in the absence of significant bacterial contamination.

Caries-Detecting Dyes

In 1972, a technique using a basic fuchsin red stain was suggested (and subsequently developed) to aid in the differentiation of the two layers of carious dentin.[5,6] Because of potential carcinogenicity, the basic fuchsin stain was subsequently replaced by another dye, acid red solution.[7] Since then, various

protein dyes have been marketed as caries-detection agents. Intended to enhance complete removal of infected carious dentin without over-reduction of sound dentin, the dye was purported to stain only infected tissue and was advocated for a "painless" caries removal technique without local anesthetic. The technique was laborious, as it was guided by staining, involved multiple dye application-and-removal repetitions and required the use of a slow-speed bur.

Tactile and visual criteria are normally used to render a cavity caries-free, and the idea of a diagnostic aid that would differentiate infected dentin was considered desirable. Subsequent clinical trials were done in the United States[8] and United Kingdom[9] involving the use of the dye in cavities prepared by dental students and judged to be caries-free by their clinic instructors; the trials revealed dye-stained dentin in 57% to 59% of cavities at the enamel–dentin junction. This finding implied that the clinical judgment of the teachers was often flawed and that the prevalence of residual decay was high. The conclusion was made despite the fact that the laboratory component of the U.K. study did not correlate dye-stained material with infection but rather with lower levels of mineralization, with or without infection.[9] Interestingly, all authors showed particular concern for the amelo-dentinal junction. It is of note that dye stain on more than 50% of the cavity pulpal floors judged by instructors to be complete was considered an inappropriate indication for further dentin removal by the researchers, as it would result in unnecessary pulpal exposures.

Accuracy of Caries-Detector Dyes

A diagnostic aid should show a very low level of false positives to avoid unnecessary treatment. Yet in one study, when the level of infection of dye-stained and unstained dentin at the amelo-dentinal junction was measured at the completion of cavity preparation, it was discovered that not all dye-stainable dentin was infected.[10] Fifty-two per cent of the completed cavities showed stain in some part of the enamel–dentin junction, but subsequent microbiological analysis of dye-stained and non-stained sites resulted in the recovery of very light levels of infection, with no differences between sites. Such bacterial levels were considered clinically insignificant. On the other hand, it has also been demonstrated that absence of stain does not ensure elimination of bacteria.[11, 12]

It is now clearly established that these dyes do not stain bacteria but instead stain the organic matrix of less mineralized dentin.[13] The lack of specificity of caries-detector dyes was confirmed in 1994 by Yip and others,[14] who correlated the location of dye-stainable dentin with mineral density. The dyes neither stained bacteria nor delineated the bacterial front but did stain collagen associated with less mineralized organic matrix. Of even greater significance was the fact that when these authors utilized the dyes on caries-free, freshly extracted human primary and permanent teeth, they discovered that sound circumpulpal dentin and sound dentin at the amelo-dentinal junction took up the stain because of the higher proportion of organic matrix normally present in these sites. Clearly, the routine use of these dyes without an understanding of their distinct limitations will result in excessive removal of totally sound tooth structure and increased likelihood of mechanical pulp exposures.

Dye staining and bacterial penetration are independent phenomena,[15] which significantly limits the usefulness of these dyes for diagnostic purposes. Quantification of the intensity of staining may give a measure of severely diseased tissue, and the contrast afforded by dyes may help identify carious dentin if tactile discrimination is unavailable. However, most clinical investigations have concluded that conventional tactile and optical criteria are the most satisfactory assessment of caries status during cavity preparation and that subsequent use of a caries-detector dye could result in unnecessary removal of sound tooth tissue. Dye-stainable status is not a good predictor for the presence or absence of bacteria in dentin and lacks the necessary specificity for the accurate detection of carious dentin.[13]

Pit and Fissure Occlusal Caries

Fissure caries continues to be a significant clinical problem, despite overall reductions in the prevalence of smooth-surface caries since the advent of fluoride. The point at which operative intervention is required depends on the presence of significant dentinal infection, and this diagnosis can be difficult in the absence of cavitation.[16] Visual occlusal cavitation has been shown to be synonymous with dentinal involvement,[17] but it is generally accepted that diagnosis of dentinal decay beneath discoloured and slightly defective fissures, or even under apparently sound occlusal fissures, can be challenging.[18]

Diagnostic methods include probing (which may actually cause infection or traumatic micro-cavitation), optical criteria, bitewing radiography and electronic caries detectors. Early detection of occlusal lesions is advantageous primarily because it enables the benefits of therapeutic prevention with sealants. As early as 1984, a National Institutes of Health Consensus Development Conference[19] concluded not only that the placement of sealants is a highly effective means of preventing pit and fissure caries but that "the evidence is overwhelming that the vitality of the dental pulp is not endangered by incidental placing of sealants over small pit and fissure lesions. In fact, minor carious lesions covered by sealants seem to become inactive and the process of tooth decay is apparently arrested by the sealant. Investigators have reported negative or reduced bacterial cultures following several years of sealing. No studies have identified significant caries progression beneath an intact sealant."

Thus, there is substantial evidence to support the contention that a small amount of diagnosed or undiagnosed dentinal caries at the base of fissures would be arrested by the application of resin sealant. Amongst other investigators, Handelman and others[20] sealed frank carious occlusal cavities following microbiological sampling of dentin. After two years, the decrease in viable micro-organisms in the sealed teeth was 99.9%. Clinical and radiological findings indicated that the lesions were arrested. Similarly, Going and others[21] covered dentinal carious lesions with a sealant for a five-year period. Re-entry revealed that sealant treatment alone had resulted in

89% caries reversal. More recent clinical studies have also confirmed the arrested progress of sealed carious dentin, demonstrating that concern about the possible progression of minor carious lesions beneath fissure sealants, undetectable on radiographs, is unfounded.[22, 23]

Use of Caries-Detector Dyes for Occlusal Caries

The value of using dyes for carious enamel detection has proven even more dubious than for dentin.[24] Many, such as procion dyes, produce irreversible staining, which would be clinically unacceptable. The intensity of fluorescent dyes has been found to correlate with mineral loss but, as with the dentinal caries-detector dyes, they are specific only for demineralization.

Dentin demineralization beneath non-cavitated enamel can be reliably predicted by an electronic caries detector. However, studies have shown that subsequent dentin samples indicate no or only a very low level of bacterial infection.[16] Neither vision nor electronic readings reliably predicted heavily infected dentin in such cases. Bitewing radiographic analysis was found to be the most reliable diagnostic method. Bacterial counts obtained from radiologically sound fissures were low, and when lesions were radiographically visible in dentin, a significant increase in dentin infection was found. This points to the use of fissure sealing as the appropriate management of affected susceptible fissures that appear sound radiographically.

Given the overwhelming evidence for efficacy and lack of clinical problems with a philosophy of erring on the side of conservatism, the trend to rationalization of invasive treatment for the "diagnosis" of occlusal carious lesions is disturbing.[25] There is a lack of substantive scientific literature supporting the use of dyes on defective or sound occlusal fissures to diagnose infected carious enamel or dentin. The use of surgical intervention subsequent to dye application, usually with air-abrasion techniques, as a method of confirming diagnosis is especially disturbing when based on the use of non-specific protein dyes to identify caries. The fact that such dyes stain normal dentin at the amelo-dentinal junction totally negates this concept. It is a great pity that the reputation of the air-abrasion technique for conservative operative dentistry is being sullied by non-scientific methods of caries diagnosis. Valid, accurate methods of diagnosis would be welcomed by dentists, but caries-detecting dyes fail to provide substantive usefulness. These non-specific dyes will stain food debris, enamel pellicle and any other organic matter trapped in substantial amounts in occlusal fissures and possibly will also stain demineralized enamel. False positives are a significant concern. Balanced against the largely insignificant consequences of false negatives in the diagnosis of incipient occlusal dentinal caries, which can be successfully sealed, the use of an unsubstantiated diagnostic procedure is clearly inappropriate. "Caries in industrialized countries is a disease of slow progression and it is unlikely that a missed borderline dentinal lesion will pose an early threat to the viability of the tooth. Yet the consequences of a false positive decision in clinical terms is the unnecessary filling of a sound tooth and initiation of a cycle of repetitive repair."[26]

Ideal caries diagnostic methods reduce the risk of unnecessary operative intervention. Currently, a combination of careful visual inspection and radiographic diagnosis would appear to best fulfill the diagnostic requirements for occlusal caries.[27] Together, such criteria produced an 82% and 91% correct diagnosis in permanent and primary molars respectively in a sample of teeth with questionable or minimal caries without visible evidence of cavitation. This level of diagnostic accuracy is of the same order as that found in an in vitro study for a new laser fluorescence system developed for detection of occlusal caries without the use of radiographs.[28] As stated by the authors, the potential utility of such methods of early accurate diagnosis "is to facilitate prevention-based management of dental caries, not merely as a device to aid in the location of dentinal lesions requiring fillings." It is imperative that the field of dentistry not negate the significant advances made in disease prevention and move backward.

Conclusions

Any diagnostic procedure for the diagnosis of carious tooth structure must be specific, valid, reliable and clinically proven. Caries-detector dyes should therefore stain only in a manner that permits proper discrimination between healthy and diseased tooth structures. As none of the available caries-detection dyes is caries specific, their routine use may lead to a profound degree of over-treatment. Unnecessarily invasive treatment weakens the tooth and is more likely to threaten the health of the dental pulp. A considerable body of evidence shows that careful and thorough use of tactile and visual criteria provides an acceptable assessment of the caries status of dentin during cavity preparation.

Similarly, unnecessary initiation of operative intervention condemns the tooth to a lifetime of restorative care through the re-restoration cycle, with concomitant economic costs and a greater likelihood of premature tooth loss. A combination of visual examination and optimal bitewing radiographs provides the most reliable diagnostic technique for predicting the need for operative treatment of infected dentin under defective or pronounced occlusal fissures. Enamel fissure defects without evidence of cavitation or dentinal involvement are best treated by fissure sealants. There is a considerable body of evidence showing that the inadvertent sealing of early dentinal caries by a fissure sealant is of little consequence, as it will become arrested and not progress. There is a lack of substantive scientific evidence supporting the use of caries-detecting dyes on apparently sound occlusal fissures to diagnose underlying dentinal caries.

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