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

(Les colorants détecteurs de caries — Quelle est leur précision et leur utilité?)

• **Dorothy McComb**, BDS, M.Sc.D., FRCD(C) •

S o m m a i r e

On prétend que les colorants détecteurs de caries que l'on trouve dans le commerce aident le dentiste à déceler les caries dentinaires. Pourtant, des recherches ont établi que ces colorants ne sont pas spécifiques à l'identification de la carie dentinaire. Il s'agit plutôt de colorants protéiques non spécifiques qui colorent la matrice organique de la dentine moins minéralisée, y compris la dentine circumpulpaire normale et la dentine saine de la zone de jonction amélo-dentinaire. Une accumulation considérable de preuves indique que les critères tactiles et optiques classiques permettent une évaluation satisfaisante de l'état de la carie au cours de la préparation des cavités. Il y a donc lieu de craindre que l'utilisation subséquente d'un colorant détecteur de carie n'entraîne l'ablation inutile de structure dentaire saine. L'utilisation de ce type de colorant a également été proposée comme aide diagnostique dans le cas de la carie occlusale. Or, bien qu'il soit difficile de poser un diagnostic de carie dentinaire sous un émail d'aspect sain, on manque d'éléments probants pour appuyer l'utilisation de colorants à cette fin et s'inquiète particulièrement des résultats faux positifs. On a démontré qu'un examen visuel attentif doublé d'un diagnostic établi par radiographie interproximale constitue la méthode diagnostique la plus fiable en présence de dentine cariée nécessitant un traitement opératoire.

Mots clés MeSH : *dental caries/diagnosis; dyes/diagnostic use*

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 microorganisms 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.

Le **D**r **McComb** est directrice de la discipline de dentisterie restauratrice à la Faculté de médecine dentaire de l'Université de Toronto.

Écrire au : Dr Dorothy McComb, Dentisterie restauratrice, Faculté de médecine dentaire, Université de Toronto, 124, rue Edward, Toronto, ON M5G 1G6. Courriel : d.mccomb@utoronto.ca.

Références

1. Mjör IA. Amalgam and composite resin restorations: longevity and reasons for replacement. In: Anusavice KJ, editor. *Quality evaluation of dental restorations — criteria for placement and replacement.* Chicago: Quintessence Publishing Co., 1989. p. 61-8.

2. Brantley CF, Bader JD, Shugars DA, Nesbit SP. Does the cycle of restoration lead to larger restorations? *JADA* 1995; 126:1407-13.

3. Anusavice KJ. Criteria for placement and replacement of dental restorations: an international consensus report. Int Dent J 1988; 38:193-4.

4. Fusayama T, Okuse K, Hosoda H. Relationship between hardness, discoloration, and microbial invasion in carious dentin. *J Dent Res* 1966; 45:1033-46.

5. Fusayama T. Two layers of carious dentin: diagnosis and treatment. *Oper Dent* 1979; 4:63-70.

6. Kuboki Y, Liu CF, Fusayama T. Mechanism of differential staining in carious dentin. *J Dent Res* 1983; 62:713-4.

7. Fusayama T. Clinical guide for removing caries using a caries-detecting solution. *Quint Int* 1988; 19:397-401.

8. Anderson MH, Charbeneau GT. A comparison of digital and optical criteria for detecting carious dentin. *J Prosthet Dent* 1985; 53:643-6.

9. Kidd EA, Joyston-Bechal S, Smith MM, Allan R, Howe L, Smith SR. The use of a caries detector dye in cavity preparation. *Br Dent J* 1989; 167:132-4.

10. Kidd EA, Joyston-Bechal S, Beighton D. The use of a caries detector dye during cavity preparation: a microbiological assessment. *Br Dent J* 1993; 174:245-8.

11. Anderson MH, Loesche WJ, Charbeneau GT. Bacteriologic study of a basic fuschin caries disclosing dye. *J Prosthet Dent* 1985; 54:51-5.

12. Zacharia MA, Munshi AK. Microbiological assessment of dentin stained with a caries detector dye. *J Clin Pediatr Dent* 1995; 19:111-5.

13. Boston DW, Graver HT. Histologicial study of an acid red caries-disclosing dye. *Oper Dent* 1989; 14:186-92.

14. Yip HK, Stevenson AG, Beeley JA. The specificity of caries detector dyes in cavity preparation. *Br Dent J* 1994; 176:417-21.

15. Boston DW, Graver HT. Histobacteriological analysis of acid red dye-stainable dentin found beneath intact amalgam restorations. *Oper Dent* 1994; 19:65-9.

16. Ricketts DN, Kidd EA, Beighton D. Operative and microbiological validation of visual, radiographic and electronic diagnosis of occlusal caries in non-cavitated teeth judged to be in need of operative care. *Br Dent J* 1995; 179:214-20.

17. van Amerongen JP, Penning C, Kidd EA, ten Cate JM. An in vitro assessment of the extent of caries under small occlusal cavities. *Caries Res* 1992; 26:89-93.

18. Weerheijm KL, van Amerongen WE, Eggink CO. The clinical diagnosis of occlusal caries: a problem. *ASCD J Dent Child* 1989; 56:196-200.

19. National Institutes of Health Consensus Development Conference Statement. Dental sealants in the prevention of tooth decay. *J Dent Educ* 1984; 48(Suppl. 2):126-31.

20. Handelman SL, Washburn F, Wopperer P. Two-year report of sealant effect on bacteria in dental caries. *JADA* 1976; 93:967-70.

21. Going RE, Loesche WJ, Grainger DA, Syed SA. The viability of microorganisms in carious lesions five years after covering with a fissure sealant. *JADA* 1978; 97:455-62.

22. Jensen ØE, Handelman, SL. Effect of an autopolymerizing sealant on viability of microflora in occlusal dental caries. *Scand J Dent Res* 1980; 88:382-8.

23. Mertz-Fairhurst EJ, Curtis JW Jr, Ergle JW, Rueggeberg, FA, Adair, SM. Ultraconservative and cariostatic sealed restorations: results at year 10. *JADA* 1998; 129:55-66.

24. van de Rijke JW. Use of dyes in cariology. *Int Dent J* 1991; 41:111-6.

25. Ross G. Air abrasion and caries detection dyes. The new standard of care. *Ont Dent* 1998; 75:43-5.

26. Downer, MC. Validation of methods used in dental caries diagnosis. *Int Dent J* 1989; 39:241-6.

27. Ketley CE, Holt RD. Visual and radiographic diagnosis of occlusal caries in first permanent molars and in second primary molars. *Br Dent J* 1993; 174:364-70.

28. Lussi A, Imwinkelried S, Pitts NB, 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.

LE CENTRE DE DOCUMENTATION DE L'ADC

Le Centre de documentation de l'ADC a en sa possession des renseignements généraux et des articles sur le diagnostic des caries dentaires. Le personnel peut également effectuer des recherches documentaires. Pour plus d'information sur les frais et services du Centre de documentation, communiquez avec nous par téléphone au **1-800-267-6354**, poste 2223 ou au **(613) 523-1770**, poste 2223, par télécopieur au **(613) 523-6574** ou par courriel à **info@cda-adc.ca**.