A comparison of digital and optical criteria for detecting carious dentin

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During the preparation of a carious tooth for restoration, the attempt is made to excavate all disease-affected tissue. Excavation is necessary to prevent continuation of the carious process and to provide a sound structural base for the restoration. Assurance that all cariously affected dentin has been removed from the cavity preparation has conventionally been obtained by the use of a mouth mirror and explorer.[1] This is a subjective assessment and has been shown to have shortcomings.[2-6] A number of investigators have developed alternative procedures for the detection of cariously altered dentin, one of which is the use of dyes that enhance visual recognition of carious dentin.[7-11] Although they have been developed and tested in vitro and in vivo, no large scale clinical trial for the efficacy of these dye materials has been published. This study compares the customarily used optical and digital criteria with a dye-enhanced optical detection method to determine whether cariously affected dentin remains within a prepared cavity.

MATERIAL AND METHODS

A demineralized dentin-staining dye was prepared by the method of Fusayama and Terachima.[12] Basic fuchsin (0.5 gm) was mixed with 100 gm of reagent-grade propylene glycol and mechanically stirred until the basic fuchsin crystals had dissolved.

The prepared dye was applied to 100 cavities prepared by third- and fourth-year dental students after complete caries removal had been corroborated by a faculty member. Forty-two preparations were scheduled for gold restorations and 58 for amalgam. Only permanent posterior teeth isolated under rubber dam were used. Dye was applied to cover the entire prepared tooth surface. The dye material was allowed 10 seconds contact time in the cavity preparation, after which the excess was flushed into the evacuation system with an air-water syringe. The preparation was dried and examined for demineralized dentin as delineated by the fuchsin dye. A color photographic record of all preparations was made at a 1:1 magnification. If fuchsin-stained regions were present, the photograph was oriented to show the areas to the greatest possible advantage. Each cavity preparation was considered separately. The following additional data were recorded for each tooth: (1) tooth number (1 to 32); (2) preparation type (MOD, DO, buccal pit); (3) the intended final restorative material, either amalgam or gold (gold foil preparations were scored as gold restorations although the preparation closely simulates that of amalgam); (4) the location within the preparation of fuchsin-stained dentin (to differentiate the dentinoenamel junction [DEJ] from other stained areas); (5) patient identification number; and (6) the depth of the preparation (A, B, C, D) according to Charbeneau et al.[1]

The test teeth were restored as planned, in a manner consistent with currently accepted procedures at The University of Michigan, School of Dentistry.

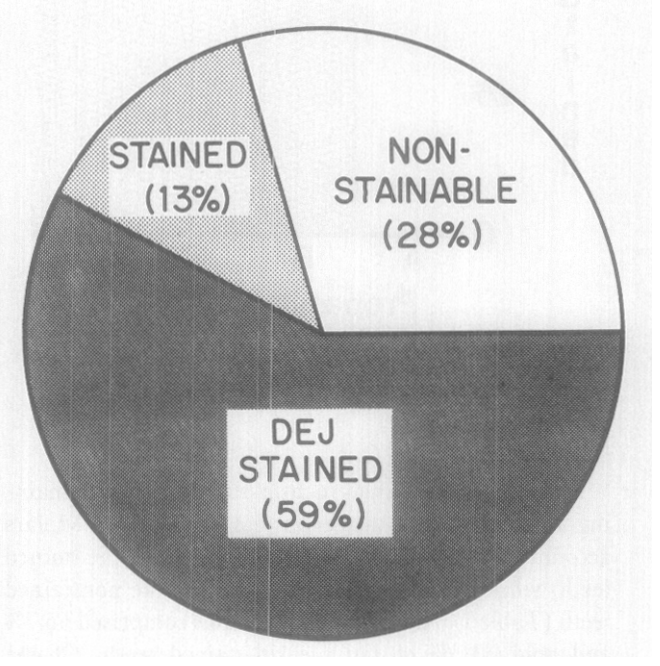

Fig. 1. Fuchsin staining by location as percent of total sample (100 teeth).

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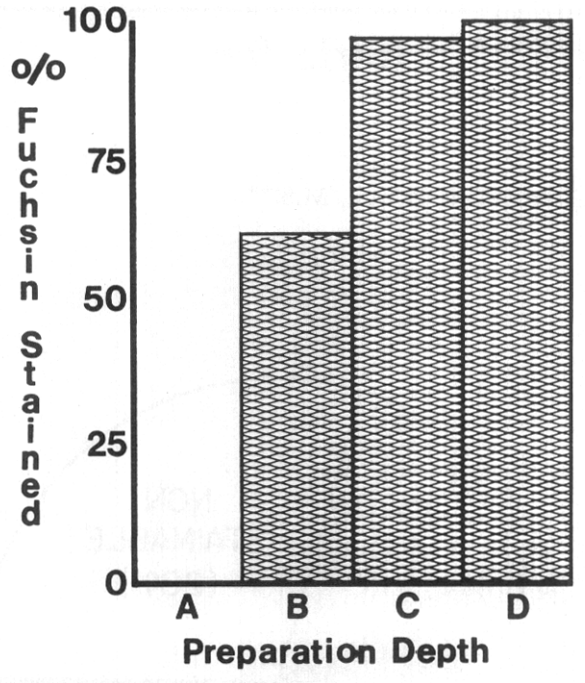

Fig. 2. Fuchsin staining in relation to cavity depth.

Table I. Fuchsin staining, molars vs. premolars*

	Molars	Premolars	Total
Stained	58	14	72
Nonstained	14	14	28
Total	72	28	100

*Fisher's exact test, $p = .003$; chi square = 7.882, $p = .005$.

Table II. Fuchsin staining, amalgam vs. gold*

	Amalgam	Gold	Total
Stained	48	24	72
Nonstained	10	18	28
Total	58	42	100

*Fisher's exact test, $p = .0049$; chi square = 6.709, $p = .0096$.

Table III. Staining vs. cavity depth*

	A	B	C	D	Total
Stained	0	36	32	4	72
Nonstained	5	22	1	0	28
Total	5	58	33	4	100

*$p < .0001$.

RESULTS

Seventy-two teeth had fuchsin-stained dentin remaining at completion of the caries removal (Fig. 1). Molars accounted for 80.6% and premolars 19.4% of the stained teeth, while premolars provided 50% of the nonstained teeth (Table I). Amalgam preparations comprised 66.7% and gold 33.3% of the fuchsin-stained teeth. Of the amalgam preparations, 82.2% were stained, while 57.1% of the gold preparations were stained (Table II). No statistical relationship could be demonstrated between the type and the depth of the preparation. Of the 100 teeth examined, five were of A depth, 58 of B depth, 33 of C depth, and four of D depth. Fuchsin staining was directly related to the depth of the cavity preparation. The deeper the preparation, the greater the probability that fuchsin-stained dentin remained (Table III, Fig. 2). Fifty-nine (82%) teeth had staining at the DEJ. The DEJ stain location was distributed as follows: proximal wall, 29; under cusp or triangular ridges, 36; gingival wall, 36. Many teeth exhibited staining of the DEJ in more than one location.

DISCUSSION

The determination of exactly what constitutes carious dentin is important to the practice of dentistry. Color alone is an unreliable guide in determining the presence of carious dentin.[1] In this study, the DEJ was cleared of all discoloration attributable to the carious process and was judged by tactile discrimination with an explorer to be sound; yet 59% of the teeth showed fuchsin staining at the DEJ.

Texture has been asserted to be the most reliable criterion in determining whether dentin is carious or sound.[1] Dentists evaluate texture as the hardness. Craig et al.[13] found that primary dentin averaged 68 Knoop hardness number (KHN), reparative or transparent dentin was recorded as high as 80 to 85 KHN, while carious dentin had values as low as 19 KHN. Terashima et al.[5] found that "experienced dentists" excavated carious dentin with spoon excavators to an average cavity floor hardness of 22.8 KHN, while those who used a large round bur in a slow-speed handpiece excavated to an average hardness of 28.4 KHN. The values in these two studies represent a difference of some 40 KHN between the dentist's clinical evaluation of sound dentin (22.8 to 28.4 KHN) and the laboratory finding that primary dentin has a hardness of 68 KHN. The results of these studies suggest either a large disparity between the "texture" of dentin and its measured hardness or a great inaccuracy in the dentist's ability to discriminate hardness clinically.

It appears that there is no clinically reliable guide on which a dentist may base a decision regarding complete caries removal. Both color and hardnesss-texture have inadequacies as consistent guides for caries removal. The present study may reflect these inadequacies in the finding that in 72% of the prepared teeth, fuchsin-stained dentin was present at the completion of caries removal. These findings may have significant clinical ramifications.

Numerous investigators have conducted bacteriologic

studies on the dentin of completed cavity preparations.[6,14-21] Almost all preparations contained a significant number of cultivable bacteria at the completion of cavity preparation. Deep lesions contained cultivable bacteria as frequently as 94% of the time.[6] This number is remarkably similar to the 97% staining found in the C-depth cavities in this study. The fate of the bacteria is uncertain. Some authors report the apparent sterilization of the prepared cavity by calcium hydroxide or zinc oxide/eugenol products.[17,19] Others have shown only a dimunition of viable organisms on a short-term basis.[20] Long-term studies have shown cultivable bacteria after 1½ years when the preparation was not subjected to medicaments.[21] The long-term fate of residual bacteria under medicaments is as yet unknown.

In a classic clinical study of amalgam failures, Healy and Phillips[22] reported that 53.5% (813) of 1521 amalgam restorations had failed as a result of recurrent caries. Mjor[23] surveyed 3527 amalgam restorations and found that 2504 or (71%) were replacement restorations. Secondary caries was the reason given most often (60%) for replacement. In an epidemiologic study of active-duty personnel in the U. S. Navy, Hyman[24] demonstrated that in the caries-active population 45% of the restorative surfaces were replacement surfaces, primarily caused by recurrent caries.

Apparently dentists are unable to detect cariously affected dentin by tactile discrimination or visual cues based on natural discoloration. A significant number of failures reported as recurrent caries may result from residual carious infections; that is, caries not removed at the initial excavation. The residual caries may have flourished under the restoration because the microleakage was sufficient to support the growth of bacteria and advance the carious process.

In this investigation, it was found that the most common area in which fuchsin-stained dentin was observed was at the DEJ. Hypothetically, if enough fuchsin-stained dentin remains, it may in fact be infected.[25] The bacteria and/or nutrient materials required for their growth are in the closest physical proximity to the softened, demineralized, and/or infected dentin at the DEJ. From this and the other studies cited, it is clear that detection and removal of all cariously affected dentin during operative procedures is not certain.

The objective guide provided by the basic fuchsin-staining technique in this study might eliminate or reduce the deficiency in clinical judgment. Caries-disclosing dyes provide a highly contrasting visual cue for removal of cariously affected dentin and reduce the reliance on subjective tactile discrimination and the variability of natural discoloration. Some authorities have questioned the advisability of using basic fuchsin in humans because of its once-supposed carcinogenicity. A careful review of the literature discloses that the original reports on carcinogenicity were anecdotic and involved the manufacture of the dye and not its subsequent use.[26] Controlled studies have subsequently shown no relationship between ingestion or injection of basic fuchsin and tumorogenicity.[27,28]

CONCLUSIONS

Within the limitations of this study, the following conclusions are made.

1. Seventy-two percent of the teeth demonstrated fuchsin-stained material after caries removal judged by visual and tactile criteria.
2. Fuchsin staining was most often encountered at the DEJ.
3. DEJ-staining occurred most often on the gingival wall under cusp and triangular ridges, and less often on the buccal and lingual proximal walls.
4. The deeper the cavity preparation, the greater the probability of finding fuchsin-stainable dentin after excavation of the caries.
5. Amalgam preparations stained significantly more often than gold preparations. No significant difference in the depth distribution of amalgam and gold preparations could be demonstrated.
6. Preparations on molars stained significantly more often than those on premolars. No significant difference in the depth distribution between molars and premolars could be demonstrated.

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Fracture resistance of human teeth with mesial-occlusal-distal cavities prepared with sharp and round internal line forms

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Investigators have used photoelastic models for stress analysis and suggested that rounded internal cavity forms produce less concentration of stress than do sharp cavity forms.[1-5] As a result, many proponents of modern cavity design suggest conservative preparations that include rounded internal forms.[6-11]

Larson et al.[12] found that all teeth with cavity preparations were significantly weaker than intact teeth, and that as the occlusal isthmus was widened, the tooth became weaker. Mahler and Terkla[13] analyzed stress of various kinds in dental structures. They reported that sharp angles in cavity preparations are harmful only when high stress (particularly tensile stress) is present. Re et al.[14] used extracted molars with Class I amalgam restorations to test the effect of rounded forms vs. sharp line angles on tooth fracture. They reported no statistically significant difference in the force needed to fracture teeth prepared with sharp or rounded line forms.

The purpose of this study was to test the significance of sharp vs. rounded internal forms as predisposing factors in tooth fracture by measuring the forces required to fracture maxillary premolars prepared with mesial-occlusal-distal (MOD) amalgam-type cavities.

MATERIAL AND METHODS

Maxillary, noncarious, unrestored, matched pairs of first premolars (right and left from the same patient) extracted for orthodontic purposes were selected for testing. The patients from whom the teeth were extracted ranged from 11 to 22 years of age.

Immediately after extraction, the teeth were placed in physiologic saline solution. The teeth were mounted in stainless steel casting rings, and the roots of the teeth

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