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An in vitro Comparison of the Ability of Fibre-Optic Transillumination, Visual Inspection and Radiographs to Detect Occlusal Caries and Evaluate Lesion Depth

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Key Words

Occlusal caries · Diagnosis · Fibre-optic transillumination · Bite-wing radiograph · Visual inspection

Abstract

The aim of this study was to compare the performance of fibre-optic transillumination (FOTI), visual inspection and bite-wing radiographs to detect occlusal caries and estimate the lesion depth. Fifty-nine extracted molars were assessed using FOTI and visual examination by 4 trained examiners and 1 examiner evaluated the bite-wing radiographs. Histological validation was performed using 250-μm sections examined with a stereomicroscope. For the three methods, the correlation between the lesion depth and the histological scores varied from 0.65 to 0.73. For dentinal caries detection, the areas under ROC curves ranged from 0.83 to 0.87. The radiographic method was poor at detecting lesions confined to enamel. FOTI, visual inspection and radiographs showed a good correlation with the histology but had difficulty in distinguishing lesions located deep in enamel or in the outer third of dentine. FOTI was shown to be as accurate as a detailed visual inspection in detecting occlusal caries.

Numerous methods have been developed to aid the reliable detection of dental caries. Of the traditional methods probing, visual inspection and radiographs are widely used and more recently, fibre-optic transillumination (FOTI), electronic caries monitor and laser fluorescence equipment have been added to this list [Lussi et al., 1999; Pine and ten Bosch, 1996]. Although these tools are often described as caries diagnostic methods, it is important to realise that they are only caries detection tools. However, detection of a lesion and estimation of its depth are important parts of the diagnostic process because if the lesion is thought to be active, this is often instrumental in determining the choice of intervention.

A particular problem appears to be the detection of occlusal caries and evaluation of the lesion depth. Many studies suggest that visual inspection and radiographs are both methods with poor performance [Huysmans et al., 1998; Ie and Verdonschot, 1994; Wenzel and Fejerskov, 1992]. Probing shows similar problems and may also produce traumatic defects in the carious enamel [Ekstrand et al., 1987]. However, a new method of meticulous visual inspection of the occlusal surface suggests that the performance of visual inspection can be greatly improved with respect to detecting and estimating lesion depth [Ekstrand et al., 1995, 1997, 1998].

FOTI is another detection approach that might provide useful information to supplement the caries diagnosis pro-

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Table 1. Criteria used for the visual, FOTI and radiographic examinations

Score	Visual	FOTI	Radiographic
0	No or slight change in enamel translucency after prolonged air drying (>5 s)	No shadow or stained area	No radiolucency
1	Opacity or discolouration hardly visible on the wet surface, but distinctly visible after air drying	Thin grey shadow appears when transilluminated	Radiolucency visible in the enamel
2	Opacity or discolouration distinctly visible without air drying	Wide grey shadow appears when transilluminated	Radiolucency visible in the dentine but restricted to the outer 1/3 of the dentine
3	Localised enamel breakdown on opaque or discoloured enamel and/or greyish discolouration from the underlying dentine	Orange brown shadow appearing to be in dentine ≤2 mm in diameter	Radiolucency extending to the middle 1/3 of the dentine
4	Cavitation in opaque or discoloured enamel exposing the dentine	Orange brown shadow appearing to be in dentine >2 mm in diameter	Radiolucency in the pulpal 1/3 of the dentine

cess but it has most widely been used for detecting approximal dentinal caries [Peers et al., 1993; Pine and ten Bosch, 1996]. Little information is available about the performance of FOTI in detecting occlusal caries and estimating its depth [Ashley et al., 1998; Ellwood et al., 1997; Verdonschot et al., 1992, 1993; Wenzel et al., 1992]. Ie and Verdonschot [1994] have compared occlusal caries diagnostic systems analysing different studies and found FOTI and electrical resistance measurements to be promising. Wenzel et al. [1992] found that FOTI was more accurate than radiographs for occlusal caries detection in outer dentine. Verdonschot et al. [1992, 1993] found in vivo that visual and FOTI examination showed lower sensitivity but higher specificity than radiographic examination. There is little if any information in the dental literature about the ability of FOTI to establish occlusal lesion depth on a ranked scale.

This in vitro study examines the ability of FOTI to detect occlusal caries and evaluate the depth of lesions on a ranked scale compared to a histological validation method. The results are compared with data obtained with the detailed visual and radiographic systems.

Material and Methods

Sample. Fifty-nine unrestored molars stored in thymol were selected. Teeth with large carious lesion on smooth and approximal surfaces were excluded from the sample. After cleaning, drawings were made of the occlusal anatomy of each tooth. One examiner selected a site in the groove-fossa system on the occlusal surface of each tooth to be examined and it was marked on the drawing. These sites were selected as having an easily located topographical position and as reflecting the spectrum of enamel changes from sound to frank cavitation.

Examination Methods. Each site was scored using the visual ranked scale shown in table 1 [Ekstrand et al., 1997]. Four hours later they were also examined using FOTI using the ranked scale described in table 1. The FOTI tip was placed perpendicular to the buccal and lingual surfaces and scanned along the surface. The FOTI equipment (Schott Fibre Optics, Doncaster, UK) had a halogen lamp (150 W), a probe with 0.5 mm tip and was set to the maximum intensity. For both visual and FOTI examinations, 1 of the 4 examiners scored the investigation site and passed the tooth to the next examiner. The scores recorded by each examiner were then compared and a consensus decision was taken in case of disagreement. On every fourth tooth (n=14) the examination procedure was repeated on a separate day to assess the reproducibility of the assessment. A radiograph was taken using Kodak Ektaspeed Plus film and a Philips Practix 90/20 (60 kV, 0.5 s) at a distance of 24 cm and processed automatically. The radiographs were examined by 1 examiner (K.R.E.) using a Matteson's magnifying glass (×2, Dental X-Ray, Copenhagen, Denmark) and scored using the criteria described in table 1. The examinations were repeated on every fourth tooth 1 week later.

Examiner Training. Prior to the visual examination 1 of the authors (K.R.E.) trained the other 3 examiners in the visual method. Two authors (D.F.C. and R.P.E.) trained the other 2 examiners in a similar way to conduct the FOTI examination. Training consisted of a 3-hour theoretical session and the examination of 50 patients.

Histological Examination. The occlusal surfaces were initially photographed using a stereomicroscope at magnifications of ×8 and ×16. Three 250-μm-thick buccolingual sections were then prepared through the investigation site at each of the occlusal surfaces as suggested by Ekstrand et al. [1995]. Photographs of the occlusal surface with the sections in situ were then made (×8). The section that best showed the examination site was then selected for further examination by the consensus decision of 3 examiners. The section was examined in water on both sides using the stereomicroscope (×5), and the side with the most extensive changes was chosen for the histological evaluation. The ranked scale for the histological evaluation of enamel and dentine changes includes: 0 = no demineralization; 1 = outer enamel demineralization; 2 = inner enamel demineralization; 3 = outer 1/3 demineralization of dentine; 4 = middle 1/3 demineralization of dentine; 5 = inner 1/3 demineralization of dentine. After 2 days, the examiners repeated the histological examinations.

Table 2. Cross tabulation of histology and FOTI scores

FOTI	Histology						
	0 (sound)	1 (outer enamel)	2 (inner enamel)	3 (outer 1/3 dentine)	4 (middle 1/3 dentine)	5 (inner 1/3 dentine)	total
0 (no caries)	5	3	1				9
1 (thin enamel shadow)	1	7	17	5			30
2 (wide enamel shadow)			6	7	1		14
3 (shadow ≤2mm in dentine)				1	2		3
4 (shadow >2mm in dentine)					1	2	3
Total	6	10	24	13	4	2	59

Table 3. Area under ROC curve and correlation between the caries detection methods and the histological scores

	Kendall's tau b	Area under ROC curve	Cut-off points							
			score 0/1 vs. histological score 2/3		score 1/2 vs. histological score 2/3		score 2/3 vs. histological score 2/3		score 2/3 vs. histological score 3/4	
			sensitivity	specificity	sensitivity	specificity	sensitivity	specificity	sensitivity	specificity
FOTI	0.71 (0.6) $p<0.001$	0.85 (0.06)	1.0	0.23	0.74	0.85	0.32	1.0	0.83	0.98
Visual	0.73 (0.6) $p<0.001$	0.83 (0.05)	1.0	0.20	0.95	0.53	0.42	0.98	1.0	0.94
X-ray	0.65 (0.6) $p<0.001$	0.87 (0.05)	0.90	0.65	0.84	0.83	0.32	1.0	0.83	0.98

Standard error is given in parentheses. Sensitivity and specificity values in identifying lesions extending into dentine at two histological thresholds (2/3 and 3/4) and at different cut-off points for detection methods were determined.

Statistical Analysis. The reproducibility of each assessment method was assessed using a weighted kappa statistic. The association between each ranked score system and the histological scoring systems was assessed using a rank correlation test (Kendall's tau b). Assuming dentinal caries as the histological threshold the area under ROC curve and its standard error were calculated using SPSS statistical software (SPSS Inc., Chicago, Ill., USA). Sensitivity and specificity were calculated using different cut-off points for each detection method for histological thresholds.

Results

A total of 59 teeth were examined with the three detection methods and by histology. Histologically 6 teeth were deemed to be caries free, 10 had caries in the outer half of the enamel, 24 had caries in the inner half of the enamel. Of those 19 cases scored with caries in dentine, 13 were in the outer third, 4 were in the middle third and 2 were in the inner third.

The reproducibility of the FOTI, visual and radiographic examinations was 0.87, 0.95 and 0.84, respectively (weighted kappa statistic). The intra-examiner reproducibility of histological scores varied between 0.75 and 0.82 and the inter-examiner reproducibility varied between 0.75 and 0.79. The consensus decision (by disagreement between examiners) was taken in less than 10% of the sample.

Cross-tabulations of the FOTI versus the histological scores are presented in table 2. Table 3 shows the respective correlation coefficients and areas under the ROC curves, sensitivities and specificities using different cut-off points to indicate dentinal caries for FOTI, visual and bite-wing radiographs. In addition table 3 also shows data concerning the sensitivity and specificity of the three methods for two histological score thresholds between 2 and 3 (enamel and dentine) and 3 and 4 (outer dentine and middle dentine).

The highest correlation (table 3) was seen between visual detection and histological scores (0.73), followed closely by FOTI with a correlation coefficient of 0.71. The lowest

correlation was seen between the radiographic detection and histology (0.63). This result was related to the poor ability of radiographs for detecting enamel lesions. However there were no statistically significant differences in the correlation coefficients detected between the three methods ($p > 0.05$).

For detection of lesions histologically extending into the dentine, the area under the ROC curves were 0.85, 0.83 and 0.87 for the FOTI, the visual and the radiographic detection systems, respectively. There were no statistically significant differences detected between the three methods ($p > 0.05$).

The cut-off point with the highest combined values for sensitivity and specificity for determining whether the lesion was in dentine (histological threshold between 2 and 3) was between score 1 and 2 for all three detection methods (table 3). However, the best combination of sensitivity and specificity for all three detection methods was for estimating lesions at the cut-off point between the outer and middle thirds of dentine (table 3). All three detection systems had difficulties in differentiating when lesions were in the inner enamel or in the outer third of the dentine (tables 2, 3).

Discussion

For all three detection methods the correlation between the assessment of lesion depth and the histological scores was promising and not significantly different from one other. This suggests that all three methods were able to rank lesions in relation to histological depth. The main difference between the three methods was the low detection level for lesions confined to the enamel for the radiographic method. The latter is in accordance with findings obtained by Ekstrand et al. [1997, 1998]. Surfaces scored as sound on the radiographs had in fact a wide range of lesion depth ranging from sound to outer dentine histologically.

For detection of any lesion histologically extending into the dentine the area under the ROC curves were similar for the three methods. Verdonschot et al. [1993] also found similar areas under ROC curves for visual inspection, FOTI and radiographic examination for dentinal caries detection in vivo. However, the present study demonstrated that the three detection methods have difficulties in deciding whether a lesion is located deep in enamel or reached the outer third of dentine. On the other hand the three methods are quite accurate in deciding when the lesion is deeper than the outer third of the dentine, despite the size of the sample in this cathegory. Of the two thresholds the latter is probably the most important for determining the restorative treatment need, particularly for groups with a low caries progression rate. Wenzel et al. [1992] found a similar performance of the three methods for deep dentinal caries detection (inner half dentine) but a statistically superior performance (ROC curve) of FOTI and visual inspection for caries in dentine just beyond the enamel-dentine junction. With respect to the visual and the radiographic detection methods these results are in agreement with the results of Ekstrand et al. [1997, 1998].

The reproducibility, in this report expressed by weighted kappa values, was excellent for all three detection methods [Fleiss, 1981]. This suggests that each of the ranked detection systems is logically structured and can be taught to students and dentists. The intra- as well as inter-examiner reproducibility of the histological evaluation were also excellent. The most difficult decision was if the lesion had just entered the dentine or was restricted to the enamel.

It is not difficult to determine lesion depth in cavitated occlusal lesions and therefore the present sample had very few cavitated lesions. The detection problem is associated with apparently sound surfaces [hidden caries, Weerheijm et al., 1992a, b] and anatomically intact occlusal surfaces with different kinds of opacities. In the present study no teeth were identified that visually or by the FOTI examination were classified as sound and which histologically had dentinal caries.

Both the FOTI and the visual procedures are visual examination methods but they rely on different optical properties of the tooth. For FOTI light scattering within the lesion is critical and for this good-quality equipment with a high intensity point source of light is required. This equipment is cheap, transportable and practical to use in field studies. FOTI has been shown to be a reliable method for detecting dentinal approximal lesions [Ie and Verdonschot, 1994]. The results from this study indicate that FOTI is a accurate as a detailed visual inspection in detecting occlusal caries.

It is concluded that following suitable training and careful examination of occlusal surfaces, FOTI provides valid and reproducible information on the status of the occlusal surface of extracted teeth. Further investigations in vivo are required to further validate the FOTI method.

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