

Diagnostic comparison of three groups of examiners using visual and laser fluorescence methods to detect occlusal caries *in vitro*

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Abstract

Background: To evaluate the accuracy of the DIAGNOdent laser device (DD) for detecting occlusal fissure caries when used by three groups of examiners.

Methods: Three final-year dental students (S), three General Dental Practitioners (G), and three Academic Clinicians (A) individually examined the non-cavitated occlusal surfaces of 25 extracted permanent molars using visual inspection (VI) then DD assessments. The presence of caries was confirmed following tooth sectioning. A cut-off limit of 30 was used for the DD to avoid over-treatment in a low caries-risk situation.

Results: For VI, individual examiner sensitivity (caries correctly diagnosed) ranged from 53 to 86 per cent, and specificity (sound teeth correctly diagnosed) ranged from 76 to 95 per cent, with low Kappa agreements. Group S achieved the highest sensitivity (80 per cent) and Groups G and A achieved the highest specificities (88 per cent). For DD, individual examiner sensitivity ranged from 19 to 77 per cent, and specificity from 71 to 97 per cent, with generally moderate Kappa agreements. Group A achieved the highest (67 per cent) and Group G the lowest (44 per cent) sensitivities, and Group G achieved the highest specificity (94 per cent).

Conclusions: There were similar widely varying results for the two diagnostic methods and for the three groups of examiners. However, the relatively high sensitivities found with VI and specificities found with DD should avoid over-treatment in low caries-risk populations.

Key words: DIAGNOdent, laser fluorescence, occlusal caries.

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INTRODUCTION

It is generally accepted that the prevalence of smooth surface dental caries has decreased markedly over the past three decades in developed countries. As a result, the prevalence of occlusal pit and fissure caries now predominates.^{1,2} Accompanying this change has been a shift to a minimal intervention dentistry treatment philosophy for the management of dental caries.³ However, effective application of this philosophy requires the reliable diagnosis of occlusal caries at an early stage.⁴

A review of many traditionally used diagnostic methods for fissure caries has shown them to exhibit low sensitivity, but high specificity.⁵ The sensitivity (the correct recognition of carious teeth) usually ranged from approximately 60 to 90 per cent, and the specificity (the correct recognition of sound teeth) was usually greater than 80 per cent, when visible fissure cavities were present.⁶ However, for dentine caries present beneath macroscopically intact surfaces (hidden caries), the sensitivity was usually much lower, ranging from 12 per cent to rarely, 80 per cent.^{7,8}

Additional probing with a sharp explorer did not significantly improve the *in vitro* diagnostic accuracy of visual inspection,¹ and may damage fragile demineralized enamel, leading to a more rapid caries progression.^{9,10} Visual inspection aided by magnification has been shown to increase significantly the *in vitro* sensitivity for caries, but not the specificity.¹¹ However, the use of magnification gave only a slight increase in sensitivity for the *in vitro* diagnosis of fissure caries in another study.⁷ Posterior bite-wing radiographs are only of diagnostic use for hidden caries if the carious process has progressed histologically well into dentine. But, their use has been shown to lead to significantly improved sensitivity when occlusal surfaces appeared macroscopically intact.^{7,12}

Efforts have been made over many years to improve on the traditional diagnostic methods for detecting early fissure caries, with the introduction of various non-invasive devices that included caries detection

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dyes, fibre-optic lights, xeroradiographs and digitized radiographs, and electronic caries monitors.¹²⁻¹⁴ More recently, a laser or light-induced fluorescence device has been introduced, the DIAGNOdent (KaVo, Biberach, Germany), which uses a diode laser ($\lambda=655\text{nm}$) to illuminate the tooth. A detailed description of the device and its mode of operation have been published.^{5,15}

Many recent *in vitro* studies^{2,16-21} and *in vivo* studies^{2,5,22-24} have been undertaken to detect occlusal fissure caries in permanent teeth when using the DIAGNOdent device. These studies have usually evaluated the sensitivities (correct caries diagnosis) and specificities (correct sound tooth diagnosis) of the laser device when compared to other diagnostic devices and traditional methods. For the *in vitro* studies, histological controls were generally used for validation of the assessments. Attempts have been made in relatively few *in vivo* studies involving the DIAGNOdent device to confirm the presence of caries by opening up fissures, which occurred only when the diagnosis of caries was thought to require operative intervention.^{5,23,24} The sensitivities of the DIAGNOdent device in these recent studies were generally higher than for the other diagnostic methods investigated, ranging from approximately 80 to 95 per cent. However, the specificities were usually lower than for the other methods, ranging from approximately 50 to 85 per cent.

No previous study has evaluated the use of the DIAGNOdent device by dental students, and compared the findings with those from more experienced General Practitioners and Academic Clinicians. Therefore, this study tests the null hypothesis that the detection of occlusal fissure caries when using either visual inspection or a laser fluorescence device is independent of the assessment method and the examiners.

MATERIALS AND METHODS

In February 1999, three final-year dental students, three General Dental Practitioners and three Academic Dental Clinicians individually assessed 25 (16 maxillary, nine mandibular) extracted permanent molar teeth at random for occlusal caries, using visual inspection and the DIAGNOdent laser device. Each examiner was given verbal instructions and a demonstration individually by the principal author on the use of the two assessment methods followed by practice before the experiment.

The occlusal surfaces of the selected teeth, which had been stored in 0.05 per cent chloramine solution, appeared to be either completely sound or to have questionably carious non-cavitated lesions, with varying amounts of fissure discolouration and decalcification, upon visual inspection with the naked eye. The occlusal surfaces of the teeth were cleaned with a plain flour of pumice and tap water slurry and rinsed thoroughly before being dried and photographed using 35mm Ektachrome ASA 100 film (Eastman Kodak, Rochester, New York, USA). Five selected occlusal sites were marked for examination on a diagram for each tooth. The occlusal surfaces of the

teeth were lightly dried with compressed air from a triple syringe before each assessment.

Visual assessment method

Using a halogen operating light and loupes (2.5x magnification), but no dental explorers, the nine examiners were asked to first score each predetermined site as being either non-carious or carious, based on their clinical judgement experience.

Laser device assessment method

The DIAGNOdent device was then used with the cone-shaped light probe tip (Type A). Following calibration of the device for each examiner and each tooth, the tip was placed perpendicular to the occlusal surface of the tooth at the predetermined site, and then tilted around a vertical axis until the highest fluorescence reading was obtained. Because the pulsed incident light is affected not only by inorganic and organic tooth substance, but also by organic stains and debris plugging fissure orifices, the fissures must be cleaned out and the teeth dried before using the device.¹⁶⁻²² Otherwise, measurements of the reflected fluorescent light will be high, resulting in false positive caries diagnosis. To reduce the possibility of false positive readings when deciding on operative treatment for caries, a conservative cut-off limit of 30 was used for the subsequent evaluations.^{5,17,24} This is especially important in low caries-risk populations.

Histological assessment method

Each tooth was sectioned buccolingually perpendicular to the occlusal surface at the selected sites using a thin diamond saw (Isomet, Buehler, Lake Bluff, Illinois, USA). The sections were examined using a stereomicroscope. Caries in either enamel or dentine was diagnosed when there was evidence either of opacity changes or discolouration.

Statistical analysis

The histological scores were used as the 'gold standard' (control) to evaluate the accuracy of the two clinical assessment methods and the three groups of examiners. Comparisons of the findings were made using Prism 3.0 statistical software (GraphPad Software Inc, San Diego, California, USA). The proportions of true diagnosis of caries (sensitivity) and of sound non-carious surfaces (specificity) correctly identified by the clinical assessment methods and examiners were calculated. For each of the two clinical methods, significant differences present between the individual examiners and the three groups of examiners were evaluated using McNemar related sample and chi-square independent sample statistics, respectively. The probability level for statistical significance was set at a 0.05. Cohen's Kappa statistic was used to measure the level of agreement between the visual inspection or DIAGNOdent device scores of the examiners and the histological control scores.²⁵

Table 1. Control v.s. visual paired observations for occlusal caries, by each examiner

Observations	Students			General Practitioners			Academic Clinicians		
	S1	S2	S3	G1	G2	G3	A1	A2	A3
Total number	124	125	125	125	120	105	120	125	125
Correct diag. %	84.7	80.8	86.4	88.8	75.8	87.6	73.3	87.2	89.6
Sensitivity %	85.7	77.3	77.3	72.7	77.3	52.6	63.6	65.2	63.6
Specificity %	84.5	81.6	88.3	92.3	75.5	95.3	75.5	92.2	95.1
Kappa	0.30	0.27	0.28	0.27	0.26	0.19	0.19	0.25	0.24
χ^2 (df=1)	7.579	7.042	2.118	0.071	11.172	1.231	7.031	0.063	0.308
P value	0.006*	0.008*	0.15	0.79	0.001*	0.27	0.008*	0.80	0.58
OR	0.19	0.26	0.42	0.75	0.21	2.25	0.33	1.00	1.60

χ^2 =McNemar paired chi-square test (with Yates' correction).

*Statistically significant difference at the 1% probability level or less.

OR=Odds Ratio. Values greater than 1 indicate under-diagnosis of caries when compared to the histological controls.

RESULTS

Despite the instructions given, not all examiners assessed every predetermined occlusal site, especially when using the DIAGNOdent device and, therefore, the numbers of observations vary in the following tables.

The findings for the visual inspections are shown for individual examiners within the three groups, in Table 1. Correct individual examiner diagnoses ranged from 73.3 to 89.6 per cent. Examiner sensitivity varied from 52.6 to 85.7 per cent, and specificity varied from 75.5 to 95.3 per cent. Individual Kappa agreements were only fair, ranging from 0.19 to 0.30. There were statistically significant differences between the visual and histological control diagnoses for several individuals within each group ($P < 0.01$). The individual odds ratios (OR) varied from 0.19 to 2.25.

The findings for the DIAGNOdent device are shown for individual examiners within the three groups, in Table 2. Correct individual examiner diagnoses ranged from 63.6 to 90.7 per cent. Examiner sensitivity varied from 18.8 to 76.9 per cent, and specificity varied from 71.4 to 96.9 per cent. With one very low exception, individual Kappa agreements were generally fair to moderate, ranging from 0.21 to 0.64. A statistically significant difference between the DIAGNOdent device and the histological control diagnosis was shown by one General Practitioner ($P = 0.01$). This person also had an OR of 6.50, indicating a significant under-diagnosis for caries.

As shown in Table 3, individual examiner differences between the visual and histological control diagnoses were statistically significant within the General

Practitioner and Academic Clinician groups ($P 0.01$). And the Cramér co-efficient (C) showed very low associations between the examiners within each group and the correctness of their diagnoses. Correct group diagnoses were all approximately 84 per cent. The final-year student group achieved the highest sensitivity of 80 per cent, and the General Practitioners and Academic Clinician groups the highest specificities of approximately 88 per cent. Overall, for all groups combined, the sensitivity with the visual inspection method was 70.8 per cent and the specificity was 86.7 per cent. The Kappa values showed moderate agreements for each group of examiners, ranging from 0.48 to 0.54.

In Table 4, individual examiner differences between the DIAGNOdent device and the histological control diagnoses were statistically significant within the General Practitioner and Academic Clinician groups ($P 0.05$). Again, the C values were also very low. Correct group diagnoses were lowest at 77.2 per cent for the Academic Clinicians. The Academic Clinician group achieved the highest sensitivity of 66.7 per cent, and the General Practitioner group the lowest sensitivity of 43.9 per cent and the highest specificity of 94.2 per cent. Overall, for all groups combined, the sensitivity with the DIAGNOdent device was 58.1 per cent and the specificity was 89.2 per cent. Again, the Kappa values were moderate, ranging from 0.43 to 0.53.

DISCUSSION

The results from this study confirmed the well-known variability found among dentists in their

Table 2. Control v.s. DIAGNOdent paired observations for occlusal caries, by each examiner

Observations	Students			General Practitioners			Academic Clinicians		
	S1	S2	S3	G1	G2	G3	A1	A2	A3
Total number	77	49	52	97	81	36	36	44	82
Correct diag. %	83.1	83.7	82.7	90.7	81.5	75.0	77.8	63.6	84.1
Sensitivity %	64.7	69.2	53.8	62.5	18.8	55.6	76.9	50.0	75.0
Specificity %	88.3	88.9	92.3	96.3	96.9	81.5	78.3	71.4	86.4
Kappa	0.52	0.58	0.50	0.64	0.06	0.23	0.53	0.21	0.55
χ^2 (df=1)	0.000	0.125	0.444	0.444	6.667	0.000	0.125	0.060	1.231
P value	1.00	0.72	0.51	0.51	0.01*	1.00	0.72	0.80	0.27
OR	0.86	1.00	2.00	2.00	6.50	0.80	0.60	1.00	0.44

χ^2 =McNemar paired chi-square test (with Yates' correction).

*Statistically significant difference at the 1% probability level.

OR=Odds Ratio. Values greater than 1 indicate under-diagnosis of caries when compared to the histological controls.

Table 3. Control v.s. visual paired observations for occlusal caries, by comparison of examiners

Observations	Students			General Practitioners			Academic Clinicians		
	S1	S2	S3	G1	G2	G3	A1	A2	A3
Correct diag.	105	101	108	111	91	92	88	109	112
Incorrect diag.	19	24	17	14	29	13	32	16	13
Total (df=2)	124	125	125	125	120	105	120	125	125
	$\chi^2=1.527, P=0.47,$ C=0.06			$\chi^2=9.121, P=0.01^*,$ C=0.16			$\chi^2=13.630, P=0.001^*,$ C=0.19		
Correct diag. %		84.0			84.0			83.5	
Sensitivity %		80.0			68.3			64.2	
Specificity %		84.8			87.5			87.8	
Kappa		0.54			0.51			0.48	

χ^2 =chi-square test. C=Cramér co-efficient of association test.

*Statistically significant difference at the 1% probability level or less.

diagnosis of caries, and treatment decisions.²⁶ There was no clear superiority of one diagnostic method over the other across all individual examiners or groups of examiners. There were no strong Kappa agreements between the two diagnostic methods and the histological controls, either for individual examiners (Table 1, 2), or for the three groups of examiners (Table 3, 4). There were also no strong Cramér associations found between individuals within the same group and the correctness of their diagnoses (Table 3, 4). Several other more recent studies have also been unable to establish a significantly superior diagnostic advantage for the DIAGNOdent device when compared to a careful visual inspection.^{2,4,27} Therefore, the null hypothesis was accepted.

One other study that evaluated two separate groups of General Dental Practitioners on their abilities to diagnose occlusal caries, also found low Kappa agreements for their visual inspections.¹⁸ Despite significant differences in the clinical experience of the two groups since graduation, there were also no significant differences in the correctness of their visual diagnoses. However, as in the present study (Table 3), the youngest examiners showed the highest group sensitivity.

The individual sensitivities especially (52.6 to 87.7 per cent), and the specificities (75.5 to 95.3 per cent), found on visual inspection of the non-cavitated occlusal surfaces (Table 1) compared favourably with those generally reported.^{1,2,7,8,23} However, the individual sensitivities (18.8 to 76.9 per cent), but not the specificities (71.4 to 96.9 per cent), found for the

DIAGNOdent device (Table 2) compared less favourably with those generally reported using lower cut-off limits.^{2,4,23}

Ideally, the diagnostic method used for fissure caries should have a very high sensitivity for dentine caries combined with a high specificity for enamel caries detection.²⁷ Usually, for non-cavitated occlusal surfaces, the DIAGNOdent device has recorded higher sensitivities and lower specificities than has visual inspection. But, inexplicably high readings may sometimes be recorded by the DIAGNOdent device for white or opaque and hypomineralized enamel.²² To avoid over-treatment, visual inspection using a ranked caries scoring system²⁸ should be preferred to diagnose non-cavitated surfaces in populations with a low caries prevalence.^{2,22} Adelaide has had fluoridated water supplies since 1971, and a high cut-off value of 30 was selected for the DIAGNOdent device to reduce the number of false positive diagnoses. This decision decreased examiner sensitivity, at the expense of some (desirable) under-treatment. However, because of its high examiner reproducibility, the DIAGNOdent device can be recommended for the reliable monitoring of small questionably active occlusal lesions.^{2,16,17}

The decision to restore a questionably carious occlusal fissure should not be made solely on the basis of visual inspection or the use of the DIAGNOdent device, but on a considered caries-risk assessment of the individual patient²⁹ and an intelligent interpretation of the device's readings.²² More recent cut-off limits recommended for the DIAGNOdent device are: 0-13,

Table 4. Control v.s. DIAGNOdent paired observations for occlusal caries, by comparison of examiners

Observations	Students			General Practitioners			Academic Clinicians		
	S1	S2	S3	G1	G2	G3	A1	A2	A3
Correct diag.	64	41	43	88	66	27	28	28	69
Incorrect diag.	13	8	9	9	15	9	8	16	13
Total (df=2)	77	49	52	97	81	36	36	44	82
	$\chi^2=0.017, P=0.99,$ C=0.01			$\chi^2=5.935, P=0.05^*,$ C=0.17			$\chi^2=6.845, P=0.03^*,$ C=0.21		
Correct diag. %		83.2			84.6			77.2	
Sensitivity %		62.8			43.9			66.7	
Specificity %		89.6			94.2			81.2	
Kappa		0.53			0.43			0.46	

χ^2 =chi-square test. C=Cramér co-efficient of association test.

*Statistically significant difference at the 5% probability level or less.

no caries; 14-20, enamel caries and preventive care advised; 21-30, dentine caries and preventive or operative care advised depending on the caries-risk assessment; >30, operative care advised.⁵ The DIAGNOdent device may be regarded as a valuable adjunct to, but not a substitute for, the careful visual inspection of occlusal fissures.^{5,22} Otherwise, its relatively low specificity generally reported for the detection of sound fissures may be incompatible with the treatment philosophy of minimal intervention dentistry and preventive dental care.

CONCLUSIONS

In this study, three groups of examiners with different clinical experiences showed highly variable individual diagnoses for occlusal caries when using either visual inspection or the DIAGNOdent device. Individual agreements with the histological controls were also relatively low. The student group of examiners showed the highest sensitivity for visual inspection, and the General Practitioner group showed the lowest sensitivity for the DIAGNOdent device. Contrary to most previous studies, the overall sensitivity for the visual inspections was relatively high, and that for the DIAGNOdent device was relatively low when using a cut-off limit of 30. This latter finding, when combined with the relatively high overall specificity found with the device in the present study, is acceptable in low caries-risk populations to avoid over-treatment.

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