

USE OF DIAGNODENT® FOR DIAGNOSIS OF NON-CAVITATED OCCLUSAL DENTIN CARIES

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Received: March 19, 2007 - **Modification:** July 23, 2007 - **Accepted:** October 4, 2007

ABSTRACT

The purpose of this study was to evaluate the use of a laser fluorescence device for detection of occlusal caries in permanent teeth. One hundred and ninety-nine non-cavitated teeth from 26 patients aged 10 to 13 years were selected. After dental prophylaxis, two previously calibrated dentists examined the teeth. Visual inspection, radiographic examination and laser measurements were performed under standardized conditions. The validation method was cavity preparation with a small cone-shaped diamond bur, when the two examiners agreed about the presence of dentin caries. It was found that the laser detection method produced high values of sensitivity (0.93) and specificity (0.75) and a moderate positive predictive value (0.63). The laser device showed the lowest value of likelihood ratio (3.68). Kappa coefficient showed good repeatability for all methods. Although the laser device had an acceptable performance, this equipment should be used as an adjunct method to visual inspection to avoid false positive results.

Uniterms: Dental caries, diagnosis. Lasers. Fluorescence.

INTRODUCTION

Caries prevalence has declined in the last decades, mainly in developed countries¹⁹. The cavitation process has shown changes in lesion behavior and in the distribution of affected sites. Caries progression rate has decreased and the occlusal surface became the most affected surface. Many authors consider the use of fluoride as the main factor for the reported changes, thus resulting in a more difficult diagnosis of occlusal caries lesion²⁰.

Traditionally, clinical examination with dental mirror and probe has been used for caries diagnosis. However, the validity of such probing has been criticized as the variations in fissure morphology, sharpness of the probe and pressure exerted by the operator may produce variable results^{6,17,18}.

The use of an explorer when there is an area of white or opaque enamel may produce irreversible defects in occlusal fissures⁶. Furthermore, it was stated that the explorer allows transmission of cariogenic flora from one infected site to another¹³ and it may be less accurate in diagnosis than visual inspection alone^{17,18}.

The use of bitewing radiographs for occlusal caries diagnosis has been questioned, due to the lack of accuracy in detecting enamel occlusal lesions^{22,28}. However, the value of this method has been reconsidered because of its

importance in the diagnosis of hidden caries³⁰.

A new method based on fluorescence measurements performed by a laser device has been growing in popularity during the past three years. When the laser irradiates the tooth, the light is absorbed by organic and inorganic substances present in the dental tissues, as well as by metabolites from oral bacteria¹⁰. These metabolites could be porphyrins that are produced by several types of oral bacteria. Studies using chromatography have found that porphyrins showed some fluorescence after excitation by red light¹⁴. For this reason, the dental tissue emits fluorescent light after irradiation by red laser and, as the carious tissue increases the emitted fluorescent light compared to healthy tissue, this causes a significant difference between carious and sound structures¹⁵.

The performance of the laser device has been reported by several *in vitro* and few *in vivo* studies. However, the results varied substantially. While some studies have shown good performance^{3,4,16,24}, others have found low values of specificity^{1,9}. According to a recent systematic review², further assessment of the laser device in clinical applications is needed. The aim of this *in vivo* study was to assess the use of a laser fluorescence device for detection of non-cavitated occlusal caries in dentin.

MATERIAL AND METHODS

One hundred and ninety-nine permanent molars and premolars from 26 patients aged 10 to 13 years were selected. The study used posterior permanent teeth with and without carious lesions. The teeth were selected according to the following criteria that have already been used in a similar study³. Each surface had to meet one of the three listed criteria to be included in the study: macroscopically intact occlusal fissure that exhibited absolutely no signs of caries; occlusal fissure with a discolored, brown or black area at the clinical examination without cavitation; grey discoloration from the underlying dentin without enamel breakdown.

Two examiners, experienced in caries diagnosis, were trained to use the laser equipment (DIAGNOdent, KaVo, Biberach, Germany) following the manufacturer instructions. The same dentists had already participated in an *in vitro* study performing a similar diagnostic with this device³.

After selection of the subjects, an explanation about the study was given and the legal guardians of the patients signed an informed consent. Ethical approval was obtained from the Ethics Committee of the Health Science Center of the University of Brasília.

Visual Inspection

After cleaning and drying the tooth surface, visual inspection was performed in a conventional dental equipment under artificial light without probing or magnification.

The presence or absence of occlusal caries was recorded using the scores shown in Table 1: (0) no caries; (1) caries confined to enamel, and (2) caries beyond the dentinoenamel junction^{3,4,17}.

The criteria used to record the visual appearance of teeth were based on Ekstrand, et al.⁷ (1998). A sound tooth (score 0) was the one in which the fissure showed no change in enamel translucency after drying. Enamel caries (score 1) was defined as an opaque white-spot lesion around the fissure that appears after tooth drying. When the enamel area had a grey discoloration from the underlying dentin, it was considered as dentin caries (score 2). Stained fissures as an isolated fact were not considered as caries lesion.

Visual examination was always carried out first in order to reduce the possibility of the laser fluorescence system producing bias in the visual scores obtained.

Bitewing Radiography

Kodak Ultra Speed dental films, held in bitewing film holders (Hawes-Neos, Bioggio, Switzerland) were used in combination with an Espectro II 50 kV, 10 mA x-ray equipment (Dabi Atlante, Ribeirão Preto, SP, Brazil) with an exposure time of 0.8 seconds. Film development was performed automatically (Perio-Pro II, Air Techniques, USA). The same investigators examined the films on a viewing box without magnification one day after visual inspection. The radiological examination was conducted blindly and independently by the two examiners, thus they could not

associate the visual appearance of the tooth and the radiographic film. The presence or absence of occlusal caries was established by the criteria shown in Table 1: (0) no radiolucency; (1) radiolucency confined to enamel, and (3) radiolucency extending into dentin^{3,4,17}.

Laser Fluorescence Method

A laser fluorescence system (DIAGNOdent - KaVo, Biberach, Germany) was used for this study. Initially, a non carious portion of each tooth was selected in order to provide a baseline measurement. The probe tip A (narrow) was then tracked across the occlusal fissure and a peak reading recorded. The probe tip was positioned on this spot and rotated around its vertical axis until the highest value was found¹⁵. The instrument must be tilted around the measuring site to ensure that the tip had picked up fluorescence from the slopes of the fissure walls¹⁴. The presence or absence of caries was determined using the cut-off points suggested by Lussi, et al.¹⁶: (0) 0 to 20: no active care or preventive care is advised (NCA or PCA); (1) 21 to 29: preventive or operative care is advised (PCA or OCA), and (2) ³ 30: operative care is advised (OCA) (Table 1).

Validation method

The validation method for diagnosis (gold standard) was determined by fissure eradication or enameloplasty⁸ using an invasive fissure sealing kit (KG Sorensen, Barueri, SP, Brazil). However, not all fissures could be validated as this is an invasive method. Thus, for ethical reasons, opening of the cavities occurred only in cases when both examiners agreed to the presence of dentin caries. The decision-making about invasive treatment was carried out when at least one diagnostic method showed score 2 by each examiner.

When both examiners decided to conduct an operative intervention, a conservative preparation was used to remove the enamel until reach the carious tissue, only at the selected site of the occlusal surface. The carious tissue was removed until hard dentin was found. The examiners used the dentin hardness criterion with an explorer to distinguish the carious and healthy dentin¹¹. Scores according to the severity of the lesion were established for each validated tooth (Table 1).

Statistical analysis

Indexes of sensitivity, specificity, positive and negative predictive values and likelihood ratio were calculated for all diagnostic methods.

Repeatability of each method was assessed by calculating Cohen's Kappa. It was used the interpretation proposed by Landis and Koch¹².

Statistics (averages and quartiles) were performed to indicate the variability of scores for the excluded teeth, opened teeth and sound teeth.

RESULTS

Operative intervention was indicated for 86 teeth by the dentists. Forty-eight teeth were not drilled because the examiners did not indicate restorative treatment. In fact, the examiners detected enamel caries or stained fissure in most of these teeth. They were excluded from the sample because

they could not be opened. Table 2 shows a comparison of DIAGNOdent's scores for the whole sample. Most excluded teeth were considered without dentin caries by both examiners. The first and third quartiles showed that score 1 was the most frequent score (Table 2).

Sixty-five teeth were considered sound exhibiting absolutely no signs of caries nor demineralized or stains in

TABLE 1- Scores for diagnosis of occlusal caries by visual inspection, bitewing radiography, DIAGNOdent laser device and validation method

Score	Visual inspection	Radiograph	Laser	Validation method
0	No caries	No radiolucency	0 to 20	No caries
1	Caries confined to enamel	Radiolucency confined to enamel	21 to 29	Caries confined to enamel
2	Caries extending to dentin	Radiolucency extending to dentin	≥ 30	Caries extending to dentin

TABLE 2- Comparison of DIAGNOdent's scores for the excluded teeth, opened teeth and sound teeth

DIAGNOdent		Excluded teeth (48)	Opened teeth (86)	Sound teeth (65)
Examiner 1	Mean (average)	0.9791667	1.8372093	0.1692308
	1 st quartile	1	2	0
	3 rd quartile	1	2	0
Examiner 2	Mean (average)	0.9166667	1.7674419	0.1230769
	1 st quartile	1	2	0
	3 rd quartile	1	2	0

TABLE 3- Sensitivity (Se), specificity (Sp), positive (PPV), negative (NPV) predict value and likelihood ratio (LR) of the methods for detection of dentin caries

Methods	Se %	Sp %	PPV %	NPV %	LR
Visual Inspection	0.50	0.95	0.83	0.80	10.11
Bitewing Radiography	0.26	0.94	0.69	0.73	4.54
Laser Fluorescence	0.93	0.75	0.63	0.96	3.68

TABLE 4- Kappa value of inter- and intra-examiner repeatability for each diagnostic system (95% confidence intervals in parenthesis)

Kappa	Visual inspection	Bitewing Radiography	DIAGNOdent
Examiner 1	0.723 (0.592-0.853)	0.819 (0.709-0.928)	0.742 (0.641-0.844)
Examiner 2	0.700 (0.572-0.828)	0.823 (0.716-0.930)	0.730 (0.629-0.831)
Examiner 1 vs 2	0.709 (0.573-0.846)	0.768 (0.650-0.885)	0.747 (0.647-0.846)

the fissures. The radiographic exam did not show pathological radiolucency. Table 2 reflects that these teeth were classified with score 0 by both examiners in the majority of the sample when laser device was used. These teeth were not excluded since they were necessary to calculate the general decision matrix (2x2 table), however these sound teeth could not be drilled either.

After operative intervention, it was found out that in 50 teeth (58%) dentin consistence was rated as soft. The other 36 teeth (42%) showed hard tissue after removing enamel and they were considered as having caries lesions restricted to enamel.

Indexes of sensitivity and specificity of the diagnostic systems for dentin caries are given in Table 3. Clinical and radiographic examination had high specificity but low sensitivity. The laser method was characterized by high values for both sensitivity and specificity. However, this device showed the lowest positive predictive value and the lowest value of likelihood ratio among the tests.

Inter- and intra-examiner reproducibility was calculated for the whole sample. However, intra-examiner repeatability was performed on a separate occasion from the main examination. Inter- and intra-examiner reproducibility was considered good for visual inspection and laser method. Radiological examination showed a very good agreement. The results are summarized in Table 4.

DISCUSSION

The establishment of a correct occlusal caries diagnosis is a complex process because it involves identification of the presence or absence of caries disease, as well as determination of its stage of development. The difficulty in diagnosing fissure caries is directly related with the complexity of the prediction of the mineral loss around the fissure walls and the proper clinical decision-making²⁶.

The primary measures used for the validation of diagnostic tests are *sensitivity, specificity, predictive values and likelihood ratio*. In the present study, all of these measurements were done to evaluate the performance of three diagnostic tests: visual inspection, bitewing radiography and laser fluorescence device.

The sensitivity of visual examination (Table 3) was moderate. This finding supports the conclusions from previous studies and confirms that occlusal caries are difficult to diagnose using only the visual exam^{17,18,29} as it is a subjective method. Despite the moderate sensitivity, the specificity was substantial for visual inspection, which is in accordance with several studies^{4,9,17,18,24}.

For radiographic diagnosis (Table 3), the obtained sensitivity was low, although the specificity was high. These results are similar to those of other studies^{1,4,16,17,18}. The limitation of the radiographic examination for occlusal caries diagnosis is related to the superposition of sound enamel that masks the evidence of radiolucency, mainly when there is caries lesion confined to enamel or superficial dentinal caries. In addition, dentin caries can only be visualized

radiographically when it is 0.5 mm beyond the dentinoenamel junction²⁸.

The laser method reflected good values for both sensitivity and specificity, as shown in Table 3. These results are similar to other studies that assessed different methods of occlusal caries diagnosis^{4,15,16,21,24}. However, values obtained for specificity by some other authors^{1,9} were lower when compared to the present work. These different results could be explained by the fact that the *in vivo* studies^{1,9,16,24}, including the present work, estimated the specificity by assuming that all unopened teeth did not have dentinal caries.

Reproducibility is another important topic in the assessment of diagnostic tests. In the present study, Kappa coefficient was calculated to verify the calibration process of the examiners. It was shown that all tested methods were reproducible to diagnose occlusal caries, as the results expressed high reliability for repeated measurements (Table 4).

A simplistic analysis of these results could lead to think that laser device is the best method to detect occlusal caries because it presented acceptable values of both indexes (sensitivity and specificity) and showed a good reproducibility. In spite of the results achieved with the laser method, Table 3 shows a moderate positive predictive value. This percentage of positive predictive value may be the responsible for a high number of false positive diagnoses. As a result, unnecessary treatment may occur^{2,5}.

In addition, the likelihood ratio for laser method was the lowest when compared to the other methods. Diagnostic tests with high true positive ratios and low false positive ratios are better discriminators for the caries disease. Hence, tests with high likelihood ratios are better than those with low likelihood ratios^{2,5}. Visual inspection and radiographic exam showed higher likelihood ratios. In fact, values of false negative results were also higher, which could produce a number of dentinal caries being left without operative treatment.

The question then should be: which one is worse? Missing the disease due to a false negative result or treating a disease-free patient due to a false positive result? In times with low prevalence of caries¹⁹, the false negative results are better tolerated when compared to the false positive results².

Given that there is the possibility of false positive results with the laser method, the visual inspection must be conducted initially, following the recommendations of cleaning and drying the fissure^{25,27}. Thereafter, if there is any doubt at a site, the laser can be used to help the decision on how to treat the fissure. However, the authors of the present study agree with Bader and Shugars² (2004) and Ricketts²³ (2005) in that DIAGNodent should not be relied on as clinician's primary diagnostic method.

It is of paramount importance to consider other factors that can influence caries progression, such as history of previous caries, dietary considerations, oral hygiene and fluoride exposure, to decide the management of a questionable fissure²⁶.

It should be pointed out that the predictive values of the presented study have been analyzed carefully (Table 3). The positive predictive value and negative predictive value are affected by disease prevalence in the population under study⁵. In the present investigation, caries prevalence was underestimated because cavitated teeth were excluded. Therefore it is important to analyze the performance of this new instrument in a representative sample of the population in which caries prevalence can be determined precisely to extrapolate the results.

Other limitation of this *in vivo* study may have been that 48 teeth could not be validated. The data could show that most excluded teeth were classified as score 1 (Table 2) by both examiners. According to the minimal invasive dentistry, enamel caries can be treated using non invasive methods. Thus, for ethical reasons, these teeth were not opened. In addition, 65 teeth exhibiting no signs of caries were not opened based on the assumption that they were not carious. The assessment of the methods performance under these conditions could lead to an overestimation of the statistical indexes. Hence, according to Bader and Shugars² (2004) in a systematic review of the laser method, these indexes are only estimated rather than calculated because the number of true negative results cannot be determined accurately.

Longitudinal studies that could follow-up the patients for several years would be more appropriate to ensure reliable results and to neutralize the possible biases of *in vivo* cross-sectional research.

CONCLUSION

The results of the present study indicated that, although the laser method showed acceptable indexes of sensitivity and specificity, it is advisable to use this resource in association with visual inspection in order to reduce the possibility of false positive results. Longitudinal studies of occlusal caries diagnosis and patient follow-up using the laser method are suggested.

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