

## Use of laser fluorescence (DIAGNOdent®) for in vivo diagnosis of occlusal caries: a systematic review

Pinheiro I V A, Medeiros M C, Ferreira M A, Lima K C

### Abstract

**This systematic review was conducted to assess the accuracy of laser fluorescence (DIAGNOdent®) for diagnosis of occlusal caries in permanent teeth, using any sort of gold standard. The MEDLINE, LILACS, BBO and Cochrane library databases accessed by BIREME were searched for English, Spanish and Portuguese-language papers published between 1982 and 2003. Four works in English were selected. DIAGNOdent® was found to be an accurate method for diagnosis of occlusal caries, mainly if employed simultaneously with visual inspection. First published in *J Appl Oral Sci* 2004; 12: 177-81.**

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*Address of first author:  
Prof IV Pinheiro DDS, MSc, PhD, Assistant Professor –  
Av. Senador Salgado Filho, 1787 – Lagoa Nova – Natal  
RN, CEP: 59056-000 – email: isauremi@ig.com.br*

### Introduction

Despite its decreasing prevalence in the Brazilian population, dental caries is still an important public health problem<sup>1,2</sup>. The diagnosis of dental caries remains a challenge, since its patterns and prevalence have greatly changed in the last few years. The difficulty in diagnosing dental caries lies not only on the morphological changes of lesions and their rate of progression, but also in the lack of a precise methodology for correctly diagnosing both the disease (accuracy) and the integrity of dental structure (specificity)<sup>3-6</sup>.

The areas most affected by dental caries are the occlusal surfaces, of which 50 to 60% are damaged by the disease<sup>7</sup>. Consequently, early diagnosis of lesions and the establishment of non-invasive treatments consequently have been highly encouraged, to preserve the surface integrity. In fact, when compared to the others, occlusal surfaces are known to be the surfaces most susceptible to caries. In addition, they are also the most frequently restored and the most difficult to diagnose<sup>8-11</sup>.

The methods traditionally employed for diagnosis of caries include clinical (visual) inspection, tactile examination by probing and bitewing radiographs<sup>1,12</sup>. Clinical examination has been proven as suitable for smooth surfaces, but inadequate for proximal and occlusal surfaces. Radiographic images, on the other hand, are useful for detecting enamel proximal enamel lesions and occlusal dentin lesions, but are usually unsuitable for identifying occlusal caries restricted to enamel. Other methods such as fibre optic transillumination (FOTI) and videoscopic examination have been under discussion and some have already been developed to help in the diagnosis of caries.

The accuracy of FOTI is very similar to that of visual examination<sup>6,13,14</sup>, whereas the videoscopic examination has a lower specificity<sup>15,16</sup>. Laser fluorescence has been also used to aid in diagnosing occlusal caries.

This review compiled all works on the DIAGNOdent® appliance, the laser fluorescence of which has been employed on *in vivo* occlusal surfaces of permanent teeth. The aim was to evaluate the diagnostic accuracy of such a device for occlusal caries.

## **Material and methods**

*Research sources:* Databases searched were MEDLINE, LILACS (Latin American and Caribbean Literature on the Health Science), BBO (Brazilian Bibliography of Dentistry) and Cochrane Library accessed by BIREME website (Latin American and Caribbean Center on Health Sciences Information - www.bireme.br).

*Types of participants:* All studies on human beings were selected, regardless of age.

*Types of study:* All diagnostic clinical trials, on human beings and occlusal surfaces were included. The following languages were chosen: English, Portuguese and Spanish.

*Type of outcome:* The outcome of interest was the presence or absence of dental caries as confirmed by the following methods: histological examination, opening of cavities or clinical examination based on scores utilized in studies based on histological corroboration.

### *Exclusion criteria*

*In situ* and *in vitro* studies performed on smooth surfaces and primary teeth.

### *Search strategy*

#### **MEDLINE:**

The following strategy was employed for MEDLINE: (Diagnodent OR laser fluorescence OR laser fluoroscopy) AND (occlusal OR occlusal) AND not vitro [Words] AND English

OR Portuguese OR Spanish [Language], from 1982 to 2003.

#### **LILACS and BBO:**

LILACS and BBO were searched from 1982 to 2003, using the terms: (*Diagnodent OR laser fluorescence OR laser fluoroscopy*) AND *occlusal* AND not vitro [Words] AND English OR Portuguese OR Spanish [Language].

All types of studies available on these two databases were searched for (theses, dissertations, monographs and papers).

#### **Cochrane Library:**

The text word *diagnodent* was used to search the Cochrane Library.

### *Review methods*

All reports identified by the search were printed out and independently analyzed by two reviewers on the basis of title, keywords and abstract (when available), to check whether the study was likely to be relevant. The full report of all relevant papers was obtained and also when a paper could not be classified. When there was disagreement a third reviewer was consulted to achieve consensus.

The reviewers were not blinded as to authors, journals, date of publication, financial support or results. The inclusion criteria were applied and the data assessed and independently extracted by two reviewers. Consensus was sought in case of discrepancy. This was conducted according to the Users' Guides in the JAMA series on the Rational Clinical Examination<sup>15,17</sup>.

## **Results**

The searches strategies yielded 11 reports from the MEDLINE database. All had been published in the English language between 2001 and 2003. Four of these met the selection criteria after reading the full articles were read. Of the seven reports excluded, 3 were literature reviews and the remaining 4 were *in vitro* investigations.

One of all the selected studies (Anttonen et al.<sup>18</sup>) examined in deciduous and permanent teeth. Nevertheless, only data

related to permanent teeth were appraised in this review. Two reports, published in 2000 and 2001, and in Portuguese language, were found in the LILACS database. These were excluded because the studies were performed on the deciduous dentition.

Three references were found in the BBO database, all in Portuguese language. Two of these were also in the LILACS database; the third was an *in vitro* study.

Four reports in English language were found in the Cochrane Library. All had already been found in the previous databases.

Therefore, four studies were selected for analysis of the methodology and data reliability (Table 1).

## Discussion

The occlusal surface is the area most susceptible to dental caries. It is also the most difficult surface for reliable detection of caries. For this reason, several investigators have attempted to discover a method capable of assisting the clinical examination in diagnosing occlusal caries. Such a method would be highly useful for incipient lesions that otherwise could not be detected by visual examination alone. In fact, this would definitely allow earlier and more conservative treatments, thus ensuring maximum preservation of dental structure.

Among the methods reviewed, laser fluorescence of the DIAGNOdent® appliance (KAVO, Biberach, Germany) has shown to be promising. However, most published articles have been about *in vitro* investigations, the data of which are not easily applied to the clinical setting. For this reason, only clinical studies that tested the accuracy of the DIAGNOdent® laser for diagnosis of occlusal caries were considered in the present literature review. These studies were also expected to use a diagnostic gold standard for comparison. In the present literature review, Lussi et al.<sup>9</sup> (2001), Heinrich-Weltzien et al.<sup>19</sup> (2002) and Anttonen et al.<sup>18</sup> (2003) regarded cavity opening as a gold standard, whereas Sheehy et al.<sup>11</sup> relied on clinical examination. The clinical characteristics achieved were compared to

the histological criteria of an *in vitro* study performed by Lussi et al.<sup>20</sup> in 1999, as well as to DIAGNOdent® (Kavo) manufacturer's criteria. Cavity opening or tooth extraction (for histological analysis) can be considered gold standards for the evaluation of diagnostic methods. However, the opening of cavities should always be avoided in borderline cases, clinical examination is satisfactory, although quite limited<sup>5</sup>. As tooth extraction would only be considered on permanent teeth extracted for orthodontic or prosthetic reasons, the reliability of any investigation is limited.

Another aspect to consider is whether the test results and gold standard were assessed independently of each other. The interpretation of a new test is likely to be influenced by the knowledge of the results of the reference standard (or vice versa). Therefore the independent interpretation of both is highly important. Assessment was accomplished with measurement of the DIAGNOdent® completed independently. As a result, the examinations were not influenced by laser fluorescence values.

Comparison between the results of DIAGNOdent® and a gold standard is represented by values of methodological sensitivity and specificity. In the study reported by Lussi et al.<sup>9</sup>, in which carious dentin was the cut-off point, the sensitivity and specificity of the experimental method (DIAGNOdent®) were 92% and 86%, respectively. When carious enamel was the threshold, sensitivity was about 96%. Similar outcomes were found for the dental caries. Anttonen et al.<sup>18</sup> observed a sensitivity of 92% and specificity of 82% with employment of a cut-off point of 30. Similarly, the study conducted by Heinrich-Weltzien et al.<sup>19</sup> revealed sensitivity values of 93% but the specificity was lower (63%) when compared to the others. The study of Heinrich-Weltzien et al.<sup>19</sup>, on the other hand, observed a specificity 20% lower than the other investigations. This was probably due to the exclusion of caries-free molars, which were assessed but not operatively validated. On the other hand, this procedure avoided the problem of false negative findings, which are common in clinical studies with respect to ethical aspects.

**Table 1:** Selected studies about DIAGNOdent® employed on *in vivo* occlusal surfaces of permanent teeth

Author/ Year	Subjects	Methodology	Results	Conclusion
Sheehy et al. <sup>11</sup> (2001)	170 permanent molars of children with mean age of 6.85± 0.58.	Gold standard: Visual examination, DIAGNOdent® manufacture r's criteria and Lussi et al. <sup>11</sup> (1999) criteria.	Kappa = 0.94 DIAGNOdent® (according to the manufacturer) Sensitivity = 70% Specificity = 87% DIAGNOdent®: according to Lussi et al. <sup>11</sup> (1999) Sensitivity = 100% Specificity = 33%	DIAGNOdent® can be useful as an aid to visual inspection. Alone, DIAGNOdent® is unable to distinguish between hypomineralized caries and stainings DIAGNOdent® values were found to be more similar to those provided by the manufacturer than those reported by Lussi et al. <sup>11</sup> (1999).
Lussi et al. <sup>9</sup> (2001)	332 occlusal surfaces of molars and premolars from 240 patients	Gold standard: opening of cavities	Kappa = 0.93 Spearman coefficient = 0.98 Visual examination: Sensitivity = 31% (in dentine )and 63% (in enamel). DIAGNOdent® Sensitivity = above or equal to 92% (when the cut point was in vivo occlusal carious dentin) and 96% for enamel caries. Bitewing radiography Sensitivity = 63%	DIAGNOdent® > sensitivity than visual inspection.  Combination of visual examination and the DIAGNOdent® is recommended.
Heinrich-Weltzien et al. <sup>19</sup> (2002)	n =97 In the 97 patients, (281 untreated first and second molars with sound occlusal surfaces or enamel and dentinal lesions) were selected. The mean age of the patients was 19.2 years (SD±1.4).	Gold standard: opening of cavities	Visual examination: Sensitivity=25% Specificity= 100%  DIAGNOdent™ Sensitivity= 93% Specificity= 63%  Kappa = 85% for examiner 1 and 91% for examiner 2.  Radiographic examination: Sensitivity= 70% Specificity= 96%	DIAGNOdent® is an important supplement for this purpose, since the recommended  DIAGNOdent® value above 20 as a cut-off for detection of occlusal dentinal caries could be confirmed as a sensitive marker for use in daily practice.  The combination of visual examination, which is highly specific, and the DIAGNOdent® laser, which is highly sensitive, is recommended.
Anttonen et al. <sup>18</sup> (2003)	613 occlusal surfaces on permanent molars in children aged 7-8 (n=55) and 13-14 years (n=54) and 436 surfaces of primary molars.	Gold standard: opening of cavities	Kappa of visual examination = 0.85. The mean values for the first DIAGNOdent® measures was 33.3 and for the second DIAGNOdent® measures that were accomplished four week later was 31.3. The Pearson's correlation coefficient = 0.74 / Intraclass correlation coefficient (ICC) = 0.78. DIAGNOdent® for permanent teeth(according to cut-off 30) Youden's index = 60% DIAGNOdent® for permanent teeth (according to cut-off 30), Sensitivity = 92% - Specificity 69% with visual examination for validation. Sensitivity= 92% Specificity 82% with validation by fissure opening.	In routine dental check-ups of children, DIAGNOdent® appears to be useful as an adjunct to visual examination.

It appears from these data that DIAGNOdent® may provide an accurate diagnosis of occlusal caries. The work published by Sheehy et al.<sup>11</sup> was an epidemiological survey and did not rely on suitable gold standards (cavity opening or histological examination). Consequently, it failed to show very clear sensitivity and specificity data, although they could be estimated from table results. When comparing the clinical results for DIAGNOdent® stated on the manufacturer's table, the outcomes were 87% specificity and 70% sensitivity. Different values were achieved when clinical characteristics were compared to values of an *in vitro* study reported by Lussi et al.<sup>20</sup>. In this case, specificity was 33%, whereas sensitivity was 100%. Such divergence in the results were probably due to the *in vitro* design of the Lussi et al.<sup>20</sup> study, compared to the *in vivo* survey done by the manufacturer. A noticeable finding is that the manufacturer's results were very similar to those revealed by Lussi et al.<sup>9</sup> in 2001, who also elected to conduct an *in vivo* investigation (86% and 92%, respectively). However, sensitivity in the Sheehy et al.<sup>11</sup> study was lower.

With regard to the subjects selected; the inclusion of a spectrum of patients very similar to those of clinical practice was observed in all studies. In fact, the samples contained all occlusal surfaces of any tooth (molar or premolar) from the maxillary or mandibular arches.

Another essential feature to be discussed is the test reproducibility and interpretation, which are directly important for clinical practice. Comparison of the final results to those of other studies requires them to be reproducible. Reproducibility reflects nothing other than the precision of diagnostic instruments. In other words, it represents the agreement of results when an examination is repeated under identical or very similar conditions. Reproducibility is a fundamental characteristic when the goal is to assess the accuracy of a diagnostic method. The kappa coefficient has been employed to measure the agreement of categorical data and seems to be very important for assessment of the reproducibility of a method<sup>21</sup>. When non-categorical quantitative data are being

considered, correlation coefficients seem to be a much better choice<sup>21</sup>. Lussi et al.<sup>9</sup> and Sheehy et al.<sup>11</sup> calculated the kappa value for DIAGNOdent® of 0.98 and 0.89, respectively. Lussi et al.<sup>9</sup> achieved a value of 0.93 in the study for categorical data. Similarly, Anttonen et al.<sup>18</sup> achieved a kappa value of 0.85, whereas Heinrich-Weltzien et al.<sup>19</sup> found a kappa value of 0.75. These figures represent good to excellent agreement. However, being reproducible is not always as important, because a test may be reproducible, but inaccurate.

It should also be mentioned that the test description should be clear enough to permit replication of the study. The DIAGNOdent® method was clearly described in all studies selected.

The results of the studies evaluated allow us to conclude that DIAGNOdent® is a reproducible and accurate diagnostic tool that may be considerably helpful for clinical diagnosis.

Considering the present literature review, the results of which were shown to be acceptable, DIAGNOdent® may be regarded as an auxiliary diagnostic method to aid in disclosure of dental caries in surfaces where they tend to be extremely hidden from the eyes. In turn, this may considerably decrease the risk of false-positive or false-negative diagnosis that could otherwise lead to equivocal and harmful treatments. With the improvement in diagnostic precision, less dental structures will be damaged and the patients will be granted with further clinical profits.

## Conclusion

The literature review demonstrated that laser fluorescence (DIAGNOdent®) is an accurate method for diagnosis of occlusal caries, particularly when associated with visual inspection. Further investigation should however be conducted in populations with caries whose patterns differ from those observed in the evaluated studies. This would certainly broaden the spectrum of teeth with a clinically doubtful diagnosis.

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摘要

本系统评阅旨在使用任何确立的标准评估激光荧光 (DIAGNOdent®) 用于诊断恒齿中咬合面龋齿的准确性。

在由BIREME进入的MEDLINE、LILACS、BBO 和 Cochrane library 数据库中搜索了1982年至2003

年间发表的英语、西班牙语和葡萄牙语的文章。

从中选出了4篇英语的文章。DIAGNOdent® 被发现是诊断咬合面龋齿的一种正确的方法, 特别是与观测检查同时使用时。首次发表于 *J Appl Oral Sci* 2004; 12: 177-81。

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Resumen

Este resumen sistemático fue conducido para evaluar la exactitud de fluorescencia de láser (DIAGNOdent®) para diagnóstico de caries oclusal en dientes permanentes, usando cualquiera clase de patrón oro. Los bancos de datos de biblioteca MEDLINE, LILACS, BBO y Cochrane teniendo acceso por BIREME fueran buscados para papeles en lenguas inglesa, española, y portuguesa publicados entre 1982 y 2003. Cuatro obras en inglés fueran seleccionadas. DIAGNOdent® se encontró ser un método acertado para diagnóstico de caries oclusal, principalmente si empleado simultáneamente con inspección visual. Publicado primero en *J Appl Oral Sci* 2004; 12:177-81,

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Resumo

Esta revisão sistemática foi realizada para avaliar a precisão da fluorescência a laser (DIAGNOdent) para o diagnóstico da cárie oclusal em dentes permanentes, utilizando qualquer tipo de *gold standard*. As bases de dados MEDLINE, LILACS, BBO e Cochrane Library, acessadas via BIREME, foram utilizadas para a busca de artigos em idioma inglês, espanhol e português, publicados de 1982 a 2003. Foram selecionados quatro trabalhos em

inglês. Foi observado que o DIAGNOdent é um método preciso para o diagnóstico da cárie oclusal, principalmente se associado à inspeção visual.

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