Effect of diagnostic method and operator's experience on the detection of occlusal caries in posterior permanent teeth: an *in vivo* pilot study

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Abstract

Objectives: To evaluate the influence of the operator's degree of clinical experience and of the diagnostic technique on the diagnosis of occlusal caries. **Methods and Materials:** Ten patients each with one tooth presenting an occlusal non-cavitated lesion were selected. Ten teeth were examined with four methods: visual inspection; visual inspection and probing; visual inspection and probing under magnification; a laser fluorescence device (DIAGNOdent Pen). Three operators were tested: an undergraduate student; a dentist with 2 years of clinical experience; a general dentist with 10 years of clinical experience. The teeth were then examined by an operator with 20 years of experience in cariology. The diagnosis performed by the latter was considered as reference. The diagnoses of the tested operators were classified as consistent or inconsistent with those of the reference. Uncertain diagnosis was recorded when the operator was unable to perform a diagnosis. Cohen's kappa statistic was applied in order to assess the agreement between the diagnoses performed by the three operators with each diagnostic method and those performed by the reference operator. **Results:** The DIAGNOdent Pen reported the highest number of consistent diagnoses with all the operators and was the sole diagnostic method with which the student did not perform inconsistent diagnoses. Conversely, visual inspection achieved the lowest number of consistent diagnoses for all the operators. The diagnoses performed by the general dentist achieved an excellent agreement with those of the reference operator with all the tested methods. The student obtained an excellent agreement with the reference operator only with the DIAGNOdent Pen. For all the operators the lowest coefficient of agreement was achieved with visual inspection. **Conclusions:** The DIAGNOdent Pen seems to be effective for an undergraduate student to perform a consistent caries diagnosis. Regardless of the operator's experience, the DIAGNOdent Pen results in a higher number of consistent diagnoses compared to the other tested methods. An experienced operator achieves a consistent diagnosis, regardless of the diagnostic technique. **Clinical significance:** The DIAGNOdent Pen could represent an advantageous complementary tool for the diagnosis of occlusal caries, particularly for inexperienced operators.

Key words: *caries diagnosis; DIAGNOdent Pen; operator's experience*
Short title: *Effect of diagnostic method and operator on caries diagnosis*

Introduction

Even though the global incidence of dental caries has decreased in the last decades, caries lesions occurring on the occlusal surfaces of posterior teeth have relatively increased.[1,2] The diagnosis of occlusal caries has always been challenging for the dental clinician, since the morphology of pit and fissures on the occlusal aspect of premolars and molars could hamper the correct detection of carious lesions with the traditional diagnostic methods.[3] The cavitation seems to occur much later nowadays due to the increased use of fluoride, which could lead to the progression of a lesion in dentin beneath clinically intact enamel. The dentist, therefore, often has to deal with non-cavitated occlusal lesions, which make the diagnostic process more difficult.[4-6]

Correct diagnosis of incipient caries warrants attention, since more importance is attributed to a limited sacrifice of

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Table 1

Number of consistent, inconsistent and uncertain diagnoses performed by the three operators with each examined method.

Operator	Diagnostic method	Diagnosis		
		consistent	inconsistent	uncertain
Student	Visual inspection	4	4	2
	Visual inspection and probing	5	2	3
	Visual inspection and probing under magnification	6	1	3
	DIAGNOdent Pen	8	0	2
Young dentist	Visual inspection	5	3	2
	Visual inspection and probing	6	1	3
	Visual inspection and probing under magnification	7	0	3
	DIAGNOdent Pen	9	0	1
General dentist	Visual inspection	7	1	2
	Visual inspection and probing	8	1	1
	Visual inspection and probing under magnification	9	0	1
	DIAGNOdent Pen	10	0	0

dental structure and a minimal therapeutic approach.[7-18] Many methods have been proposed for caries diagnosis, such as visual inspection - with or without magnification - and/or probing, radiographs, transillumination, techniques based on electrical current measurements and dyeing techniques. More recently a laser fluorescence device (DIAGNOdent; KaVo, Biberach, Germany) has been introduced in the clinical practice.[19,20] Each diagnostic method is characterized by sensitivity and specificity, which represent, respectively, the ability to identify diseased and sound teeth. The assessment of the diagnostic accuracy of a certain technique and the comparisons among different methods have been mostly based on the evaluation of these two parameters.[21-31]

The reliability of caries diagnosis could be also dependant on the experience of the operator and on his familiarity with a diagnostic method. In order to become more operator-friendly, the DIAGNOdent device was improved from the DIAGNOdent 2095 type to the DIAGNOdent 2190, better known as DIAGNOdent Pen. The latter, due to its compact size and peculiar design, which resembles the handpiece of a dental unit, should allow for easier use. Even though good intra- and inter-examiner reproducibility has been reported for DIAGNOdent measurements, [21,23,25,29,31-34] to date little information is available on the effect

that the operator's variability could exert on the outcome of *in vivo* caries diagnosis performed with this device.

Thus, the aim of the present pilot study was to assess the performance of four different methods used for the diagnosis of occlusal non-cavited lesions by three operators with different degrees of experience. The null hypothesis tested was that there is no difference in the outcomes of the tested caries diagnostic techniques used by three operators with different degrees of experience.

Materials And Methods

Ten patients aged between 19 and 35 years, each with one posterior tooth (i.e. premolar or molar) presenting a non-cavitated lesion on the occlusal aspect were selected for the study according to a protocol approved by an ethics committee of the University of Siena. Informed written consent was obtained from each patient.

A total of 10 teeth were examined with four different methods for the diagnosis of caries:

Group 1: Visual inspection;

Group 2: Visual inspection and probing;

Group 3: Visual inspection and probing under 2.5× magnification (EyeMag Smart; Carl Zeiss, Jena, Germany);

Group 4: Diagnosis with a laser fluorescence device (DIAGNOdent Pen; KaVo, Biberach, Germany).

Despite the fact that probing is no longer recommended by scientists nowadays, it was included in the present investigation as it has long been performed for caries diagnosis and is still used in many dental offices.

Prior to examination calculus deposits were removed with a hand scaler and a soft rubber prophylaxis cup was used to eliminate discoloration and plaque from the tooth surface. All the diagnostic procedures were performed in a dental unit under a standard operating light. The teeth were briefly dried with an air syringe and then examined. After examination with one of the above mentioned methods each lesion was recorded as carious or non carious. Uncertain diagnosis was recorded if the operator was not able to perform a diagnosis.

The diagnosis of each suspicious lesion was performed separately by three different operators with different degrees of clinical experience:

• Operator 1: An undergraduate student attending final year of the dentistry faculty;
• Operator 2: A young dentist with 2 years of clinical experience;
• Operator 3: A general dentist with 10 years of clinical experience.

Each operator was unaware of the diagnostic evaluations performed by the other two.

The operators were trained in the use of the DIAGNOdent Pen before starting the investigation. All the measurements were performed with the Fissure Probe of the DIAGNOdent Pen device, which was positioned on the target site and rotated around its long axis. In order to identify the area where the eventual carious process was most advanced, the highest value displayed by the device was recorded. The device was calibrated with the ceramic standard disc before each evaluation. A patient-specific baseline reading was performed for each patient on an apparently sound tooth prior to evaluating the lesion. The DIAGNOdent Pen was used following the indications of Lussi & Hellwig[35] regarding the cut-off values for enamel and dentin caries:

• 0-7: Sound tooth;
• 7.1-12: Enamel caries;
• 12.1-19: Deep enamel caries;
• >19: Dentin caries.

Reading values >7 were assumed to predict the presence of caries, whereas values ≤7 indicated no caries.

For the methods based on visual examination (i.e. visual inspection, visual inspection with probing and visual inspection with probing and magnification) the visual diagnostic criteria proposed by Ekstrand et al.[36] were followed:

• Score 0: No or slight change in enamel translucency after prolonged air drying (> 5s);
• Score 1: Opacity or discoloration hardly visible on the wet surface, but distinctly visible after air drying;
• Score 2: Opacity or discoloration distinctly visible without air drying;
• Score 3: Localized enamel breakdown in opaque or discolored enamel and/or greyish discoloration from the underlying dentin;
• Score 4: Cavitation in opaque or discolored enamel exposing the dentin beneath.

The recording of a score 0 was assumed to predict the absence of caries; recordings of scores from 1 to 4 were deemed to predict the presence of caries either in enamel (scores 1 or 2) or in dentin (scores 3 or 4).

When probing was performed, the feeling of "sticking" by the withdrawal of the probe from the fissure was considered predictive of caries.

In order to ensure adequate treatment, all patients were further examined by an operator with 20 years of experience in cariology, who was not involved in the study. The latter was unaware of the diagnoses performed by the other operators and performed his own diagnoses using the methods thought to be the most appropriate, including radiographs where necessary. The subsequent diagnostic outcome was considered as a reference for the validation of the diagnoses performed by the three tested operators and the choice of the treatment indicated for each patient was based on that. When operative intervention was required, the lesion was opened by drilling and the number of teeth correctly diagnosed as carious by the reference operator was recorded.

The diagnoses of the operators involved in the study were classified in the following way:

Consistent diagnosis: When the diagnostic outcome (presence or absence of caries) was in agreement with the evaluation of the 20 years caries-experienced operator;

Inconsistent diagnosis: When there was no agreement between the diagnosis performed and the evaluation of the 20 years caries-experienced operator.

The lesions previously recorded as "uncertain" were also reported but not included in the statistical evaluation.

Statistical analysis

The kappa statistic was applied in order to assess the agreement between the diagnoses performed by the three operators with each diagnostic method and those performed by the reference operator. Kappa coefficients ≥ 0.70 were assumed to indicate excellent agreement. The calculations were handled with the SPSS 12.0 software for Windows (SPSS Inc., Chicago, IL, USA).

Table 2

Cohen's kappa coefficients of agreement between the diagnoses performed by each operator with each tested method and those performed by the reference operator.

Operator	Diagnostic method	Cohen's kappa coefficient
Student	Visual inspection	<0.001
	Visual inspection and probing	0.300
	Visual inspection and probing under magnification	0.696
	DIAGNOdent Pen	1
Young dentist	Visual inspection	0.250
	Visual inspection and probing	0.696
	Visual inspection and probing under magnification	1
	DIAGNOdent Pen	1
General dentist	Visual inspection	0.750
	Visual inspection and probing	0.769
	Visual inspection and probing under magnification	1
	DIAGNOdent Pen	1

Results

All the lesions diagnosed as carious by the caries-experienced operator and subsequently opened by drilling exhibited the presence of carious tissues, thus confirming the diagnosis of the reference operator.

Table 1 reports the number of consistent, inconsistent and uncertain diagnoses performed by each operator with each tested method. Table 2 reports the outcome of the Cohen's kappa statistic.

The DIAGNOdent Pen recorded the highest number of consistent diagnoses for all the operators and was the sole diagnostic method with which the student did not perform inconsistent diagnoses. Conversely, visual inspection achieved the lowest number of consistent diagnoses for all the operators.

The diagnoses performed by the general dentist achieved an excellent agreement with those of the reference operator with all the tested methods. The student obtained an excellent agreement with the reference operator only with the DIAGNOdent Pen. For all the operators the lowest coefficient of agreement was achieved with visual inspection.

Discussion

The outcomes of the tested caries diagnostic techniques used by three operators with different degrees of experience differed among each other. Thus, the tested null hypothesis was rejected.

In the present study the diagnosis of occlusal caries lesions was performed with four different methods by three operators with a different degree of clinical experience. The operator variability has been previously investigated as a potential factor that may affect the outcome of different clinical procedures.[37-41] Dentists with a long clinical background may be more familiar with certain techniques, compared to young dentists at the beginning of their clinical career and to students with limited clinical training. The operators involved in the present study can be considered representative of three completely different levels of clinical experience. According to the results of this study, the number of consistent diagnoses seemed to increase with the operator's experience with all tested diagnostic methods. The coefficients of agreement confirmed this finding, as the general dentist with 10 years of clinical experience was able to achieve an excellent

agreement with the expert in cariology with all the tested techiques. Nevertheless, the limited number of patients included in the present pilot study, and the subsequent small number of examined teeth, could represent a limitation and, therefore, the results of this investigation should be further supported by studies including a higher number of subjects. Closer examination of the results revealed that the DIAGNOdent device was the only diagnostic technique which enabled the dental student not to perform inconsistent diagnoses. This finding might indicate that the device could be effective for inexperienced operators in order to perform a correct diagnosis of non-cavitated caries lesions. Kühnisch et al.[34] observed a good intra- and inter-examiner reproducibility comparing the use of the DIAGNOdent Pen by dental students and experienced dentists on non-cavitated occlusal lesions *in vitro*. The authors noticed that the measurements performed by the students were even more precise than those performed by the dentists, suggesting that the device could be used effectively by inexperienced operators, since its functioning is easy to understand. These *in vitro* results[34] support those of the present clinical investigation.

Several *in vitro*[21,23,26,30,43,44] and *in vivo*[24,25,31,42] studies have compared the effectiveness of different caries diagnostic methods and the results were mostly expressed in terms of sensitivity and specificity. In the present study different diagnostic techniques were compared according to their ability of allowing a consistent diagnosis to that of a reference operator. The Cohen's kappa statistic detected a significant difference among the performances of the diagnostic methods used by the three tested operators, with the DIAGNOdent Pen achieving a coefficient of agreement of 1 for all the operators. Visual inspection showed the worst performance, achieving the lowest number of consistent diagnoses and, subsequently, the lowest coefficients of agreement for all the operators. The number of consistent diagnoses increased progressively when the visual inspection was associated with the use of an explorer and with magnification. It has been reported that visual inspection alone is not completely reliable for the detection of occlusal caries.[6] The inaccuracy of this method could be related to the inability of distinguishing between a non-cavitated carious lesion and a simple staining of the pit or fissure. Furthermore, a lesion extended in dentin beneath intact enamel could be incorrectly identified. The use of a dental probe rose concerns for the diagnosis of non-cavitated lesions, because excessive pressure on the partially demineralised enamel could result in an increase of the cavitation.[45-47]

According to some *in vitro* studies[21,27,28] the DIAGNOdent

device allows for an estimation of the depth of the demineralization process, particularly in the case of enamel lesions, providing more reliable results than the traditional clinical methods. However, the use of the device has not been recommended as the gold standard for caries diagnosis. Nevertheless, to date, the DIAGNOdent has been advised as a complementary diagnostic tool used in combination with the common visual diagnostic techniques, to assist the clinician when taking operative decisions.[21,27,28] This is in accordance with the results of the present study, where the DIAGNOdent was the most effective method in providing consistent diagnoses, even though it was not superior than the other tested methods for an experienced operator.

In the present investigation sensitivity and specificity of the tested diagnostic methods were not calculated, as the diagnosis was expressed only as consistent, inconsistent or uncertain.

The histological evaluation of carious lesions has been considered the gold standard in many *in vitro* studies, in order to validate the diagnostic accuracy of different methods.[21,22,26,28,30,43,44] In *in vivo* studies the validation of the outcomes of different diagnostic techniques has been performed by opening the lesions of the teeth requiring an operative treatment with a drill, and evaluating the lesion's depth with an excavator.[24,25,31] In the present investigation, the diagnosis performed by a caries-experienced operator has been considered as a reference. This way, a comparison of the diagnoses of the three tested operators with those of the reference operator was obtained also for those teeth recorded as sound, which could not be otherwise evaluated due to the ethically unacceptable sacrifice of tissue required for opening the fissures of a probably sound tooth.

Within the limits of this study it might be concluded that the DIAGNOdent Pen seems to be more effective for an undergraduate student when performing a consistent caries diagnosis. Moreover, regardless of the operator's experience, the DIAGNOdent Pen allows for a higher number of consistent diagnoses compared to the other tested methods. An experienced operator achieves consistent diagnosis, regardless of the diagnostic technique.

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