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Using laser fluorescence (DIAGNOdent) in surveys for the detection of noncavitated occlusal dentine caries

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Objective The aim of this study was to evaluate the use of the DIAGNOdent system in epidemiological studies to detect noncavitated occlusal caries lesions, and compare the results with those found in radiographic examinations. ***Methods*** The sample consisted of 1,290 occlusal surfaces of permanent molars, examined in 179 schoolchildren aged 12-15 years. The methods used were: visual inspection, radiographic examination and DIAGNOdent exam, with radiographic examination being considered the gold standard, and noncavitated caries lesions identified in dentin under sound enamel. The inclusion criterion of this study was to have sound occlusal surfaces on visual inspection. The sensitivity and specificity, positive and negative predictive values were used for statistical analysis. ***Results:*** Of the 1,290 surfaces examined during visual inspection, 918 were scored as clinically sound. Of these, 789 were examined by radiographic examination and DIAGNOdent, considering that in more than half of them (410) there were coincident results in the absence of noncavitated lesion in both methods (radiographic examination by DIAGNOdent), with specificity of 74% and negative predictive values of 82% and 155 coincident surfaces with presence of caries, with sensitivity of 64% and positive predictor values of 53% for DIAGNOdent. ***Conclusion*** These results suggest that although DIAGNOdent is not a substitute method for the radiographic examination in surveys, it may be an alternative as an auxiliary to visual inspection.

Key words: DIAGNOdent, epidemiology, noncavitated occlusal caries, radiographic examination.

Introduction

The diagnosis of carious lesions is essential in the prevention and treatment of the disease. Despite the significant reduction in its prevalence in recent decades, the proportion of occlusal carious lesions has increased, and noncavitated occlusal lesions have been considered extremely difficult to detect (Anttonen *et al*, 2003). This difficulty is higher in epidemiological studies, in which the exams have been carried out without the aid of auxiliary diagnostic methods such as radiographic examination or DIAGNOdent.

Earlier, Weerheijm *et al* (1990) described the lesion in noncavitated dentine as one that is not clinically diagnosed using the accepted visual-tactile criteria, such as cavitation, opacity and change of color, but is detected only on radiographs as a radiolucent lesion in dentine. Now, there are carious lesion detection systems (Ekstrand *et al*, 1998; Pitts *et al*, 2004a) that register early visible signs which are considered to be good indicators of presence or absence of an enamel or dentine lesion, even without a visible cavity (Kühnisch *et al*, 2008).

Clinical trials using several methods of detection have demonstrated that the prevalence of noncavitated caries in dentine ranges from around 3% to 50% (Kidd *et al*, 1992; Weerheijm *et al*, 1992). Therefore, in epidemiological studies the radiographic examination could be an auxiliary method to use. However, it is rarely considered appropriate in epidemiological examinations, unless the individuals concerned will receive subsequent dental treatment as part of the study. Other diagnostic methods are also rarely used. Nevertheless, Pitts *et al* (2004b), consider that the availability of reproducible, objective, quantitative detection systems could be a benefit to survey work in the future, when methods using light, laser-induced fluorescence may well provide tools for epidemiological use.

The laser fluorescence system (DIAGNOdent) has the advantage of being simple to use, easy to transport and does not emit ionizing rays as does X-Ray equipment. Furthermore, studies have shown good reproducibility of the examination (Anttonen *et al* 2003; Heinrich-Weltzien *et al*, 2002). However, there are few studies demonstrating the use of DIAGNOdent in epidemiological investigations.

Therefore, the aim of this study was to evaluate the use of the DIAGNOdent in epidemiological studies to detect noncavitated occlusal dentine carious lesions, and to compare its results with those of radiographic examinations.

Methods

Approval for the study was obtained from the Human Research Ethics Committee of Piracicaba Dental School, State University of Campinas (Report n. 067/2003). The exams were performed between August 2004 and June 2005.

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Sample.

The sample size estimate was based on the highest prevalence of noncavitated lesion of 50%, according to earlier studies, adding a loss of 20%, resulting in a total of 327 schoolchildren aged from 12 to 15 years. As this was a multistage sample, firstly 20 schools were selected at random from among all public schools in Piracicaba, Brazil. In the second stage, from a list of all the schoolchildren aged 12 to 15 (a total of 6,994) at these 20 schools, a sample consisting of 327 children was required. Next, 6,994 was divided by 327 = 21. After this, a number between 1 and 21 was randomly drawn, which happened to be 19. This was considered to be the random starting number. Thus the 19th child on the list was selected as the first individual of the sample, and after this every 21st child was chosen until the total of 327 had been selected.

In this study, the exclusion criteria were as follows: children whose parents did not sign a consent form and children who were not within the stipulated age bracket.

The examiner training and calibration process took place in daily sessions, for a total of 36 hours, with theoretical and practical training. The intraexaminer agreement for the visual exam was 0.9 (unweighted Kappa).

The visual inspection was performed by one examiner under natural light, using a dental mirror No 5 and ball-ended CPTIN probes, indicated for epidemiological surveys of oral health (WHO, 1997).

After the diagnosis resulting from this first exam, children who had at least one sound first or second permanent molar remained in the research program.

Radiographic Examination (RE)

The radiographs were taken of the same sound teeth selected during the visual inspection. They were taken using an X Prodental 70 Intra appliance (60 kV, 10 mA, 0,4 s; Prodental Equip. Odontol., Ribeirão Preto, Brazil), with bitewing positioners (Jon Han Shin PF 682, Jon Ind., São Paulo, Brazil) and Kodak Ultraspeed Film (Eastman Kodak Company, Rochester, USA), followed by processing in an automatic processor.

The radiographs were assessed by the same examiner who had performed the visual examination; however, in different situations, so that the results of the first exam did not influence the radiographic examination. The assessments were performed under ideal conditions for radiographic interpretation, at 2x magnification in a dark room using a standard radiographic illuminating box and peripheral light block out. The criteria used were proposed by Ekstrand *et al* (1997) as shown in Table 1.

After the radiographic examination the dental surfaces were cleaned (toothbrush prophylaxis) and dried with compressed air. After this, the occlusal surfaces of the same teeth were examined by DIAGNOdent by the same examiner.

To obtain the DIAGNOdent readout, a probe tip A (for occlusal surfaces) was used and the device was calibrated according to the manufacturer's instructions. The probe device was calibrated against the porcelain reference object and calibrated on a sound surface of the tooth itself prior to the examination of the suspected site. The tip was then placed perpendicular to the occlusal fissure and slightly tilted circular movements were performed along the entire fissure. The maximum fluorescence reading was recorded for the site. This laser fluoresce reading was subtracted electronically from the fluorescence of the occlusal site under examination. The criteria used are shown in Table 2.

Statistical Analyses

The sensitivity and specificity were calculated, the radiographic examination being considered the "Gold Standard". The authors based their evaluation on the definition of a noncavitated lesion being one non-clinically diagnosed by accepted visual-tactile criteria such as cavitation, opacity and change of color, but which is detected only on radiographs as a radiolucent lesion extending into dentine.

The results of visual inspection, radiographic examination and DIAGNOdent were compared and the following criteria were considered: a sound occlusal surface in the visual inspection would be sound by criteria R0 and R1 on the radiographic examination, and D0 and D1 by DIAGNOdent; and noncavitated occlusal caries would be decayed by R2, R3 and R4 on the radiographic examination and D2 by DIAGNOdent.

Data were processed by using Excel 97 software (Microsoft Corp., Redmond, Washington).

Results

A total of 54.7% of the parents agreed to participate hence 179 children were examined.

Visual Examination

Of the 1,290 occlusal surfaces of permanent molars examined in the 179 children chosen, 918 (71.2%) were clinically sound, 296 (22.9%) filled and 76 (5.9%) decayed. About 30% of the schoolchildren had no obvious dentin caries (DMFT=0). The mean DMFT of the group was 2.3.

The re-exam was performed in 10% of the children, and the intraexaminer agreement was 0.94 (unweighted Kappa).

Table 1. Criteria used in the radiographic examination, Ekstrand *et al*, 1997.

Score	*Criteria*
R0	No radiolucency visible
R1	radiolucency visible in the enamel
R2	radiolucency visible in the dentine but restricted to the outer 1/3 of the dentine
R3	radiolucency extending to the middle 1/3 of the dentine
R4	radiolucency in the pulpal 1/3 of the dentine

Table 2. Criteria used for DIAGNOdent

Score	*Criteria*
D 0 (00-20)	Sound
D 1 (21-30)	Enamel lesion
D 2 (31-99)	Dentine lesion

Radiographic Examination

Of the 918 occlusal surfaces diagnosed as sound during the visual examination, 129 (14%) were excluded from the radiographic analysis because they had orthodontic bands and also due to problems related to the radiograph itself during processing, such as distortion and flaw. Therefore, 789 surfaces were assessed by radiographic examination.

Of the 789 surfaces analyzed, 523 (66.2%) presented no radiolucency suggesting caries (R0); 25 (3.2%) presented radiolucency in the radiographic examination suggesting enamel caries (R1); 231 (29.3%) presented caries in the outer third of the dentine (R2), and 10 (1.3%) in the middle third (R3 and R4); that is, 241 noncavitated carious lesions in dentine (Table 3).

The re-exam was performed in 10% of the radiographs, and the intra-examiner agreement was 0.61 (unweighted Kappa).

DIAGNOdent

Of the 789 occlusal surfaces diagnosed as sound during visual inspection 361 (45.8%) were considered sound using DIAGNOdent (D0), 135 (17.1%) presented demineralization in the enamel (D1) and 293 (37.1%) in the dentine (D2) (Table 3).

Of the 548 surfaces that presented noncavitated lesions on the radiographic examination (R0+R1), 410 (74.8%) also presented no carious lesion in the DIAGNOdent (D0+D1); however, 138 (25.2%) presented (D2). Of the 241 surfaces with noncavitated lesion by radiographic examination (R2+R3), 155 (64.3) also presented carious lesion using DIAGNOdent (D2) and 86 (35.7) presented no lesion (D0+D1). These results showed specificity of 74%, sensitivity of 64%, positive predictor values of 53% and negative predictor values of 82%.

Of the 293 surfaces diagnosed as D2 (dentin caries) using DIAGNOdent 127 (16.1%) were R0 using radiographic examination, 11 (1.4) were R1 and 145 (18.4) were R2. Only the surfaces scored as R3 and R4 (deep caries) on the radiographic examination agreed with the results of the DIAGNOdent as showed in Table 4.

Table 5 shows the agreement between the examinations with 410 sound surfaces (true-negative) and 155 decayed surfaces (true-positive); and disagreement with 138 decayed surfaces (false-positive) and 86 sound surfaces (false-negative).

The number of lesions detected by each method and the percentage of additional lesions in the visual inspection which were diagnosed using both radiographic examination and DIAGNOdent (19.6%) are shown in Table 6.

Discussion

At present, occlusal carious lesions represent the majority of lesions found in permanent teeth (Hanningan *et al*, 2000). The use of fluoride in caries prevention changed the pattern of the disease, making it difficult to diagnose by traditional methods. The changes in lesion morphology could lead to the presence of occlusal dentine caries

Table 3. Number and percentage of sound and decayed occlual surfaces in the radiographic examination and DIAGNOdent in teeth considered sound in the visual inspection (WHO).

	Sound				*Decayed*					
Radiographic Examination	*R0*		*R1*		*R2*		*R3*		*R4*	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
	523	66.2	25	3.2	231	29.3	7	0.9	3	0.4
Total	548 (69.4%)				241 (30.6%)					

Diagnodent	*D0*		*D1*		*D2*	
	n	*%*	*n*	*%*	*n*	*%*
	361	45.8	135	17.1	293	37.1
Total	496 (62.9%)				293 (37.1%)	

Table 4. Distribution of DIAGNOdent categories related to radiographic examination.

		Radiographic examination										*TOTAL*
		R0		*R1*		*R2*		*R3*		*R4*		
		n	*%*	*n*	*%*	*N*	*%*	*n*	*%*	*n*	*%*	
DIAGNOdent	D0	308	39.1	7	0.9	46	5.8	0	0	0	0	361
	D1	88	11.1	7	0.9	40	5.1	0	0	0	0	135
	D2	127	16.1	11	1.3	145	18.4	7	0.9	3	0.4	293
	TOTAL	523	66.3	25	3.1	231	29.3	7	0.9	3	0.4	789

Table 5. Number of occlusal surfaces examined by radiographic examination and DIAGNOdent.

Score	*DIAGNOdent*		*Total*
Radiographic Examination	*0-30*	*>30*	
R0 and R1	410[a]	138	548
R2 and R3	86	155[a]	241
Total	496	293	789

[a] Agreement between two sistems

Table 6. Occlusal dentine caries detected by all methods (n=789).

Lesions detected by visual inspection	76
Lesions detected by radiographic examination	241
Lesions detected by DIAGNOdent	293
Lesions detected by radiographic examination and DIAGNOdent (results agreement between them)	155
Percentage of coincident lesions between the radiographic examination and DIAGNOdent added to visual inspection	19,6%

under a fissure which appears to be intact to the naked eye (Lussi *et al*, 1999). This difficulty is also present in epidemiological studies, in which auxiliary diagnosis methods are rarely used.

In Brazil, a continental-sized country with diverse social-economical realities, the major part of epidemiological studies are conducted using the WHO criteria without air-compressed equipment and artificial light or the aid of auxiliary diagnostic methods, which makes it even more difficult to detect noncavitated lesions in enamel or in dentine.

Considering the definition of noncavitated dentine caries (hidden caries) described by Weerheijm *et al* (1990), and the impossibility of performing a histological analysis in this study, the radiographic examination was used as the gold standard to test the accuracy of the DIAGNOdent in epidemiological studies. This method (radiographic examination) is considered efficient because it indicates a direct relation to mineral loss. (Huysmans and Longbottom, 2004).

The conventional radiographic examination is not able to detect early caries lesions limited to the enamel, but when this examination is used with visual inspection, it significantly increases the accuracy of the diagnosis of occlusal dentine caries (Ekstrand *et al*, 1997). The results of the present study confirmed these data, since the 30% of the surfaces considered sound in visual inspection (WHO) were considered decayed in the radiographic examination.

In vivo studies tested the accuracy of the DIAGNOdent after minimal operative intervention (Anttonen *et al*, 2003; Heinrich-Weltzien *et al*, 2002; Lussi *et al*, 2001) and found sensitivity values between 92% and 93%, and specificity between 82% and 86%, which were considered good values. Another *in vivo* study (Kühnish *et al*, 2008), which had epidemiological characteristics similar to those of the present study, demonstrated that noncavitated carious lesions could be somewhat "overscored" with the DIAGNOdent device, when compared with the use of the ICDAS II criteria.

Of the 789 surfaces examined using the two methods (radiographic examination and DIAGNOdent), 565 (71.6%) presented coincident results, being 52% of the 565 negative results (absence of disease) and 19.6% positive (presence of disease); that is, when it is impossible to use the radiographic examination in epidemiological studies, the DIAGNOdent could detect about 19.6% more lesions than would be detected by visual inspection only (considering the radiographic examination as the gold standard), which could contribute to a planning strategy closer to reality.

Nevertheless, when the sensitivity and specificity of the method are analyzed, the results of this study were lower than those of the majority of the studies mentioned previously, mainly as regards sensitivity. This difference can be related to professional cleaning and drying of the teeth. Although the majority of the studies included previous drying of the teeth when the DIAGNOdent exam was performed (Heinrich-Weltzien *et al*, 2002; Rocha *et al*, 2003), this was not done in the present study, because in epidemiological studies conducted in Brazil, compressed air is rarely used to dry teeth. The aim of this study was to evaluate the performance of DIAGNOdent according to the reality of these studies. However, according to Mendes *et al* (2004), the fluorescent signals for wet surfaces show only small differences in measurements in the same site, when dry, and they do not seem to interfere in the result of the diagnosis. With regard to cleaning, the professional used a toothbrush to perform this, however, in some studies, such as that of Aleksejuniene *et al* (2006), it was even considered unnecessary, when the presence of biofilm did not influence the DIAGNOdent readout. The population assessed in the present study did not show a high score of enamel defects (Cypriano *et al*, 2003); however, there is no guarantee that no occlusal surface was affected or that all of them were stain-free.

The lesions which were not diagnosed by the radiographic examination are another aspect to consider. Lussi *et al* (2001) compared the radiographic examination and the DIAGNOdent in an *in vivo* study, in which the radiographic examination diagnosed 45% of the lesions, and the DIAGNOdent more than double this value. Even so, when various methods of diagnosis were compared, Rodrigues *et al* (2008) showed that the probability of dentine caries detection was higher for radiographic examination and DIAGNOdent. If this comparison had been made in the present study, although this was not the objective, the percentage of carious lesions in dentine diagnosed by DIAGNOdent would have been slightly higher than the percentage diagnosed by radiographic examination.

The results of the present study corroborate the studies suggesting that the combination of methods would be the best choice to detect noncavitated dentine caries even in epidemiological studies. Thus, the DIAGNOdent system can be useful in epidemiological studies as an auxiliary to visual inspection.

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