Laser fluorescence on dental caries detection under epidemiological setting

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Abstract

Aim: To evaluate reproducibility of visual exam under artificial lighting (VI) and DIAGNOdent™ (DD) exams, their validity and their association (VI+DD) in examining occlusal dental surfaces under epidemiological setting. **Methods:** One hundred and sixty five 12-year-old schoolchildren from public schools from Piracicaba, SP, Brazil, were examined under epidemiological setting using different diagnostic criteria (D1, D1+D3 and D3). Kappa statistics was adopted for reproducibility study, while sensibility, specificity and accuracy were adopted for validity study. **Results:** The intra/interexaminer Kappa for VI and DD exams at D1, D3 and D1+D3 criteria were 0.88/0.82 and 0.04/0.18, 0.91/0.85 and 0.36/0.35, 0.88/0.83 and 0.30/0.32, respectively. The VI was the most accurate exam at D1 (A=87.38%) and D1+D3 (A=82.45%) criteria, while VI+DD was the most accurate exam at D3 criterion (A=75.29%). **Conclusions:** Initial caries lesions can be satisfactorily detected by VI exam, while DD exam improved the VI exam sensitivity at D1 and D3 diagnostic criteria under epidemiological setting.

Keywords: dental caries, epidemiology, dental health surveys, diagnosis; lasers.

Introduction

Dental caries is currently seen as the reflex of signs of a past or ongoing disease, resulting from the dynamic balance between de-/re-mineralization of hard dental tissues, being reversible provided it is detected early. Dental caries is a process beginning with subclinical manifestations of enamel demineralization at atomic level, culminating in spontaneous cavitation of dental surface. The closest dentists can come to measuring the carious process itself is by the clinical detection of evidence of past occurrence of this process on the dental surfaces[1].

One of the challenges of modern dentistry is the early diagnosis of dental caries in occlusal tooth surfaces, particularly in children and young adults. Dentists are faced with a new epidemiological profile of this disease, characterized by a considerable portion of the world's child population being free of dental caries, with less prevalence of cavited carious lesions and greater prevalence of initial carious lesions in dental enamel, an increasing prevalence of 'hidden caries' lesions

in dentin, and polarization of dental caries through underprivileged socioeconomic groups[2-5].

New methodologies and diagnostic adjunct technologies have been suggested to improve the precision of the diagnosis of initial carious lesions[5-8]. Laser fluorescence measurement of the hard dental tissues has shown to be quite promising for this purpose[9-10]. The aim of this study was to evaluate the reproducibility and validity of dental occlusal caries exams under epidemiological setting in a 12-year-old schoolchildren group.

Material and methods

This study was approved by the Ethics Committee of Piracicaba Dental School/UNICAMP (protocol #082/2006), and conducted in accordance with resolutions 196/96 from the National Health Council of the Brazilian Ministry of Health, and 179/93 of Dental Professional Code of Ethics from Brazilian Dental Council. The study was conducted under a cross-sectional design in two stages. Participation was voluntary and written informed consent was obtained from all children's parents/caregivers.

Stage 1

The reproducibility of the visual exam under artificial lighting (VI) and the laser fluorescence exam performed with DIAGNOdent™ 2095 (KaVo, Biberach, Germany) (DD) on posterior tooth occlusal surfaces, under epidemiological conditions, was verified. One benchmark examiner and 3 experienced examiners participated. The examiners were submitted to nine 4-hour training/calibration sessions conducted by the benchmark examiner.

The sample included thirteen 12-year-old randomly selected children enrolled in a public school of Piracicaba, SP, Brazil, presenting low to high prevalence of dental caries,

who had not participated in the examiners' previous clinical training. Children with fixed orthodontic appliances, severe fluorosis and enamel hypoplasia or serious systemic disease were replaced by children free of such conditions. This number of participants and the interval between the calibration sessions was based on Assaf et al. (2006)[5].

VI was performed with a flat buccal mirror, CPI probe (debris removal) and artificial lighting. All children performed supervised toothbrushing for 2 min (Bass modified with fluoridated toothpaste) before the dental examination. Each dental surface was dried for 5 s[5] with a compressed air jet from a portable dental unit (Proquest Delivery System, model 4010; Compressor Technologies Ltd, Englewood, NJ, USA) before the exams. At D1 diagnostic criterion, the tooth condition was codified on 'with initial lesions on enamel' and 'without such condition'. At D1+D3 diagnostic criterion carious lesions ('cavited or not' and 'none') in enamel and/ or dentin were registered. At D3 diagnostic criterion, only dental caries in dentin or none, according to conventional World Health Organization (WHO) diagnostic criterion[11] and suspected 'hidden caries' lesions were registered. The criteria and codes adopted as D1+D3 and D3 criteria were based on Assaf et al. (2006)[5] (Table 1).

The DD exam was accomplished in accordance with manufacturer's recommendations. However the scale for interpreting and classifying its readings were defined by Zanin et al. (2005)[12] (Table 1).

The interexaminer agreement was obtained at first calibration session. For intraexaminer agreement, a second calibration session was performed after a 10-day interval to avoid bias memorization[5]. The weighted Kappa statistics was adopted. The data obtained were not dichotomized.

Stage 2

The sample for this stage included 165 randomly selected 12-year-old schoolchildren with the same clinical

Table 1. Codes for dental exams

Visual exam		DIAGNOdent™		Bitewing (benchmark examiner)	
Code	Classification	Code (reading values)	Classification	Code	Classification
0	Sound	0 (0 – 10)	Sound surface	0	Absent surface
IL	Enamel initial carious lesions	1 (11 – 20)	Enamel carious lesions	R1	Radiolucency in enamel
1	Decayed	2 (21 – 99)	Dentin carious lesions	R2	Radiolucency in enamel/outer dentin
1IL	Decayed + initial lesions			R3	Radiolucency in dentin
2	Filled, with decay			4	Filled
2IL	Filled, with decay + initial lesions		5	Sound	
3	Filled			R6	Impossible diagnosis
3IL	Filled + initial lesions				
4	Missed by caries				
5	Missed by other reason				
6	Sealant				
6IL	Sealant + initial lesions				
7	Bridge abutment, special crown or veneer/implant				
8	Unerupted tooth				
T	Trauma				
9	Not recorded				

characteristics of the Stage 1. A total of 2,187 occlusal surfaces were examined. The examiner who had the highest intraexaminer Kappa values in Stage 1 was selected to conduct the exams. The validity of VI, DD and VI+DD exams was evaluated. The data were dichotomized in 'with' and 'without caries'. The SAS System for Windows™ 9.1 (SAS Institute Inc., Cary, NC, USA) was used at both stages.

At D1 diagnostic criterion, the validation standard was the VI exam performed by benchmark examiner, while for D1+D3 diagnostic criterion, it was VI exam combined with bitewing radiography exam (VI+BW) performed by benchmark examiner. The VI+BW exam enables a more refined detection and evaluation of occlusal carious lesion depth, especially when the carious lesion is confined to dentin[13]. Although the value of bitewing radiograph has been questioned in epidemiological surveys[14], it has been proven important in studies in which histological validation or tooth drilling is unfeasible and unethical[13], especially when suspicious carious lesions are confined in enamel.

The sample DMF-T index was 1.00 (SD = 1.65) according to WHO diagnostic criterion[11]. When enamel initial carious lesions were detected, the DMF-T index was 5.74 (SD = 4.29). The difference among the DMF-T index obtained by dental exams under all diagnostic criteria was evaluated by ANOVA and Tukey's test. Significance level was set at 5%.

Results

The reproducibility for VI and DD exams is presented in Table 2. The intraexaminer agreement was 'almost perfect' for the VI exam at all diagnostic criteria. However, the intraexaminer agreement for the DD exam was 'slight' at D1 criterion and 'fair' for the others criteria. The intraexaminer agreement was 'fair' at D1 and 'moderate' at D3 and D1+D3 criteria for the benchmark examiner performing DD exam (Table 2). The interexaminer agreement was 'almost perfect' for VI exam at all diagnostic criteria. For the DD exam, the interexaminer agreement was 'slight' at D1 and 'fair' at the

others criteria (Table 2).

The number of carious lesions detected by VI, DD, VI+DD examinations, and by the benchmark examiner (VI+BW exam) is expressed in Table 3. The VI+DD exam detected the largest number of occlusal caries for all diagnostic criteria. A trend to overestimate caries detection was observed for VI+DD exam under D1 and D1+D3 criteria in relation to benchmark examiner (Table 3).

The validity of the VI, DD and VI+DD examinations is presented in Table 4. At D1 criterion, the highest sensitivity was found by VI+DD exam. At D3 criterion, the highest sensitivity was found by DD exam; the highest accuracy was found for DD and VI+DD exams at this diagnostic criterion. At D1+D3 criterion, the highest value for sensitivity was found for the VI+DD exam, however the best accuracy was observed for VI exam (Table 4).

Differences among the DMF-T indexes obtained by VI, DD and VI+DD exams, at D3 and D1+D3 criteria were revealed by the Tukey's test (Table 5).

Discussion

In view of the current dental caries development profile, seeking new methodologies and diagnostic methods that can identify its earliest stages is the intention of dentists in order to accomplish more conservative and effective treatment plans. Likewise, researchers can use different study designs and conduct studies that can prove or refute their hypotheses[6-8,15-18]. The

Table 3. Number of carious lesions detected by the dental exams

	D1	D3	D1+D3
VI	721	30	729
DD	345	337	682
VI+DD	870	341	980
VI+BW	755	652	953

VI: visual exam under artificial lighting; DD: DIAGNOdent™; BW: bitewing radiography exam.

Table 2. Reproducibility for dental exams

	Visual Exam					
	1st Calibration			**2nd Calibration**		
	D1	D3	D1+D3	D1	D3	D1+D3
INTRA	–	–	–	0.88 (0.89)	0.91 (0.93)	0.88 (0.89)
	–	–	–	[0.87 – 0.89]	[0.86 – 0.95]	[0.88 – 0.89]
INTER	0.82	0.85	0.83	0.83	0.83	0.84
	[0.81 – 0.83]	[0.81 – 0.87]	[0.82 – 0.84]	[0.81 – 0.87]	[0.80 – 0.86]	[0.82 - 087]
	DIAGNOdent					
	1st Calibration			**2nd Calibration**		
	D1	D3	D1+D3	D1	D3	D1+D3
INTRA	–	–	–	0.04 (0.32)	0.36 (0.50)	0.30 (0.46)
	–	–	–	[0.01 – 0.06]	[0.23 – 0.52]	[0.23 – 0.39]
INTER	0.15	0.35	0.32	0.18	0.77	0.60
	[0.07 – 0.21]	[0.23 – 0.54]	[0.26 – 0.39]	[0.04 – 0.30]	[0.75 – 0.80]	[0.56 – 0.66]

( ) Benchmark examiner's Kappa value
[ ] Examiners' Kappa value intervals

Table 4. Validity of the dental exams

Exams	D1			D3			D1+D3		
	Sn	Sp	A	Sn	Sp	A	Sn	Sp	A
VI	79.47	91.55	87.38	3.85	99.67	71.21	68.10	93.52	82.45
DD	26.16	88.37	66.10	36.10	92.04	75.24	57.10	85.71	73.03
VI+DD	83.31	83.17	83.22	34.67	92.45	75.29	80.48	82.74	81.75

VI: visual exam under artificial lighting; DD: DIAGNOdent™.
Sn = sensitivity; Sp = specificity; A = accuracy

Table 5. DMF-T index for dental exams

Exams	D3		D1+D3	
	DMF-T*	SD**	DMF-T	SD
VI	0.46a	0.80	4.93b	3.70
DD	2.12b	2.00	4.13a	2.93
VI+DD	2.71c	2.18	6.60c	3.71

VI: visual exam under artificial lighting; DD: DIAGNOdent™
* Different letters indicate statistically significant difference (p<0.05)
** Standard deviation

D1+D3 criterion is more refined than the conventional WHO diagnostic criteria and has shown to be successful in this task[2,5]. In the present study, the D1+D3 criterion was responsible for a 574% increase in the DMF-T index at D3 criterion for the sample on Stage 2. Although the diagnostic complexity increases with D1+D3 in relation to D3, an increase on the accuracy of VI and VI+DD exams was verified. A further step searching for a more accurate dental caries diagnostic is the addition of diagnostic adjuncts to the traditional visual clinical exam.

The present study evaluated the reproducibility and validity of caries detection by laser fluorescence according to the D1, D3 and D1+D3 diagnostic criteria, under epidemiological setting. This adjunct technology is based on the principle that demineralized dental surfaces colonized by bacteria and exposed to their metabolites exhibit an increased fluorescence in comparison with sound enamel when excited by a diode laser beam (655 nm) emitted by DIAGNOdent™. Because of its high sensitivity, but low specificity, the combination of DIAGNOdent™ with traditional diagnostic methods, such visual exam, is justified[10,19]. However a great deal of the studies evaluating this technology is performed under laboratorial and/or clinical conditions, not under epidemiological conditions. This way, the preliminary comparisons made in this study, as well its design, require caution in both interpretation and generalization.

The intraexaminer reproducibility of DD examination concerning all diagnostic criteria was lower than in *in vitro* studies[16] and *in vivo* clinical trials[12,17]. This can reflect the difficulty to keep an adequate oral hygiene level in epidemiological conditions and that the presence of plaque on dental occlusal surfaces worsens DIAGNOdent™ accuracy[20-21]. Although DIAGNOdent's™ manufacturer recommends previous professional prophylaxis, the previous supervised toothbrushing adopted in this study can be implemented with similar success[20]. After that, vigorous oral rinse was performed to remove any toothpaste residues, which could interfere on DIAGNOdent™ readings[20-21]. Drying of

dental surface to be examined was also performed as recommended[5,22]. The Kappa values of the second calibration session for interexaminer agreement were higher than those of the first session, suggesting that the oral hygiene level improved during this period. The reproducibility of DD exam contraindicates its use on epidemiological surveys. The reproducibility was more influenced by the examination setting than the examiners' ability to operate the DIAGNOdent™ device.

An accuracy of at least 80% was obtained by VI and VI+DD exams at D1 and D1+D3 criteria. The lower values of sensitivity and accuracy for dental examinations at D3 criterion are due to the validation method adopted (VI+BW exam), which is more sensitive than the dental examinations adopted, detecting dentin carious lesions under sound enamel, which are not detectable by the visual exam alone. So, the sensitivity was extremely low for VI examination at D3 criterion.

The assertive that DD exam should be used as an adjunct diagnostic tool[6,8,10,18] is corroborated by the sensitivity values for VI+DD exam under D1 and D1+D3 criteria. However the accuracy values of VI+DD exam were slightly inferior to the accuracy of VI exam at D1 and D3 criteria. Although an increasing VI exam sensitivity can be seen, the good results of the DD exam found in clinical setting[17] were not found in the present study.

As in a previous study by Pereira et al.[9], data available from multiple diagnostic methods did not improve the accuracy of examiners, but it influenced the number of surfaces indicated for operative treatment. For D1 and D1+D3 criteria, the combination of DD with VI decreased its accuracy. However, the number of surfaces indicated to treat was overestimated with VI+DD exam in relation to benchmark examiner. The DD exam increased the accuracy of VI for D3 criteria. Discrepant amounts of caries detected between dental exams and benchmark examiner for D3 criterion was due to validation method. For D3 criterion, VI+BW exam allowed detecting more dental caries than the other diagnostic methods.

The financial costs of the inclusion of the bitewing radiograph and DIAGNOdent™ examinations in dental caries surveys are limitations to the use of these adjuncts on such surveys. However, when the public health services support financially those epidemiological surveys such limitations can be solved. In epidemiological dental caries surveys, the bitewing radiograph must be used for suspicious cases only due to the ethical concerns.

Another limitation of this study was the validation process. Facing to the actual prevalence of initial carious

lesions in enamel, treatable by preventive proceedings, other ways to validate diagnostic methods, that are not histological (extracting teeth) or biopsy (drilling suspicious surfaces) are necessary. The VI + BW exam adopted in this study, although it is far from the ideal method, was one of them. More and more, detection of initial carious lesions is necessary for planning actions in oral public health services[3]. A meticulous visual examination using D1 criterion was sufficient for this purpose, corroborating with Heinrich-Weltzien et al.[17]. For D3 and D1 + D3 criteria, the DIAGNOdent™ showed its potential to supplement the VI exam on epidemiological surveys[18,23]. However, caution and additional *in vivo* studies, under epidemiological settings, are needed to corroborate or refute those results.

The results of the present study reveal that a meticulous visual exam is sufficient to detect initial carious lesions in enamel using D1 diagnostic criterion. It was also observed that the combination of laser fluorescence and visual exam improved its sensitivity according to D1 and D3 diagnostic criteria under epidemiological setting.

Acknowledgements

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