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Occlusal caries diagnosis in permanent teeth: an *in vitro* study

Diagnóstico de cárie oclusal em dentes permanentes: estudo in vitro

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ABSTRACT: The reduction in caries prevalence has not occurred uniformly for all dental surfaces. As the occlusal surfaces are still the most likely sites for the development of lesions, new methods of diagnosis are still being evaluated. This study compared a laser fluorescence (LF) system (DIAGNOdent) with the Ekstrand's visual system for *in vitro* detection of occlusal caries. A total of 57 extracted molars with macroscopically intact occlusal surfaces were selected. Two-examiners assessed 110 sites by visual inspection (VI) and LF. After ten days from the first measurement, all teeth were re-evaluated through the same methods by each examiner. Caries extension was histologically assessed (X 40). The methods were compared by means of sensitivity, specificity, intra- and inter-examiner reproducibility and area under the ROC curve. The kappa's test showed good intra- and inter-examiner reproducibility for both methods. VI and LF showed similar sensitivities for both examiners, however, VI showed higher specificities than LF. The overall analysis, as demonstrated by the area under the ROC curve, showed that VI had a better performance than the LF device. It was concluded that the Ekstrand's visual system is more reliable than the LF device. LF should be considered only as an adjuvant for occlusal caries diagnosis.

DESCRIPTORS: Lasers; Fluorescence; Dental caries; Molar; Diagnostic techniques and procedures.

RESUMO: A redução da prevalência de cáries não ocorreu uniformemente para todas as superfícies dentárias. Como as superfícies oclusais ainda são as mais susceptíveis ao desenvolvimento de lesões, novos métodos de diagnóstico ainda estão sendo avaliados. Este estudo comparou um sistema de fluorescência a laser (DIAGNOdent – DD) com o método visual de Ekstrand na detecção de cárie oclusal. Um total de 57 terceiros molares com superfícies oclusais macroscopicamente intactas foram selecionados. Dois examinadores examinaram 110 sítios por inspecção visual (IV) e DD. Após dez dias da primeira mensuração, todos os dentes foram novamente avaliados pelos mesmos métodos. A extensão de cárie foi validada por exame histológico (40 X). Os dados foram analisados quanto a sensibilidade, especificidade, reprodutibilidade intra e interexaminador e área sob a curva ROC. O teste kappa demonstrou boa reprodutibilidade intra e interexaminadores para ambos os métodos. A IV e o DD apresentaram sensibilidade semelhante para ambos os examinadores, entretanto, a IV apresentou maior especificidade que o DD. A análise geral, através da área sob a curva ROC, mostrou que a IV teve um melhor desempenho que o DD. Concluiu-se que o critério visual proposto por Ekstrand é mais confiável para o diagnóstico de cáries oclusais. O DD deve ser considerado apenas como um coadjuvante no exame de cárie em superfícies oclusais.

DESCRITORES: Lasers; Fluorescência; Cárie dentária; Molar; Técnicas de diagnóstico e procedimentos.

INTRODUCTION

Despite the fact that the prevalence of dental caries has declined considerably, it is still a problem of great importance, mainly in Brazil. The reduction in caries prevalence has not occurred uniformly for all dental surfaces and the occlusal surfaces are still the most likely sites for the development of lesions.

Several methods of dental caries diagnosis have been used for more than half a century. Although there are known drawbacks, visual inspection (VI) alone has been claimed to be the best diagnostic method in populations with low caries prevalence, but it is unable to correctly detect caries lesions because of its low sensitivity[12]. On the

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other hand, the use of a sharp probe along with the visual method does not appear to improve the diagnostic accuracy[16,21]. It may contaminate other sound sites[14], damage the fissure[3] as well as facilitate the lesion's progression[29].

The main drawbacks of the conventional methods are that they still rely on the dentist's subjective interpretation, that it is difficult to evaluate a lesion's progression and that some clinicians decide on an unwarranted invasive intervention. In the search for more accurate diagnostic approaches, investigators have used alternative non-invasive and instrument-based techniques for detecting and quantifying demineralization lesions[5,11,18]. These techniques include electrical conductance measurements, light scattering and quantitative laser/light induced fluorescence (LF). A new device is the KaVo DIAGNOdent® (KaVo, Biberach, Germany), which generates a laser light that is absorbed by both inorganic and organic tooth substances and by metabolites from oral bacteria[11]. In the presence of caries, light with a higher wavelength is re-emitted, and the changes are registered in a digital number scale. Promising results have been published with this LF device[2,18,19,24,27]. However, its accuracy still lacks further studies that should be conducted in order to verify how far this method works in other samples.

The LF device can be considered a valuable tool as an adjunct to visual inspection mainly for long-term monitoring of caries and for assessing the outcomes of preventive interventions, as the caries progress can be quantitatively measured; however its performance still needs validation. Therefore the aim of this study was to validate histologically the use of DIAGNOdent (LF) for the detection and quantification of caries on intact occlusal surfaces; to compare the use of this device with VI and to evaluate the inter- and intra-examiner reproducibility of both diagnostic methods.

MATERIALS AND METHODS

A total of 57 molars presenting macroscopically intact occlusal surfaces were selected and cleaned to remove any debris. Inclusion criteria for teeth in this study were the apparent absence of occlusal restorations and fissure sealants, absence of hypoplastic pits and frank occlusal cavitation. The teeth were stored in a physiological saline solution before the beginning of the study. The Ethics Committee, School of Dentistry, University of São Paulo, approved the study.

All teeth were properly identified. The occlusal surfaces were cleaned with pumice slurry and copiously washed with water. Then, a drawing was done and all sites identified. Data were collected at 110 suspected sites in the fissures. Two examiners watched the same instructive session on diagnostic procedures using two representative teeth for each VI scoring system[4] (Table 1). They were also trained on how to use the LF device, according to the manufacturer's directions.

Visual examination (VI)

After removing each tooth one-by-one from distilled water, the sites were examined under a

TABLE 1 - Criteria used for visual, radiographic and histological examination[4].

Score	Visual	Radiographic	Histological
0	No or slight change in enamel after prolonged air-drying (10 s)	No radiolucency visible	No enamel demineralization or a narrow surface zone of opacity (edge phenomenon)
1	Opacity or discoloration hardly visible on the wet enamel, but distinctly visible after air-drying	Radiolucency visible in enamel	Enamel demineralization limited to the outer 50% of the enamel layer
2	Opacity or discoloration in enamel distinctly visible without air-drying	Radiolucency visible in dentine, but restricted to the outer 1/3 of dentine	Demineralization involving between 50% of the enamel and 1/3 of dentine
3	Localized enamel breakdown in opaque or discolored enamel and/or grayish discoloration from the underlying dentine	Radiolucency extending to the middle 1/3 of dentine	Demineralization involving the middle 1/3 of dentine
4	Cavitation in opaque or discolored enamel exposing dentine	Radiolucency in the pulpal 1/3 of dentine	Demineralization involving the inner 1/3 of dentine

standard dental operating light at an eye-tooth distance of 20 cm. If no visible signs were seen on the wet occlusal surface, the examiners were allowed to dry the teeth with compressed air.

DIAGNOdent readings (LF)

The measurements with the LF device were made after calibration of the device with the ceramic standard. The assessment of the teeth with the LF fiber-tip was performed according to the distributor's instructions. The laser tip (A tip) was positioned on a sound enamel region to provide a baseline measurement. After that, the laser tip was positioned on the target site and rotated around its long axis; the highest value was then recorded.

To verify intra-examiner reproducibility the examiners re-performed all examinations after a period of 7 to 10 days.

Validation

The sites were sectioned in a buccal to lingual direction using a 0.3 mm thick diamond saw mounted in a microtome (Labcut 1010, Extec Co., CT, USA). An experienced examiner evaluated the two sections of each site under a stereomicroscope (40 X) and reflected light (SZPT Olympus, Tokyo, Japan), and the side with more extensive alterations was classified according the Ekstrand's criteria[4].

Statistical analysis

Reproducibility of the VI system was assessed using unweighted kappa statistics. This was performed for repeated readings carried out by each examiner (intra-examiner reproducibility) and for the second series of scores made by pairs of examiners (inter-examiner reproducibility). Kappa values from 0.4 to 0.75 denote good reproducibility[6]. The same procedure was performed for LF values only after categorization of the measurements (Table 2).

The scale that correlates the lesion extension and the range of the LF values was obtained by performing three ROC analyses. This analysis was performed after dichotomization of the histological scores into three cuts-offs: H1 (no demineralization or demineralization limited to the outer half of enamel), H2 (demineralization extending to the inner half of enamel up to the upper third of dentin) and H3 (demineralization extending into ½ of dentin). The best cut-offs for each dichotomization were obtained, allowing the composition of Table 2.

Sensitivity and specificity were calculated using the threshold between 2 and 3 for VI (Table 1). For the categorized LF data, threshold was set between H2 and H3 (Table 2). The McNemar's Change test was applied to compare the performance of the diagnostic methods for each examiner. ROC analysis was also conducted to compare the diagnostic performance of the three methods for occlusal caries diagnosis. In addition, a non-parametric statistical test was applied to estimate the significance of areas under ROC curves[8].

TABLE 2 - Ranked scale used in the DIAGNOdent examination.

Score	Range	Interpretation
H1	< 15	No demineralization or demineralization limited to the outer half of enamel
H2	15-19	Demineralization extending into the inner half of enamel up to the upper third of dentin
H3	> 19	Demineralization extending into deeper dentin

RESULTS

Histological examination showed that 20 sites were classified as score 0; 24 as score 1; 50 as score 2; 14 as score 3; and 2 as score 4. Hence, 16 out of 110 sites were classified as "carious", which represents approximately 14.5% of the sample.

Table 3 gives unweighted kappa values for inter-examiner reproducibility for each ranked scale. Kappa statistics showed good reproducibility for all methods.

TABLE 3 - Unweighted kappa values for intra- and inter-examiner reproducibility for ranked scoring systems for each of the diagnostic methods.

Diagnostic methods	Intra-examiner reproducibility		Inter-examiner reproducibility
	examiner 1	examiner 2	examiners 1-2
Visual	0.75	0.74	0.52
DIAGNOdent	0.58	0.69	0.63

Sensitivities, specificities and areas under ROC curve (Az) are shown in Table 4. VI and the LF showed similar sensitivities ($p > 0.05$) for both examiners, however, VI showed higher specificities than LF ($p < 0.05$). The overall analysis, seen by the area under the ROC curve, shows that VI had a better performance than the LF device.

DISCUSSION

The greater sensitivity of VI compared with LF for the detection of carious lesions was not found in some previous studies[1,17,18]. This is likely to be due to the selected VI system employed in these studies, which attempted to predict the severity of a lesion (i.e, no lesion, enamel lesion and dentine lesion) instead of using systems that attempted to characterize some features on the occlusal surface[4].

As shown in Table 4, the sensitivity (68.7%; 69.7%) and specificity (85.1%; 91.5%) values for the VI are within the range of the values provided by the literature. When nine studies of VI for the diagnosis of occlusal caries were reviewed, the sensitivity ranged from 0.12 to 0.80, and the specificity, from 0.67 to 0.97[13]. The great variability of sensitivity and specificity values for VI found in the literature may reflect other variables such as the scoring systems used, the conditions of the samples, cut-off points, and validation methods. Disease prevalence in the selected sample can be another variable. An increase of the number of teeth with visually apparent cavitation can increase the sensitivities values[15].

The VI has been considered an invaluable tool in the last decades. Due to its high specificity, this diagnostic method avoids overtreatment, mainly in low caries prevalence populations. However, only recently, the VI has also demonstrated high sensitivity values[2,24], which is important to avoid undertreatment. This has been due to the employment of the VI proposed by Ekstrand *et al.*[4] (1997). These authors demonstrated, in a laboratory setting, a good correlation between occlusal signs and the histological depth of the lesion, which implies that the poor sensitivity values of other workers' VI could be attributed to a failure in selecting appropriate VI criteria.

However, the application of this ranked scoring system requires extensive training of representative macroscopic occlusal signs of each score beforehand. This previous calibration procedure is of paramount importance in order to obtain positive results. In fact, one may consider that the bad performance of the Ekstrand's visual system[4] in other recent published papers[10,22,23] could conceivably be attributed to the lack of experience in using this VI system. The LF device can be considered an adjuvant tool for occlusal caries diagnosis. However, this system cannot be used as a substitute for VI, since its sole use could lead to overtreatment. According to the Ekstrand's visual system[4], the presence of discoloration, visible without air-drying, is an indicator of demineralization involving between 50% of the enamel and the outer 1/3 of dentine. Thus, all sites presenting this visual pattern are considered sound by the visual inspection, while for the LF diagnostic method there is a high tendency of being considered caries-affected, which results in a high rate of false-positive answers. Recent evidence has shown that the LF device tends to overscore discolored sites[7,9,25].

Although some researchers have detected a good to excellent performance of the LF device[17,18,19,24,27], others have not observed this trend[22,23]. Several factors may account for this difference, such as the recommended cut-offs for interpretation of the LF measurements[9] and the storage medium of the sample before the beginning of the study[20,26,28].

If we carefully examine the best cut-off points used for LF readings in clinical studies, one should observe that values higher than 19-20 indicate dentinal involvement and are currently used as a threshold between "sound" and "carious" sites[1,19,30], which is in agreement with the present investigation. Therefore, when LF readings were higher than 20, it is likely that the lesion has extended into

TABLE 4 - Performance of the diagnostic methods in diagnosing occlusal carious lesions using threshold between 2 and 3 in each scoring system: sensitivity, specificity and area under ROC curve (A_z) (*).

	Sensitivity (%)		Specificity (%)		Az	
Examiner	1	2	1	2	1	2
Visual examination	68.7a	69.7a	91.5c	85.1c	0.884e	0.833e
DIAGNOdent	81.2a	75.0a	66.0d	60.6d	0.767f	0.669f

(*) Different letters indicate statistically significant differences among values within the same column ($p < 0.05$).

dentine. One should bear in mind, however, that the use of this criterion could lead to overtreatment in discolored sites.

CONCLUSION

A meticulous VI enables the dentist to score earliest signs of caries changes or to differentiate between fissures with or without discoloration, staining or opacities. The LF showed a good performance on occlusal caries diagnosis. However, due to its relative high cost and performance inferior to that obtained through the Ekstrand's visual criteria, it should be considered only as an alternative method for occlusal caries diagnosis.

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