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Clinical effectiveness of fluorescence, digital images and ICDAS for detecting occlusal caries

Efetividade clínica da fluorescência, imagens digitais e ICDAS na detecção de cárie oclusal

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Resumo

Introdução: A detecção de pequenas lesões de cárie ainda é um desafio para profissionais da Odontologia, que em sua prática clínica dispõem de uma grande variedade de métodos para detectar cáries nas superfícies oclusais. **Objetivo:** Avaliar clinicamente a efetividade da câmera de fluorescência Vista Proof, da microcâmera intraoral digital Vista Cam e do critério visual ICDAS (International Caries Detection and Assessment System) para detecção de lesões de cárie nas superfícies oclusais. **Material e método:** Cento e sete dentes posteriores de pacientes adultos foram examinados visualmente e por meio de radiografias digitais por um examinador que os classificou de acordo com a presença ou ausência de cárie. Os dentes foram então avaliados por outro examinador que utilizou o ICDAS, fluorescência e imagens digitais ampliadas. A efetividade dos métodos foi mensurada por meio da sensibilidade, especificidade, razão de verossimilhança positiva e negativa. Para cada método, a curva ROC (Receiver Operating Characteristic) e a área sob a mesma - AUROC (Area Under the ROC curve) foram estimadas. **Resultado:** Houve excepcional capacidade discriminante para as imagens intraorais (AUROC=0,93) e para o ICDAS (AUROC=0,91), com diferença estatística não significativa entre eles (z=0,35, p=0,73). A fluorescência apresentou capacidade discriminante aceitável (AUROC=0,78), embora tenha sido menor que os outros. A razão de verossimilhança positiva para a fluorescência foi 2,32, comparado a 20,58 para a imagem intraoral e 58,11 para o ICDAS. **Conclusão:** Ambos os métodos e o ICDAS exibiram um adequado desempenho clínico, sendo que o ICDAS e a imagem intraoral foram mais efetivos que a fluorescência.

Descritores: Cárie dentária; efetividade; diagnóstico; fluorescência.

Abstract

Introduction: The detection of small caries lesions is still a challenge for dental professionals who in their clinical practice have a wide variety of methods to detect caries on occlusal surfaces. **Objective:** To clinically assess the effectiveness of the Vista Proof fluorescence camera, the Vista Cam digital intraoral micro camera and the International Caries Detection and Assessment System (ICDAS) visual criterion for detecting caries lesions on occlusal surfaces of permanent teeth. **Material and method:** One hundred and seven posterior teeth from adult patients were examined visually and by means of digital radiographs by an examiner who rated them according to the presence or absence of occlusal caries. The teeth were then assessed by the other examiner using ICDAS, fluorescence and magnified digital images. The effectiveness of the methods was measured based on sensitivity, specificity, positive and negative likelihood ratio. For each method, the Receiver Operating Characteristic (ROC) curve and the Area Under the ROC curve (AUROC) were estimated. **Result:** There was exceptional discrimination capacity for the intraoral images (AUROC=.93) and the ICDAS (AUROC=.91), with no significant statistical difference between them (z=.35, p=.73). The fluorescence exhibited an acceptable discrimination capacity (AUROC=0.78), although it was lower than the others. The positive likelihood ratio for the fluorescence was only 2.32, compared to 20.58 for the intraoral image and 58.11 for the ICDAS. **Conclusion:** Both methods and the ICDAS exhibited an adequate clinical performance, although the ICDAS and intraoral image were more effective than the fluorescence.

Descriptors: Dental caries; effectiveness; diagnosis; fluorescence.

INTRODUCTION

Nowadays, three main aspects are taken into consideration when discussing dental caries: prevention, control and a proper diagnosis, which often includes the detection of lesions at the earliest possible stage[1]. However, the detection of small lesions, especially on occlusal surfaces, is still a challenge for dental professionals[2-5], mainly due to the complex anatomy of dental grooves and fissures[6-8], overlapping structures during radiography and the increased number of hidden caries lesions caused by the continuous use of fluorides[9,10].

In their clinical practice, dentists use a wide variety of methods to detect caries on occlusal surfaces[11,12]. These methods include visual inspection, visual-tactile inspection, radiographs, digital radiographs, laser or light fluorescence based-methods, electrical impedance measurements[12], intraoral images[13], dyes and fiber-optic transillumination[11].

An ideal method to detect caries lesions should be fast and easy to use, with high sensitivity and specificity[14,15], as well as reliability and an accessible cost. This will enable the documentation and detection of caries at an early stage, without causing discomfort for the patient, as well as the possibility of differentiating reversible and irreversible damage, with similar effectiveness when applied to all dental surfaces[16]. Nevertheless, satisfying all of these requirements is not an easy task.

The International Caries Detection & Assessment System (ICDAS)[17] is an accessible set of criteria for dentists, researchers and professors and presents acceptable sensitivity and specificity to the detection of occlusal caries[4,5,10,18,19]. According to this system, caries detection on coronal teeth surfaces is a process that comprises two stages. The first stage involves classifying each tooth surface according to its condition (sound, sealed, restored, with or without a dental crown, or missing). The second stage involves the classification of the extent of the lesion on an ordinal scale[17].

Methods that use fluorescence are based on the phenomenon that caries lesions fluoresce differently from healthy tissues when excited by light in specific wavelengths[2]. The Vista Proof fluorescence camera [Dürr Dental, Bietigheim-Bissingen, Germany] uses gallium nitride light-emitting diodes (GaN LEDs) that emit blue light at 405 nanometers (nm) on the teeth surface[4,5]. The light emitted from this wavelength stimulates porphyrins present in the cariogenic bacteria to emit red light, which contains less energy, as opposed to sound enamel, which emits green light[4]. This fluorescence is recorded by the camera, transferred to a computer and processed by DBSWIN software [Dürr Dental, Bietigheim-Bissingen, Germany]. A digital image is then generated, showing lesions in different colors, and numerical information about the depth of caries is also provided. Since the images can be stored in the patient's database, Vista Proof can facilitate the control of the lesion's progress over time[7,13,20].

Digital intraoral cameras, such as the Vista Cam device [Dürr Dental, Bietigheim-Bissingen, Germany], are ergonomic and provide enlarged images, which have significantly improved communication with patients, favoring a correct diagnosis and allowing professionals to save the data. However, there are no reports in the literature of studies that used Vista Cam as an auxiliary method of caries diagnosis.

Therefore, the aim of the present study was to clinically assess the effectiveness of the ICDAS visual criterion, the Vista Proof fluorescence camera and the Vista Cam digital intraoral camera in detecting caries lesions on occlusal surfaces of permanent teeth. The null hypothesis was that the effectiveness of these different methods would not differ among them.

MATERIAL AND METHOD

Ethical Aspects

This study was approved by the Research Ethics Committee of the Araraquara Dental School – UNESP (Brazil) under protocol number 47/11 and was conducted in full accordance with the World Medical Association Declaration of Helsinki. All participants signed an Informed Consent Form.

Sample Design

This was an observational cross-sectional study with a convenience non-probabilistic sampling design. Prior to the definitive study, the MedCalc statistical software was used to calculate the sample size using the data obtained in the pilot study. It was considered α=0.05, β=0.20, minimum AUROC of 0.70 and null hypothesis=0.5. This way, a minimum sample size of 63 teeth was calculated.

It were considered eligible to participate in this study young adult patients (male and female, 18 to 28 years old) with sounded or decayed teeth who regularly attended the Clinic of Restorative Dentistry at Araraquara Dental School (UNESP), from August to December 2012. Patients were selected for the study from a previously screening. The exclusion criteria were teeth with sealants/restorations of any kind or malformations, such as fluorosis, enamel hypoplasia, amelogenesis imperfect and/or hypomineralization. Third molars were also not assessed, nor patients who were using fixed orthodontic appliances at the time of the assessment, as the orthodontic band overlaps dental structures during the performance of radiography.

One hundred and seven posterior teeth (42 molars and 65 premolars) from 14 young adult patients comprised the eligibility criteria and were included in this study. All individuals who participated in this research and needed treatment were attended at the Clinic of Restorative Dentistry or referred to other clinics of the Araraquara Dental School (UNESP), depending on their requirements.

Study Variables and Procedures

In the present study, the effectiveness of the ICDAS criterion, the Vista Proof fluorescence camera and the magnified digital image (Vista Cam) were assessed in relation to detecting caries lesions on occlusal surfaces based on visual inspections plus digital radiographs, which were considered as the comparison standard.

Firstly, the examiners were trained and calibrated in the proposed methods using 62 extracted teeth and 60 teeth from patients of the

Restorative Dentistry Clinic, with a one week interval between the assessments. For the examiners' calibration the same criteria that will be described below for definitive study were used.

After the calibration process, an experienced examiner (A) examined the 107 teeth visually and radiographically. The participants received professional prophylaxis with pumice and water and then had their teeth visually examined and classified, based on the presence or absence of caries. In addition, the teeth were also radiographed using an RX device (Dabi Atlante®). Phosphor plates [Dürr Dental, Bietigheim-Bissingen, Germany] were coupled to interproximal positioners [Indusbello®] and subsequently scanned by the VistaScan Mini [Dürr Dental, Bietigheim-Bissingen, Germany] device and processed using DBSWIN software (Figure 1).

One week later, the examiner A analyzed the radiographs on a microcomputer. The presence or absence of a radiolucent image on the enamel or dentin characterized the presence or absence of caries lesions, respectively[21].

Seven days after the visual exam, the volunteers received new prophylaxis with pumice and water and had their teeth assessed (wet and dry) by another examiner (B) by means of ICDAS visual criterion[11]. This examiner was also trained in a pilot study and used the artificial light of a dental lamp, an air jet and a dental mirror. ICDAS scores were classified as follows: from 0 to 2 - absence of caries; from 3 to 6 - presence of caries.

Afterwards, the same participants were submitted to a new assessment using the Vista Proof fluorescence camera. The same examiner, who had been previously trained according to the manufacturer's recommendations, captured images of the occlusal surfaces of teeth using the Vista Proof fluorescence camera. After drying with an air jet for 5 seconds, the camera was positioned perpendicularly to the occlusal surface of the teeth. The results were automatically interpreted by DBSWIN software, which created images of 720×576 pixels that ranged from green (around 510 nm wavelength)[7] to red (around 685 nm wavelength) and provided a numerical value for the severity of the lesion (Figure 2).

Subsequently, examiner B classified the images based on their scores (Table 1).

Finally, digital images of the occlusal surfaces of the teeth were captured by examiner B using the Vista Cam digital intraoral camera (Figure 3).

The images obtained were coded and recorded in a microcomputer for posterior analysis by the same examiner, who classified them according to the ICDAS criterion.

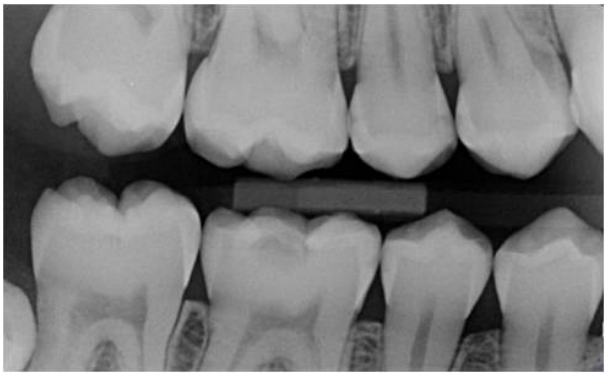

Figure 1. Radiographic image of posterior teeth.

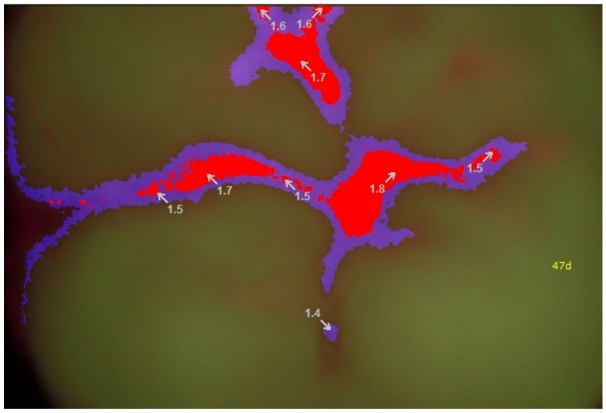

Figure 2. Fluorescence image of a posterior teeth.

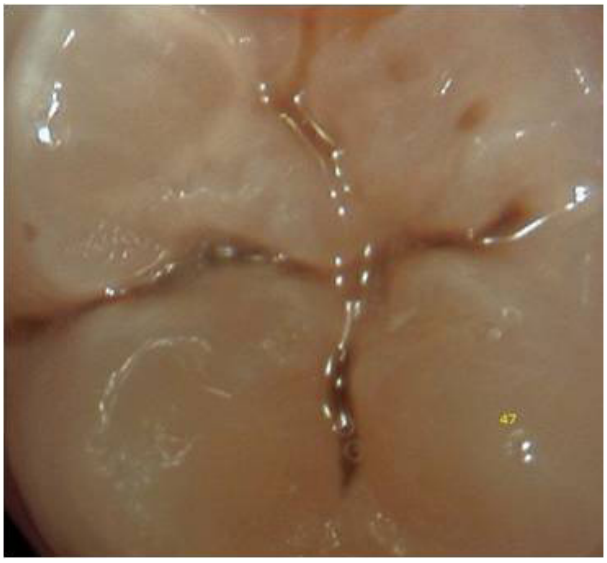

Figure 3. Digital image of a posterior teeth.

Table 1. Classification of fluorescence images, obtained by Vista Proof, according to the depth of caries lesions

Color	Classification according to the manufacturer	Lesion depth (mm)	Score	Final classification
Green	Healthy enamel	<1	0	Absence of caries
Purple	Initial enamel caries	1≤x<1.5	1	Presence of caries
Red	Caries in dentinoenamel junction	1.5≤x<2	2	Presence of caries
Orange	Caries in dentin	2≤x<2.5	3	Presence of caries
Yellow	Deep caries in dentin	x≥2.5	4	Presence of caries

Statistical Analysis

A – Pilot study

The intra-examiner reproducibility of the visual and radiographic examinations was estimated using the Kappa statistic (κ). The intra-examiner reproducibility of the fluorescence, magnified digital images and ICDAS were estimated using the Kappa statistic with linear weighting (κ_{pl})[22] by point and a 95% confidence interval ($CI_{95\%}$). The agreement obtained was classified based on the proposal of Landis, Koch[23]. An agreement level with a minimum classification of "great" for visual and radiographic exams and a minimum classification of "good" for the other methods was considered adequate.

Table 2. Intra-examiner reproducibility for methods to detection occlusal caries

	Intra-examiner Agreement - κ ($CI_{95\%}$)	
	A x A	**B x B**
Visual inspection	0.878 (0.782-0.974)	-
BW digital radiography	0.960 (0.882-1.000)	-
ICDAS	-	0.959 (0.928-0.990)
Intraoral Image	-	0.943 (0.907-0.979)
Fluorescence	-	0.656 (0.556-0.757)

B – Definitive study

Concerning the effectiveness of the ICDAS, fluorescence and magnified digital images in relation to the visual inspection and digital radiographs, the sensibility, specificity, positive likelihood and negative likelihood ratio of the tests were estimated. The Receiver Operating Characteristic (ROC) curve was constructed and its area (AUROC) was estimated. The discriminant capacity of each test was classified, as described by Hosmer, Lemeshow[24].

The areas of the different methods were compared using the z statistic. The significance level chosen was 5%. The analysis was conducted using MedCalc® 12.4.0 software (Mariakerke, Belgium).

RESULT

Table 2 displays the intra-examiner reproducibility obtained for the occlusal caries detection methods, by point and 95% confidence interval.

With the exception of the fluorescence, which exhibited good reproducibility, all other methods produced a great agreement.

Table 3 displays the quantity of occlusal lesions detected by each method, in comparison to the visual and radiographic examinations.

Figure 4 displays the ROC curves constructed using the occlusal caries detection methods, according to the visual and radiographic examinations.

The effectiveness of the three methods is described in Table 4.

An exceptional discriminating capacity for the ICDAS and intraoral images was recorded, with no statistically significant differences between them (z=0.348; p=0.727). The fluorescence exhibited acceptable discriminating capacity, although it was lower than the other two methods. This way, the null hypothesis was rejected.

Table 3. Number of occlusal lesions detected by each method, according to visual inspection and BW digital radiography

Method	Visual inspection and BW digital radiography		Total
	Absence of caries	**Presence of caries**	
ICDAS			
Absence of caries	68	0	68
Presence of caries	1	38	39
Total	69	38	107
Intraoral image			
Absence of caries	66	4	70
Presence of caries	3	34	37
Total	69	38	107
Fluorescence			
Absence of caries	40	1	41
Presence of caries	29	37	66
Total	69	38	107

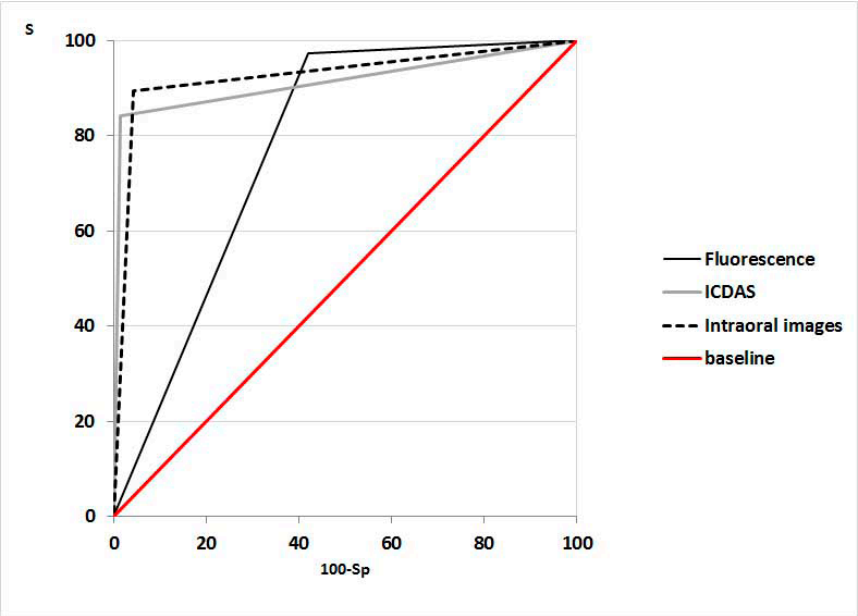

Figure 4. Receiver Operating Characteristic (ROC) curves for ICDAS, fluorescence and intraoral images, according to visual inspection and BW digital radiography.

Table 4. Effectiveness of auxiliary methods for detecting occlusal caries in premolars and molars

	AUROC ($IC_{95\%}$)	Sensitivity	Specificity	*LR+	*LR–
Fluorescence	0.777[b] (0.686-0.842)	97.37	57.97	2.32	0.045
ICDAS	0.914[a] (0.844-0.959)	84.21	98.55	58.11	0.16
Intraoral image	0.926[a] (0.858-0.967)	89.47	95.65	20.58	0.11

*LR: Likelihood Ratio; [a,b] same letters indicate statistical similarity (Z-Test; α=5%).

DISCUSSION

The complex anatomy of dental grooves and fissures on the occlusal surfaces of teeth make it difficult to accurately detect caries lesions[6-8]. Although several detection methods have been described in the literature[7-9,17], choosing the ideal method it is not an easy task.

In order to make a suitable decision, it is important to consider the calibration of the device and the examiners, since good reproducibility is the first step in obtaining consistent results from different examiners at different assessment periods[20]. Moreover, a lack of reproducibility may result in an inaccurate treatment plan and intervention[25]. Thus, calibration is a crucial element in both laboratory and clinical research, as well as among educators, who assist dental students in their training.

A histological examination is the gold standard for determining the extent to which tissue is affected by dental caries in *in vitro* studies[21]. Thus, a limitation of this study was the impossibility of performing histological examination and opening the teeth classified as non-carious. Therefore, visual inspection and digital BW radiography were selected as the comparison standard.

In order to avoid potential bias, examiner A analyzed the radiographs one week after the clinical examination. Furthermore, one examiner performed the clinical and radiographic examination and a second examiner used the other evaluation methods. Examiner B also followed the manufacturer's recommendations for using Vista Proof, such as drying the teeth for 5 seconds and positioning the camera perpendicular to the occlusal surface of the teeth.

The images from the Vista Proof fluorescence camera were classified using scores provided by the manufacturer, based on the depth of the lesion, and the intra-examiner reproducibility was considered "good"[7,20,26]. For other methods of caries detection, reproducibility was "great", which is essential in investigation studies and also in clinical practice. The reliability for the visual examination with ICDAS, when used by six different examiners, ranged from "regular" (κ=.59) to "great" (κ=.82) in a previous study[17], which described this criterion as a practical system with content validity. Similar reproducibility was found by Shoaib et al.[15] when assessing the occlusal surfaces of deciduous teeth.

In the present study, the sensitivity of the Vista Proof camera for occlusal lesions was 0.97, indicating a strong ability to detect caries lesions when they are actually present. Similar findings were described by Schwendicke et al.[27]. Nonetheless, this method exhibited worse specificity (0.58) than the intraoral image (0.96) and the ICDAS (0.98), indicating that the fluorescence camera

detects more false-positive results than the others. In this case, it would be an overtreatment (a clinical intervention on healthy teeth). High sensitivity (0.86) for the Vista Proof camera was described by Rodrigues et al.[7] in an in vitro study of occlusal lesions on dentin. The authors stressed that, despite the high sensitivity observed for this device (0.86), it did not adequately detect caries lesions on enamel.

An exceptional discriminatory capacity (AUROC=0.91 to 0.96) for the Vista Proof fluorescence camera was found by Jablonski-Momeni et al.[26]. Although the present study only found an acceptable discriminatory capacity (AUROC=.78 (.69 to .84)), these findings indicate that the Vista Proof fluorescence camera can be considered appropriate for the detection of caries, but should be used in association with other methods.

Similar to the Vista Proof fluorescence camera, the Vista Cam is ergonomic and enables the storage of magnified images on the patient's database. Consequently, communication, the archiving of images and the control of lesion progression become easier over time. Nevertheless, until now, this is the first study that assessed the performance of the Vista Cam digital intraoral camera as an auxiliary method of detecting caries. In the literature, we only found studies that assessed (in vitro) the performance of the Vista Cam iX[12,26], a version of the camera with a more simple optical set. Although the Vista Cam iX has multiple functions on the same camera (intraoral and fluorescence camera), only the fluorescence was used in the previously published studies and the data obtained were compared with those found for the Vista Proof camera. Thus, it is difficult to compare the intraoral image data from the present study with similar data in the literature.

The present study recorded an excellent equilibrium between sensitivity and specificity for the Vista Cam digital intraoral camera (0.89/0.96) and for the visual inspection with the ICDAS criterion (0.84/0.99). The larger areas under ROC curves (0.93 (0.86-0.97) for the Vista Cam and 0.91 (0.84-0.96) and for ICDAS indicates that the ICDAS criterion and magnified images can add important information to a visual exam, facilitating the detection of caries lesions. The magnified images also improve the vision field of dentists and allow them to plan the treatment with more precision.

The positive likelihood ratio expresses the number of times that it is more probable to find a positive result among people who exhibit caries lesions, when compared with people without caries. The ICDAS exhibited the highest value, indicating that the chance for a positive test to be true is 58.11 times greater than the chance of it being false. Hereafter, the highest result was for the intraoral image (20.58), followed by fluorescence (2.32). Similar results for Vista Proof (2.28) was found by Rodrigues et al.[7].

The negative likelihood ratio observed for the ICDAS (0.16) indicates that the chance of a negative result being true in relation to a false-positive result is 100:16, or 6.25 times. For the intraoral image, the chance was 9.1 times and for fluorescence, the chance was 22.2.

CONCLUSION

Both methods and the ICDAS exhibited an adequate clinical performance, although the ICDAS and intraoral image were more effective. These data could assist dentists and researchers when choosing the best method of detecting caries lesions on occlusal surfaces, while also highlighting the importance of the association of methods to obtaining a correct diagnosis.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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