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CASE REPORT

Caries diagnosis using light fluorescence devices: VistaProof and DIAGNOdent

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Abstract The modern concept of minimally invasive dentistry encompasses early detection of incipient carious lesions and their treatment. Due to the low sensitivity of visual inspection and radiography in the detection of occlusal hidden carious lesions under a macroscopically sound surface, several devices have been developed to increase detection accuracy. DIAGNOdent is one of the tools used for that purpose and VistaProof is a new device recently introduced into the market. They both use light fluorescence to detect incipient carious lesions. DIAGNOdent is based on the fact that carious lesions show higher level of fluorescence than sound tissues when excited by light at specific wavelength. Vistaproof is based on the same principle, but it uses a different wavelength of excitation than DIAGNOdent and a video camera for the detection of fluorescence. The aim of this article was to compare these two devices and present their clinical use.

Keywords DIAGNOdent · VistaProof · Minimal invasive · Caries diagnosis

Introduction

The increased effort of prevention and the widespread use of fluorides have resulted in a significant decrease of the prevalence of occlusal caries in most developed countries [1–3]. However, some lesions are still detected and it is of paramount importance to diagnose them in their earliest stages to treat them with minimally invasive procedures. The detection of small lesions, especially on occlusal surfaces, is still difficult for dental professionals [4]. The difficulty of precise detection is related to factors such as the complex anatomy of pits and fissures and the increasing prevalence of hidden caries [5, 6].

In addition to visual inspection, several methods have been developed and recommended as diagnostic tools to identify and quantify early carious lesions.

In the past decades, the use of an explorer was the standard method for diagnosis. However, under the light of today's knowledge, it is worldwide accepted that probing does not improve the diagnostic performance; furthermore it can irreversibly damage areas of demineralized enamel and may lead to more rapid progression of the carious process [7–10].

Visual inspection can be improved when combined with radiographic examination. While bitewing radiographs are considered to be of major importance for detecting proximal caries, they have a limited value to detect small carious lesions in occlusal surfaces because of the superposition of tooth's structure [11].

Several non-destructive methods using optical instruments exist, amongst which laser fluorescence technology (DIAGNOdent, KaVo, Biberach, Germany) is one of the most studied and widely used [12, 13]. This method is based on the phenomenon that carious lesions show higher level of fluorescence than sound tissues when excited by red light.

Recently, a new fluorescence camera (Vistaproof, Dürr Dental, Bietigheim-Bissingen, Germany) has been developed and is now available in the market. The device is based on the same principle of increased fluorescence in carious lesions but using a different wavelength of excitation than Diagnodent. It provides the practitioner with the

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possibility to save and store images of occlusal surfaces analyzed by the software, which shows the regions of teeth that emit an increased level of fluorescence.

The use of these new non-invasive diagnostic tools allows early diagnostic to treat the lesion by remineralization or minimal restoration. The aim of this paper was to present the clinical application of these two diagnostic devices relying on light fluorescence in the particular case of early occlusal carious lesions' detection.

Materials and methods

Within the frame of routine dental treatment six patients aged from 25 to 28 years with good oral hygiene were included into the study. Three clinical cases are illustrated (Figs. 1, 2, 3, 4) while a total of six patients' DIAGNOdent and VistaProof values are reported in Table 1. Measurements were performed by three calibrated dentists who were previously trained in the use of the two devices. The inclusion criteria of the analyzed surfaces were absence of enamel anomalies such as hypomineralization or hypoplasia and absence of visible cavitation. Teeth that showed any intrinsic or extrinsic staining, restorations or sealants were excluded from the study.

All evaluated teeth were cleaned with a prophylactic paste (DEPURDENT®, Dr. Wild & Co. AG, Muttenz, Switzerland) by means of a rotating prophylactic brush for about 10 s and with a water-powder jet cleaner (AIR-FLOW® HANDY 2+, EMS, Nyon, Switzerland) containing sodium bicarbonate powder. To remove powder remnants clogged in the fissures, teeth were rinsed with water spray for 5 s each. After slight drying with compressed air, digital photographs of the occlusal surfaces were taken to select the sites for evaluations. Carious sites non-evident under clinical visual inspection on each occlusal surface were selected and three dentists assessed the fissure surfaces.

The occlusal fissures were measured by the LF (light fluorescence) system (DIAGNOdent) after calibration of the device using a ceramic standard, in accordance with manufacturer's instructions. Using a small 1 mW laser, the system emits red light at 655 nm. This is carried to one of two intra-oral tips that emits the light and collects the resultant fluorescence. DIAGNOdent does not produce an image of the tooth. Instead, it displays a numeric value on two LED displays. The first display indicates the current reading while the second one gives the peak reading of the examination. A small twist of the top of the tip enables the machine to be reset and ready for another site examination and a calibration device is supplied with the system. The DIAGNOdent measurements reflect the amount of fluorescence. A two-component fiber optic bundle transmits laser light into the tooth, while the other component transmits fluorescence from the tooth to a sensor that quantifies its intensity. Healthy tooth structure exhibits little or no fluorescence, while carious tooth structure exhibits fluorescence proportional to the amount of decay [14].

Tip A, designed for pits and fissures, was used in this study and the device was moved around in the occlusal fissure system until the highest value was obtained. The peak value was recorded. For dentin caries level, the cut-off values were 30 according to the manufacturer's suggestions [15].

The second device used in this study was a fluorescence camera (VistaProof, Dürr Dental, Bietigheim-Bissingen, Germany). With this system, images of the teeth are taken, subsequently analyzed by the software and stored in the computer.

VistaProof uses a light with a wavelength of 405 nm and a specific software that boosts the fluorescence emitted by the tissue. A viewer software (Dürr Dental) is used to digitize the video signal to create images of 720 × 576 pixels with 3 × 8 bit RGB color depth and resolution of 72 pixels/inch (computer screen resolution). These images

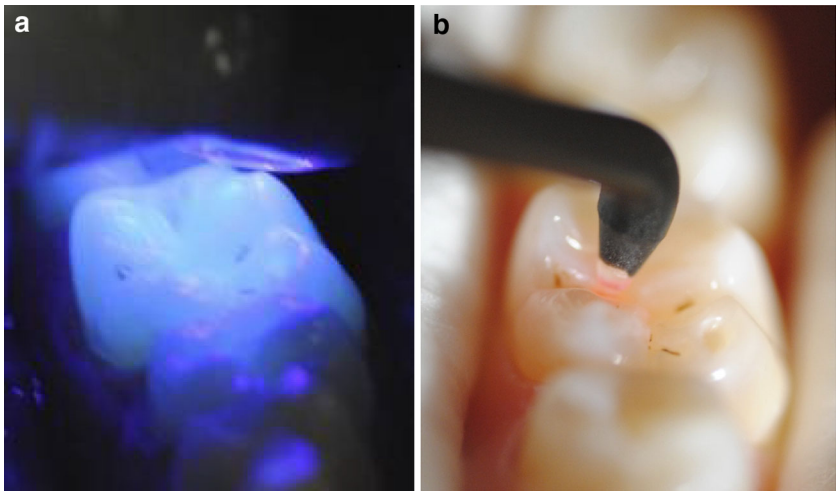


Fig. 1 **a** Clinical view of caries examination using VistaProof. **b** Clinical view of caries examination using DIAGNOdent

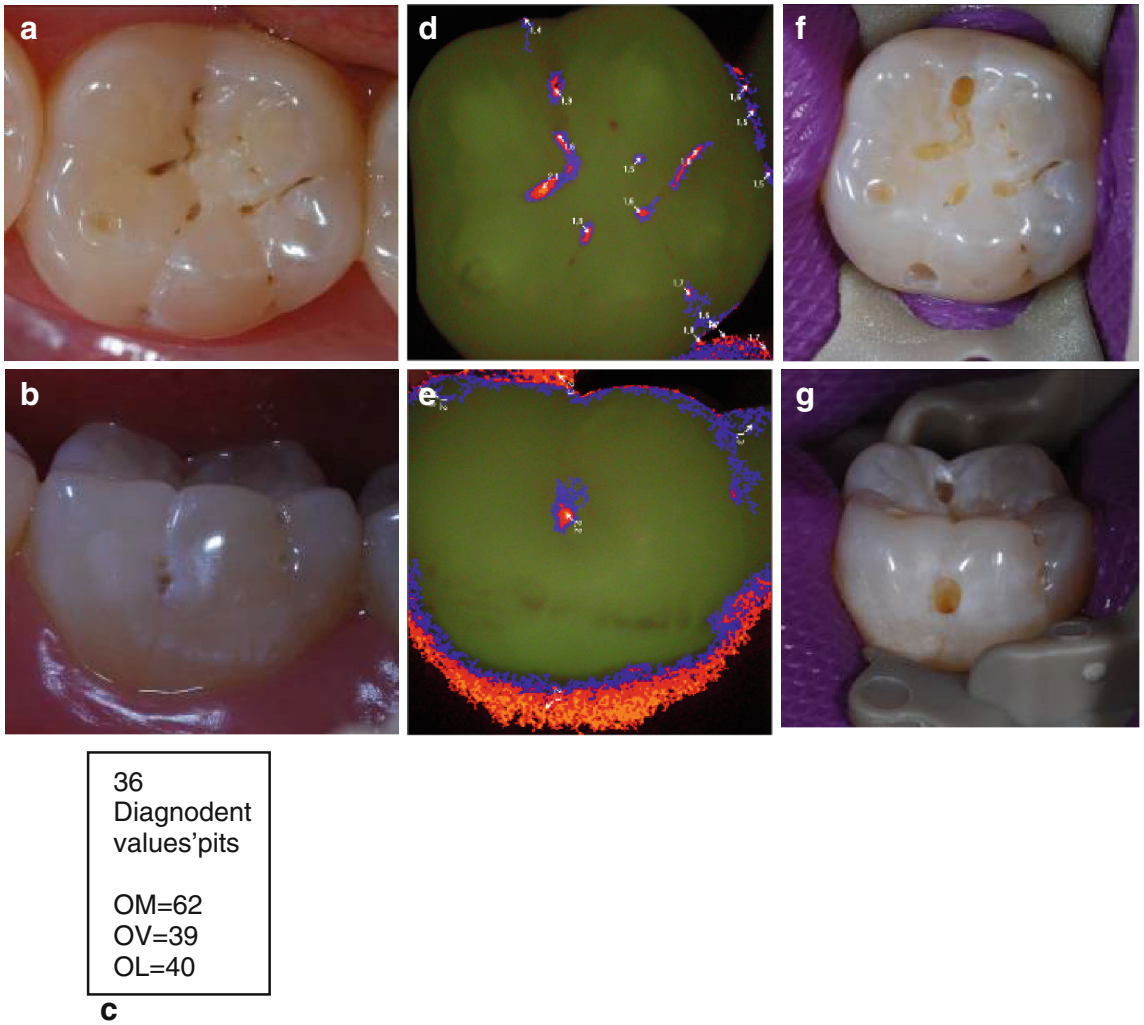


Fig. 2 Patient of 28 years old. **a** Clinical occlusal view before treatment. **b** Clinical vestibular view before treatment. **c** DIAGNOdent values. **d** VistaProof occlusal image. **e** VistaProof vestibular image. **f** Clinical occlusal view after complete excavation of the carious lesion. **g** Clinical vestibular view after complete excavation of the carious lesion

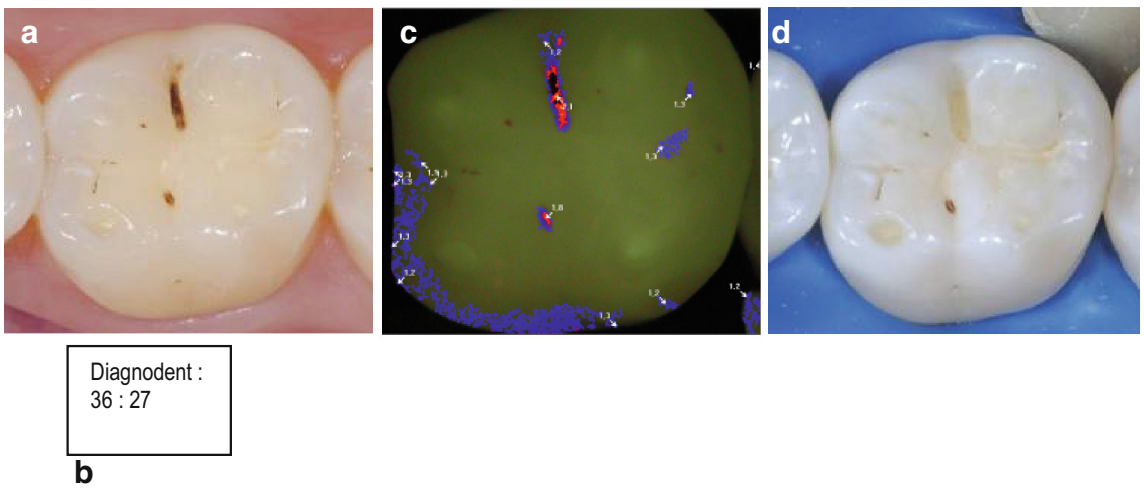


Fig. 3 Patient of 25-year old. **a** Clinical occlusal view before treatment. **b** DIAGNOdent values. **c** VistaProof occlusal images. **d** Clinical view after complete excavation of the caries

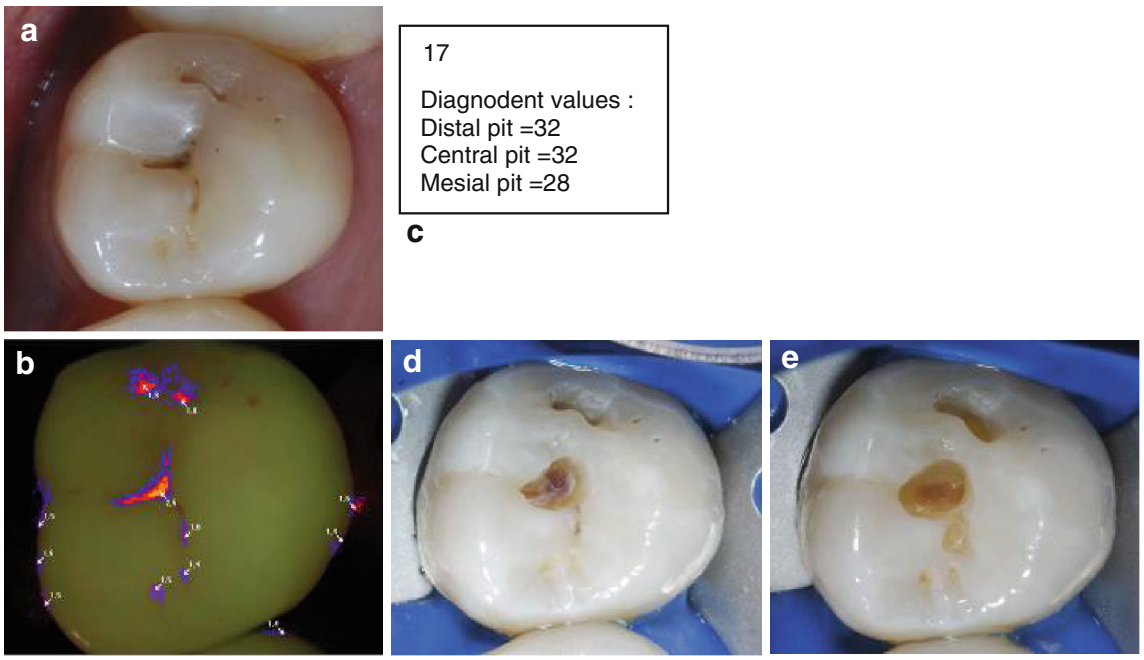
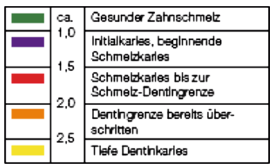


Fig. 4 Patient of 28 years old. **a** Clinical view before treatment. **b** VistaProof image. **c** DIAGNOdent values. **d** Intra-operative image during carious excavation. **e** Clinical view after complete excavation of the carious lesion

Table 1 Illustration of values with DIAGNOdent (DD) and VistaProof (VP) of six clinical cases

CASE 1	FISSURE	DD	VP	CLINIC
	M	62	1.9	Carious
	V	60	2.2	Carious
	MV	39	2.1	Sound
CASE 2	V	27	2.1	Sound
CASE 3	D	32	2.5	Carious
	O	32	1.9	Carious
CASE 4	D	39	2.3	Sound
	L	43	2.2	Sound
CASE 5	D	99	2.1	Carious
	C	41	2.4	Carious
	M	29	1.7	Sound
CASE 6	D	45	2.2	Carious
	O	37	2.1	Carious



are analyzed with the software, which quantifies the red and green components of fluorescence. The software shows the intensity of fluorescence in false colors according to a look-up table (LUT) varying from green (~510 nm wavelength) to red (~680 nm wavelength). The outcome value, ranging from 0 to 3 [16] corresponds to the lesion's severity and represents the intensity ratio of the red and green fluorescence. Carious lesions reaching dentin are present when values are higher than 2.0, which is illustrated by VistaProof as an orange or yellow spot on the screen.

Results

Clinical cases with colored fissures were chosen and the values of both DIAGNOdent and VistaProof were obtained. Six teeth were examined and 13 sites were measured (Table 1). Out of these 13 readings, accordance between both devices was achieved on 7 cases only: 6 for carious lesions and only one for sound surface with divergent results for 5 other sites.

Discussion

DIAGNOdent and VistaProof are two methods based on fluorescence for the detection of early caries lesions. It is well known that these methods are no diagnostic tool by themselves but that they may help to complete the diagnosis, especially in cases of hidden caries [5, 6]. They also allow monitoring of lesions over time. This ability is of great importance in the field of ultra-conservative dentistry because it enables dentists to quantitatively identify progressing lesions, which is impossible with conventional tools [17].

It is important to point out that both fluorescence devices present some limitations. A high value of fluorescence may result from other reasons than caries, such as the

presence of stains, fluorescent prophylactic paste, biofilm, disturbed tooth development or re-mineralization [18–20]. Such alterations may lead to some bias, increasing the danger of false-positive results. False-positive readings can lead to unnecessary treatment of a sound tooth. This stresses the importance of cleaning the teeth to ensure that even the deepest pits are exempt from deposits and to associate the fluorescence-based diagnosis with clinical inspection.

The DIAGNOdent device is a small, lightweight, battery-powered, chairside, hand-held instrument and the small tip allows measurements at different angles to the tooth surface. Its small tip with a diameter of about 1 mm^2 can be put in contact with the tooth surface, whereas VistaProof has a large tip of about 1 cm^2. Obviously, light density is less important with the second device and, even if four diodes are used, light scattering is high.

Extensive literature is available on DIAGNOdent and in vitro and in vivo studies have edited cut-off values that correlate with the histological status [15].

With DIAGNOdent, the optical tip is swept over the entire fissure, but in general only the peak value is recorded. This means that when a dentist wants to follow the evolution of demineralisation , he has to keep a record of the specific location of his measurements. This aspect, together with the fact that the device has to be carefully calibrated before each use, requires some time to use this device for prevention and follow-up.

VistaProof, on the other hand, is based on an intraoral camera, which is self-calibrating and allows two-dimensional capturing of the tooth surface together with relative caries score. Due to this measuring principle, it allows dentist to follow carious lesion's evolution more rapidly. Another advantage of this device is the use of blue light as detecting tool, which seems to be more effective than the red light used by the DIAGNOdent in detecting porphyrin activity [21]. It seems, in fact, that DIAGNOdent as well as VistaProof do not measure the intrinsic changes in enamel structure. Some authors [21, 22] claim that they measure the degree of bacterial activity [21]. This theory is supported by the fact that porphyrins, which are a product of bacterial metabolism, show higher level of fluorescence than the surrounding healthy dental tissues. Anyway, some disadvantages have to be taken in account when VistaProof is considered. Measurements obtained by this device are representative only of a static measurement, which means that a decay that is not perpendicular to the capturing device cannot be detected. Another disadvantage of VistaProof is the lack of consensus in literature about the cut off values. Values proposed by the manufacturer are, in fact, very close, which may lead to erroneous clinical decisions. Furthermore, in spite of the high sensitivity obtained for the device, a weak correlation with histological findings has been observed [23].

Other details have to be taken into account. It has been demonstrated that red light and also infrared fluorescence radiation penetrate deeper into the teeth because it is less absorbed and scattered by dental tissues than light of shorter wavelengths. On the other hand, the fluorescence intensity increases when irradiating with blue light (488 nm) in comparison with red (655 nm) excitation [21]. Moreover, the literature mentions that the red light is more efficient in detecting dentinal caries but presents some limitation in initial enamel lesion diagnosis. Thus, it can be concluded that blue light might be more effective in detecting early enamel lesions.

Moreover, blue light allows sound enamel to fluoresce, which displays the shape of the tooth on the images showing the localization of lesions on the occlusal surface. Thus, the VistaProof grants saving and storing images of the teeth. This cannot be achieved using red light because only carious lesions fluoresce in the infrared spectrum.

Another point to discuss is the influence of surrounding light that can interfere with both DIAGNOdent and VistaProof measures. It has, in fact, been observed during this study that the readings of the VistaProof are influenced by surrounding light and may change the results. The black cap provided with the machine is mandatory for clinical use and even the unit light should be switched off at all times during measurements.

Only a few in vitro studies have been performed to test the performance of VistaProof in detecting caries lesions in the occlusal surfaces of permanent teeth [23]. No scale for interpretation of these readings is available in the literature since this method was only recently developed and introduced into the market. As recommended by the manufacturer, the plastic protective cover was used in this study and the choice of thick or thin spacer depended on the buccal situation [24].

Further studies are needed to investigate the possible use of these devices during carious excavation and detect possible remnants of decay. Previous study showed, in fact, that DIAGNOdent could not be used because the pulp seemed to alter the readings [25]. VistaProof could, on the other hand, be tested for this purpose due to the fact that blue light penetrates much less into the tissue, excluding, in this way, bias originated by the underlying pulp.

In this study, the lack of accordance between both devices is surprising. It might be related to the different capacity of fluorescence detection. Anyway, within the limitation of this study, VistaProof seems to be more specific while DIAGNOdent seems to be more sensitive. Caution has to be paid in interpreting these results due to the low number of cases evaluated.

Furthermore, more cases and recordings are needed to directly compare the results and efficiency of both devices to determine which device adapts better to each specific clinical situation.

Conclusions

Minimally invasive dentistry is the new trend in modern dentistry which allows optimal esthetic outcomes together with maximum conservation of sound tissues [26]. In this perspective, the concept of diagnostic tools that accurately identify incipient carious lesions is extremely appealing [27]. DIAGNOdent and VistaProof try to fulfill this need, even if some limitations are still present. DIAGNOdent has been widely described and studied in the literature, whereas VistaProof has recently been introduced to the market. Neither device can be defined as the exclusive instrument for precisely detecting caries, but they both have their own advantages. They can, actually, be considered as interesting tools that can be used in complementing clinical inspection. Further clinical and histological studies are needed to precisely define the cut-off values, especially for VistaProof.

Conflict of interest The authors declare that they have no conflict of interest.

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