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Accuracy of VistaCam iX Proxi's Infrared Waves and DIAGNOdent for Detection of Proximal Caries

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Objectives Considering the significance of early detection of caries and determining the extent of carious lesions for appropriate treatment planning, as well as introduction of new diagnostic tools, this study aimed to compare VistaCam iX (850 nm infrared), and DIAGNOdent (655 nm) for detection of proximal caries in posterior teeth.
Methods This in vitro study was performed on 40 extracted sound posterior teeth. VistaCam and DIAGNOdent examinations were performed. The teeth were sectioned for histopathological examination under a stereomicroscope to determine the presence/absence of caries and extent of carious lesion, if any (to serve as the gold-standard). Data were analyzed with the Cohen's kappa statistic, and Wilcoxon Rank Sum test.
Results The specificity of VistaCam iX and DIAGNOdent was 71.4% and 42.8%, respectively. Their sensitivity was 100% and 40% for enamel caries, and 92.8% and 53.5% for dentin caries, respectively (P=0.048). The specificity and sensitivity of DIAGNOdent were higher, and it had lower rate of false positive and false negative results.
Conclusion Considering the higher sensitivity and significantly lower rate of false negative results of VistaCam iX for detection of proximal caries, it may be recommended as an efficient tool for caries detection.
Keywords Dental Caries; Diagnosis; Infrared Rays

Introduction

Despite the promotion of public health and advances in science and technology, dental caries remains a major public health dilemma worldwide.[1] The process of caries development can be prevented or stopped. Carious lesions that are detected early can be managed by noninvasive approaches such as fluoride therapy, antimicrobial therapy, diet correction, or low-level laser therapy. These modalities can stop the progression of caries or even reverse it.[2] Clinical examination and radiography are the most commonly used diagnostic methods for caries detection in clinical practice. Both of these methods have high specificity but low sensitivity; thus, they may fail to detect initial caries in some cases. Detection of proximal caries is far more difficult due to contact with the adjacent tooth and impossibility of direct observation. Proximal carious lesions often remain undetected in their initial phase of development. Over the past few years, various methods have been introduced to enhance the detection of proximal caries without using radiography such as fiber optic transillumination and laser fluorescence.[3, 4] The first report on caries detection by fiber optics dates back to 1995.[5] Fiber optic transillumination is an economical and non-invasive method of caries detection, which can be used for both occlusal and proximal caries.[3, 6-8] Bacterial metabolites within carious lesions produce fluorescence which can be enhanced by laser light. Accordingly, DIAGNOdent 2095 (LF; KaVo, Biberach, Germany) was introduced to serve as an aid for detection of caries under restorations. In 2006, a new laser fluorescence device namely DIAGNOdent 2190 (LF pen; KaVo, Biberach, Germany) was introduced to aid in detection of occlusal and interproximal caries. The LF pen uses a low powered 655 nm diode laser to analyze and quantify the fluorescence emitted from bacterial porphyrins and other chromophores.[9, 10] The optimal accuracy and efficacy of DIAGNOdent have been confirmed for detection of proximal and occlusal caries, secondary caries under amalgam, composite and glass ionomer restorations, and calculus both in vitro and in vivo.[9, 11, 12]
Digital imaging fiber optic transillumination is a new technology that uses infrared (IR) and near IR wavelengths for caries detection. The main difference between this system and other methods is that digital imaging fiber optic transillumination uses visible light while other systems use invisible light with a long wavelength.[5, 13-16] In recent years, non-invasive technologies have focused on caries detection by using light in IR and near IR wavelengths. In this regard, new systems were introduced to the market such as DIAGNOcam (Kavo, Biberach, Germany) and VistaCam iX (Durr Dental, Bietigheim-bissingem, Germany) intraoral cameras.[3, 17] VistaCam iX consists of a flexible arm that has optical fibers for data transfer, a USB connection for linking to a personal computer, LED systems as the IR source, CCD receptor to receive the reflected light, and a special software for computer display. VistaCam iX has a Proxi interchangeable head and a 2IR LED with 850 nm wavelength. The output power of the device is 6 mW, and its optical output part measures 7 x 9 mm. When light is irradiated to the mesial and distal surfaces of the adjacent tooth, it passes through the transparent structure of the enamel and is scattered by the carious lesion. The scattered and reflected lights are received by the CCD receptor, leading to development of white points on the image in comparison with sound enamel, which is visualized by DBSWIN or VISTA SOFT programs.[3, 4, 13, 18, 19] A shiny reflection on images also develops due to wet surface, but it does not compromise the diagnosis, since the examiner can easily differentiate between these shiny points and gray and

white points resulting from damaged crystals of the tooth structure. A mirror reflection also develops due to amalgam or ceramic inlays, which disappears and reappears again upon movement of the device tip; while the white image resulting from caries is always stable. In older generations, a white halo would be observed on the image in some cases due to light reflection of the round glass of the internal lens of the camera. This white halo was also resolved by replacing the glass with a special covered lens in the next generations.[4] Considering the absorption spectrum and reflection of IR, some researchers recommend that wavelengths between 1300 and 1700 nm have the highest potential to reveal caries in this technology due to low scattering and optimal absorption within this range, culminating in excellent contrast for differentiation between carious lesions and sound enamel. [20, 21] However, the effect of water in and on the enamel should be considered as the most important influential factor when selecting the intra-oral device specifications for in vivo conditions. Accordingly, 850 nm is the suitable wavelength to obtain the best diagnostic image.[4] Among the advantages of IR are different representation of demineralized lesions compared with other changes such as pigmentation, developmental defects, fluorosis, and cracks. Furthermore, IR images are real-time, enabling the dentist to detect carious lesions from a view which may remain hidden on bitewing radiographs. However, IR has some disadvantages such as inability to assess the periodontal status around the tooth, and imprecise inspection of the depth of caries, and distance from the pulp chamber. [17, 22-29] Nevertheless, IR has the ability to reveal proximal lesions.[30] Thus, IR may be used to determine the severity and extent of occlusal caries, detect secondary caries under composite restorations, demineralized tissue under sealants, and buccal surface caries, and determine the extent of dehydration of the tooth structure during demineralization.[17, 22-29] The aim of this study was to investigate the accuracy of VistaCam iX Proxi with IR light at 850 nm wavelength in comparison with DIAGNOdent with a light wavelength of 655 nm for detection of proximal caries.

Methods and Materials

This in vitro diagnostic study was conducted on 40 extracted molars and premolars (IR.SBMU.RIDS.REC.1395.365). The inclusion criteria were sound teeth with slight discoloration or non-cavitated carious lesions that were not directly visible when the teeth were in contact. Teeth with restorations and cavitated carious lesions were excluded. The collected teeth were disinfected by immersion in 1% sodium hypochlorite for 12 hours. The teeth were then stored in saline. The teeth were mounted in two silicon blocks in contact with each other to simulate the clinical setting. Next, VistaCam iX (Durr Dental, Bietigheim-Bissingem, Germany) was used to obtain IR images from the proximal surfaces of the mounted teeth. For this purpose, the teeth were dried and immersed in a medium with low light transmission to simulate the oral environment. Next, VistaCam iX and its holder were placed on the occlusal surface of the teeth over the contact area to capture an image according to the manufacturer's instructions (Figure 1). Afterwards, DIAGNOdent pen 2190 (LF; KaVo, Biberach, Germany) was used twice by each of the two observers. The DIAGNOdent pen was calibrated prior to each measurement. In case of presence of carious lesion, its extension was classified and recorded as follows:

DIAGNOdent values 0-7 = (0) no caries at the contact area

DIAGNOdent values 8-15 = (1) enamel caries

$\geq$ 16 = (2) dentin caries

The images were observed by two observers who had been trained about the enhancement and interpretation of images. The two observers expressed their clinical judgment regarding presence/absence of carious lesions and their extension at each contact area using the following scoring system:

0= no caries at the contact area

1= enamel caries

2= dentin caries

Figure 1- VistaCam iX Proxi's real time image

The observers evaluated the images again after 2 weeks to calculate intraobserver reliability. The inter-observer reliability was also calculated. The DBSWIN software was used for the observation and assessment of IR images. Next, the samples were studied histologically as the gold-standard. For this purpose, At least three sections were made from each sample at the site of carious lesion using a cutting machine (Isomet; Bueher, USA). Microscopic slides were prepared and observed under a stereomicroscope (SZX9; Olympus, Japan) (Figure 2). Presence/absence and extent of carious lesions were recorded using the following scoring system:

0 = minimum caries

1 = caries within the enamel

2 = caries in dentin

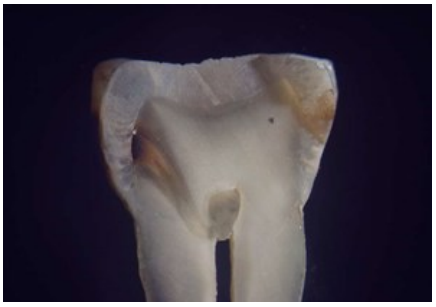

Figure 2- Histopathological analysis

Next, the results obtained from different methods were compared with each other, and also with the results of histological analysis as the gold-standard. After data collection, the data of the two observers were examined, and

the kappa coefficient of agreement was calculated between the two observers for the first and second observations. The absolute and relative frequency values of correct diagnoses by using each of the two methods were reported. Also, the kappa agreement coefficient between the two methods was calculated by the standard method and reported. Finally, disagreements were resolved by discussion until a consensus was reached before comparing the results with the gold standard. The sensitivity of DIAGNOdent and VistaCam iX Proxi was calculated for the three different extents of carious lesions and reported. The specificity of the two methods for detection of sound teeth was also calculated. To calculate the correlation coefficient, Cohen's kappa statistic, and Wilcoxon Rank Sum test were used to compare the results between the two methods and with the gold standard by SPSS 21.

Results

Histological assessment of 40 teeth, as the gold-standard, revealed that 7 teeth were sound, 5 teeth had enamel caries, and 28 teeth had dentin caries.

The agreements were as follows:

The intra-observer agreement was 0.67 for the first observer and 0.65 for the second observer in using VistaCam, and 0.70 for the first observer and 0.66 for the second observer in using DIAGNOdent (Table 1).

The inter-observer agreement for the first observation of VistaCam iX Proxi images was calculated to be 0.78; this value was 0.81 for the second observation. The inter-observer agreement for the results obtained from the first DIAGNOdent assessment was 0.55. This value was 0.77 for the second assessment (Table 2).

Table 1- Intra-observer agreement

		VistaCam results			Total	DIAGNOdent results			Total
		Sound	Enamel caries	Dentin caries		Sound	Enamel caries	Dentin caries	
first observer	Sound	5	0	0	5	10	0	0	10
	Enamel caries	1	6	5	12	2	9	5	16
	Dentin caries	0	1	22	23	0	1	13	14
Total		6	7	27	40	12	10	18	40
Kappa agreement					0.67				0.70
Second observer	sound	5	0	0	5	7	2	4	13
	Enamel caries	1	8	4	13	0	12	0	12
	Dentin caries	0	3	19	22	1	2	12	15
Total		6	11	23	40	8	16	16	40
Kappa agreement					0.65				0.66

Table 2- Inter-observer agreement

		VistaCam results			Total	DIAGNOdent results			Total
		Sound	Enamel caries	Dentin caries		Sound	Enamel caries	Dentin caries	
first observation	Sound	5	0	0	5	7	2	1	10
	Enamel caries	0	10	2	12	5	9	2	16
	Dentin caries	0	3	20	23	1	1	12	14
Total		5	13	22	40	13	12	15	40
Kappa agreement					0.78				0.55
Second observation	sound	6	0	0	6	8	4	0	12
	Enamel caries	0	7	0	7	0	10	0	10
	Dentin caries	0	4	23	27	0	2	16	18
Total		6	11	23	40	8	16	16	40
Kappa agreement					0.81				0.77

Based on the obtained agreement coefficients, the inter-observer agreement was higher in the second observation for both the DIAGNOdent and VistaCam iX Proxi. Eventually, the results of the second observation were chosen for the comparison with the gold-standard and the disagreements between the two observers were resolved by discussion. The final results of DIAGNOdent and VistaCam iX Proxi were compared with the gold standard (results of histological analysis) using the kappa coefficient of agreement. Table 3 compares the results of VistaCam iX Proxi with the gold-standard.

Based on the results of Table 3, the total agreement coefficient of the VistaCam was 0.79. Of 7 sound teeth, VistaCam diagnosed 5 to be sound, 1 with enamel caries, and 1 with dentin caries. Therefore, the specificity of VistaCam for sound surfaces was 71.4% and the percentage of false positive results was 28.5%. Also, 1 tooth with dentin caries was misdiagnosed as sound. Therefore, the negative predictive value of VistaCam was 83.3%. Of 5 samples with enamel caries, all of them were correctly diagnosed with enamel caries. Therefore, the sensitivity of VistaCam for surfaces with enamel caries was 100% and the percentage of false negative results was 0%. Furthermore, 1 sound tooth and 1 tooth with dentin caries were misdiagnosed with enamel caries. Therefore, the positive predictive value for surfaces with enamel caries was 71.4%. Of 28 teeth with dentin caries, VistaCam correctly diagnosed 26 teeth, 1 was misdiagnosed as sound and 1 with enamel caries. Therefore, the sensitivity of VistaCam for surfaces with dentin caries was 92.8% and the percentage of false negative results was 3%. In addition, 1 of sound teeth was misdiagnosed with enamel caries. Therefore, the positive predictive value of VistaCam for surfaces with dentin caries was 96.2%. Table 3 compares the results of

DIAGNOdent with the gold-standard.

Table 3- Comparison of the results of VistaCam iX proxy and DIAGNOdent with the gold standard

		Gold standard			
		Sound	Enamel caries	Dentin caries	Total
VistaCam	Sound	5	0	1	6
	Enamel caries	1	5	1	7
	Dentin caries	1	0	26	27
Total		7	5	28	40
DIAGNOdent	Sound	3	2	7	12
	Enamel caries	2	2	6	10
	Dentin caries	2	1	15	18
Total		7	5	28	40

Based on Table 3, the total agreement coefficient of DIAGNOdent was 0.168. Of 7 teeth that were diagnosed as sound by DIAGNOdent, 3 were correctly detected as sound, 2 had enamel caries and 2 had dentin caries. Therefore, the specificity of DIAGNOdent for detection of sound surfaces was 42.8%, and the percentage of false positive results was 57.1%. Furthermore, 2 of the teeth with enamel caries and 7 of the teeth with dentin caries were misdiagnosed as sound by the DIAGNOdent. Therefore, the negative predictive value of DIAGNOdent was 25%. Of 5 teeth diagnosed with enamel caries by DIAGNOdent, 2 were correctly diagnosed with enamel caries, 2 were diagnosed as sound, and 1 was diagnosed with dentin caries. Therefore, the sensitivity of DIAGNOdent for detection of enamel caries was 40%, and the percentage of false negative results was 40%. Also, 2 sound teeth and 6 teeth with dentin caries were misdiagnosed by DIAGNOdent as having enamel caries. Therefore, the positive predictive value of DIAGNOdent for surfaces with enamel caries was 20%. Of 26 teeth with dentin caries, 15 were correctly diagnosed with dentin caries, 7 as sound, and 6 with enamel caries. Therefore, the sensitivity of DIAGNOdent for surfaces with dentin caries was 53.5% and the percentage of false negative results was 25%. On the other hand, in this device, 2 sound teeth and 1 tooth with enamel caries were misdiagnosed with dentin caries by DIAGNOdent. Hence, the positive predictive value of DIAGNOdent for surfaces with dentin caries was 83.3%. Comparison of the results of DIAGNOdent and VistaCam iX Proxi with the gold standard revealed a significant difference (P=0.048).

Discussion

Considering the reversibility of carious lesions in case of early diagnosis (before cavity formation), it is imperative to find more precise methods for caries detection. At present, various imaging modalities are available for assessment of dental caries. studies have investigated the accuracy of different imaging modalities for this purpose, reporting controversial results. This study was performed to compare the diagnostic accuracy of two diagnostic tools: VistaCam iX Proxi which employs IR light to detect caries and DIAGNOdent pen for detection of proximal caries. According to the obtained results, the specificity of VistaCam iX Proxi for sound surfaces was 71.4%, while this value was 42.8% for DIAGNOdent. This indicates that false positive results are less likely to occur by DOAGNOdent for sound surfaces. Thus, unnecessary treatment is prevented. To the best of the authors' knowledge, no previous study is available comparing the diagnostic accuracy of VistaCam and DIAGNOdent for detection of enamel caries. Some studies reported lower accuracy of DIAGNOdent than bitewing radiography[10, 31-34], and some others reported the superiority of DIAGNOdent to bitewing radiography. [35-37] In the present study, enamel carious lesions were not divided into two groups of inner- and-outer half caries because the management of both would be the same, and preventive measures are only taken. With regard to enamel caries, the sensitivity of VistaCam iX Proxi was 100% while this value was 40% for DIAGNOdent, suggesting considerably higher sensitivity of VistaCam iX Proxi for detection of initial enamel caries, which are reversible. Employing a non-invasive approach without using ionizing light will be useful in preventive dentistry and for monitoring of high-risk patients. Considering dentin caries, the sensitivity of VistaCam iX Proxi and DIAGNOdent was 92.8% and 53.5%, respectively, suggesting higher sensitivity and diagnostic accuracy of VistaCam iX Proxi for monitoring of patients and detection of extent of carious lesions. False negative results are less likely in using VistaCam iX Proxi while the likelihood of correct detection of dentin caries is higher. Comparison of VistaCam iX Proxi and DIAGNOdent with the gold-standard revealed a correlation coefficient of 0.79 for VistaCam iX Proxi and 0.16 for DIAGNOdent, indicating higher accuracy of VistaCam iX Proxi for correct detection of the extent of carious lesion. Only one previous study was found to compare DIAGNOdent and caries detection with IR.[38] However, they did not use VistaCam iX Proxi. Their study had an in vivo design, and cavity preparation in dentin served as the gold standard. They showed higher performance of IR images than bitewing radiography and higher performance of bitewing radiography than DIAGNOdent. some studies compared DIAGNOdent with bitewing radiography[9, 10, 31, 32, 35, 36], and some others compared IR images with bitewing radiography. [4, 5, 7, 16, 26, 39, 40] The majority of studies showed higher performance of bitewing radiography than DIAGNOdent and stated that DIAGNOdent must be used with another method of diagnosis. Some studies comparing bitewing radiography and IR images have reported contradictory results. Maia et al. (2011) compared the diagnostic accuracy of IR images and bitewing radiography for detection of initial proximal caries, and observed that IR images had higher sensitivity for caries detection compared with bitewing radiography.[39] Russotto et al, (2016) in their in vivo study on the accuracy of IR images for detection of proximal caries observed that IR images had higher sensitivity for detection of proximal caries. Furthermore, false positive responses were also more likely to occur, confirming the results of the present study.[40] However, Kuhnisch et al. (2016) assessed the validity of IR radiation for detection of interproximal dentin caries, and found that the diagnostic power of bitewing radiography and IR images was the same for dentin caries.[16] Sochtig et al, (2014) in their in

vivo study on diagnostic accuracy of IR radiation for caries detection found that both bitewing radiography and IR images had the same diagnostic accuracy for detection of proximal and occlusal caries.[7] Baltacioglu and Orhan (2017) compared the diagnostic accuracy of bitewing radiography and IR images for detection of proximal caries, and found no significant difference between the two types of images. They reported that IR radiation may be used for caries detection with acceptable accuracy.[5] Abogazalah et al. (2017) evaluated the efficacy of bitewing radiography and IR images for detection of non-cavitated proximal caries in vitro, and observed that both types of images had the same diagnostic accuracy for this purpose.[41] Furthermore, Jablonski-Momeni et al. (2017) evaluated the diagnostic accuracy of VistaCam iX Proxi for detection of enamel caries in vivo, and found no significant difference between the diagnostic accuracy of bitewing radiography and IR images for detection of proximal enamel caries.[4] Difference between the results of previous studies and the present findings can be due to different methodologies, types of carious lesions, study design, types of devices, different IR radiation wavelengths, and using different techniques as the gold standard. In total, VistaCam iX Proxi appears to be a suitable diagnostic modality for caries detection with or without radiography, and its application can be beneficial for patient monitoring and early detection of initial caries. Eventually, it can be stated that this system can function as an excellent diagnostic tool especially for monitoring of patients at high risk of caries, pregnant women, children, patients with an extreme gag reflex, or large torus, and sites which cannot be radiographically examined.[17, 21]

Conclusion

Considering the high sensitivity and considerably low percentage of false negative responses of VistaCam iX Proxi in detection of dental caries, it may be recommended as an efficient tool for caries detection especially enamel caries, and may serve as an adjunct to bitewing radiography and clinical examination. It can be utilized for preventive measures and monitoring of pediatric patients, and those who have contraindications for imaging.

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Conflict of Interest

No Conflict of Interest Declared■

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