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Original Article

Comparison of diagnostic effects of infrared imaging, visual inspection, and bitewing radiography in primary occlusal caries of permanent teeth

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ABSTRACT

Background: This study compared the diagnostic efficacy of VistaCam iX infrared camera, visual inspection, and bitewing-radiographs for the detection of primary occlusal caries of permanent teeth.

Materials and Methods: In this *in vitro* experimental study, 80 extracted human premolars were evaluated. The occlusal surfaces of these teeth were demineralized by immersion in a demineralizing agent. Then, the International Caries Detection and Assessment System (ICDAS II), bitewing-radiography, and Proxi head of VistaCam iX were used to inspect them. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for each diagnostic modality. Data were analyzed using SPSS. Twenty-five at $P < 0.05$ level of significance with one-way analysis of variance and Games–Howell test.

Results: Bitewing-radiography had significantly lower sensitivity than ICDAS II and VistaCam ($P < 0.05$). ICDAS II was comparable to VistaCam, with no significant difference in sensitivity ($P > 0.05$). ICDAS II had a significantly higher PPV than bitewing-radiography and VistaCam ($P < 0.05$). The sensitivity of bitewing radiography was significantly lower than that of ICDAS II and VistaCam ($P < 0.05$). ICDAS II was comparable to that of VistaCam with no significant differences in sensitivity ($P > 0.05$). ICDAS II had a considerably higher PPV than bitewing-radiography and VistaCam ($P < 0.05$). The NPV of ICDAS II visual inspection was significantly higher than that of bitewing-radiography and VistaCam ($P < 0.05$). The ICDASS II and VistaCam had a repeatability coefficient of 47.4%. For bitewing-radiography and VistaCam, this value was 44.2% and 83.4% for ICDAS II and bitewing-radiography.

Conclusion: Visual inspection seems to be superior to bitewing-radiography and VistaCam in detecting primary occlusal caries of permanent teeth.

Key Words: Bitewing, dental caries susceptibility, dentistry, fluorescence, radiography

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INTRODUCTION

Acidogenic bacteria demineralize tooth surfaces resulting in dental caries. In recent years, preventive interventions have lowered the prevalence of dental caries while increasing the proportions of occlusal caries. Carious lesions are hard to detect especially in the initial stages.[1] Early and invasive caries detection is a fundamental and critical aspect of diagnosis and treatment planning.[2] The initial step is visual inspection detecting a wide range of caries from minor enamel lesions to large dentin lesions. The International Caries Detection and Assessment System (ICDAS-II) Approach is a well-established visual system that ranks tooth surfaces from zero to five, with the score of zero representing a caries-free surface.[2,3] This process requires a clean, dry, and well-lit tooth surface. Furthermore, it is difficult to detect noncavitated caries on occlusal surfaces leading to inspection sensitivity of below 30%.[4,5] Consequently, complementary methods should be utilized to avoid false-positive and false-negative results, especially in noncavitated lesions.[1]

Bitewing radiography is a useful method to detect occlusal lesions of molars and premolars and improves the sensitivity of visual examination.[6] Visual inspection combined with bitewing radiography can detect most carious lesions and distinguish almost all healthy teeth.[4] Radiation exposure and dependency on the cooperation of patients are the most prominent disadvantages of bitewing radiographs.[7] These factors make this method not suitable for pregnant women, uncooperative children, and patients with low caries risk.[5,8]

The auto-fluorescence of chromophores in enamel and dentin is another supplementary technique in caries diagnosis. The chromophores of bacteria and caries can be detected by subtracting the fluorescence of a healthy tooth surface from that of a carious one.[9-11] VistaCam (Classic, CL and IX, Durr Dental, Bietigheim-Bissingen, Germany) is a caries-detection fluorescence camera that records the reflected light by emitting 450 nm violet light. After filtering 495 nm or below light, 510 nm (green-yellow) light indicates a healthy tooth surface and 680 nm light suggests bacterial metabolites. The DBSWIN program converts the pictures into numerical scores of zero to three. These gadgets can digitize and preserve data, making treatment planning and communication more convenient.[3,8,12]

The sensitivity and specificity of new devices and techniques must be evaluated by histological evaluation, which is the gold standard for carious lesions.[1,13] To the best of our knowledge, no study has evaluated the effectiveness of VistaCam iX in identifying occlusal caries. Therefore, the goal of this research is to assess the effectiveness of VistaCam in detecting occlusal caries compared to X-rays and visual examination.

MATERIALS AND METHODS

This *in vitro* study used 80 extracted human permanent premolars without enamel hypoplasia or fluorosis which were extracted for orthodontic purposes. Soft tissue and calculus were carefully removed using a toothbrush and a scaler. The teeth were then sterilized for 20 min in sodium hypochlorite (2%) and preserved in formalin (10%).[14] The inclusion criteria were premolar teeth that were caries-free on the occlusal surface. If the proximal surface of a tooth had a slight carious lesion that did not affect the occlusal surface, that tooth would be included. Teeth with anomalies, structural defects, large carious lesions, cavities, or fractures were excluded and replaced.

This study was approved by the Ethics Committee of Tehran University of Medical Sciences under the identification code of IR.TUMS.DENTISTRY.REC.1396.2659.

Sample preparation

The teeth were mounted in putty impression material by putting the marginal ridges in contact with each other. Then, red dental wax was utilized in interproximal areas to simulate their condition in the oral cavity and take bitewing radiography in a condition that is close to that of the mouth. Two 3 mm × 3 mm windows were formed on the occlusal surface using adhesive. The rest of the tooth was covered in acid-resistant nail polish to compare the surfaces exposed to acid to the surfaces covered with polish. After the polish had dried, the glue was removed. The teeth were then immersed in a demineralization solution containing calcium chloride (2 mmol/L), tri-sodium phosphate (2 mmol/L), and stat buffer (75 mmol/L) at a pH of 6.4 for 4 days.[15,16]

International Caries Detection and Assessment System II

A specialized dentist inspected the occlusal surfaces of prepared teeth using direct vision, reflected light,

and a three-in-one syringe. ICDAS II criteria were used to categorize the teeth:

- Code zero: Healthy surfaces
- Code one: Initial signs of change in enamel visible to the naked eye
- Code two: Changes in the enamel that can be seen even when wet
- Code three: Loss of enamel due to caries without dentin exposure
- Code four: Dark shadow in dentin with or without enamel loss
- Code five: A cavitated carious lesion limited to exposed dentin
- Code six: An extensive cavity due to caries with exposed dentin.[17]

Radiography

Bitewing radiographs were taken from prepared teeth with the radiation emitted tangentially on the occlusal surface. The distance between the film and the tooth was 5 cm, while the source and the film were 32 cm apart. The X-ray machine Kodak 2200 intra-oral X-ray system (Eastman, Kodak Co. Rochester, NY, USA) and size two Insight films (Eastman Kodak Company Paris, France) were used. The camera was a CCX intra-oral device with an 8 mm focal point, 70 kVp voltage, 8 mA, a filter, and an exposure time of 16 s. To imitate diffused and weakened radiation hitting the face, 1 cm of soft tissue-like material was placed around the teeth. The films were processed with solutions made the same day on an automatic film processor (Velopex, Extra-x, Medivance Instruments Ltd., London, UK, and NW107A). Figure 1 shows examples of the X-rays. A radiologist evaluated the radiographs in a dark room using a magnifier to assign a code to the occlusal surface:

- Code zero: No radiolucency
- Code one: Radiolucencies in the outer half of the enamel
- Code two: Radiolucencies penetrating the inner layer of enamel and reaching the denting enamel junction (DEJ)
- Code three: Radiolucencies involving the outer half layer of dentin
- Code four: Radiolucencies in the inner half of dentin with or without pulp involvement.[18,19]

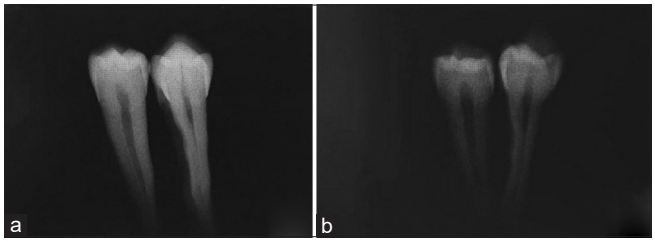

Figure 1: Radiographs of teeth, (a) without occlusal caries, (b) with occlusal caries.

VistaCam iX

The intraoral fluorescent camera with a wavelength of 405 nm digitally recorded the reflected light. Some examples are displayed in Figure 2. Yellow-green light (510 nm) indicates a healthy tooth surface and red light (680 nm) suggests a carious tooth surface. DBSWIN software converted these data into numerical scores of zero to three:

- 0–1: Healthy enamel
- 1–1.5: Primary caries (outer layer of enamel)
- 1.5–2: Caries in the inner layer of enamel
- 2–2.5: Caries in the outer layer of dentin
- 2.5–3: Caries in the inner layer of dentin.[20]

Histological assessment

The teeth were encased in acrylic blocks with their occlusal surfaces exposed for histological evaluation. With a diamond saw and cooling Mecatome T210 (Presi, Grenoble, France) each tooth was cut into layers of 1 mm thickness from the mesiodistal direction. The histological layers were examined using a 10X Olympus SZ 60 stereomicroscope from Japan as demonstrated in Figure 3. The histological assessment was completed by another researcher who was not involved in the previous stages of the study (a blind study) and assigned ratings based on the Downer scale:[21]

- Score zero: No demineralization
- Score one: Demineralization in the outer half of enamel
- Score two: Demineralization in the inner half of enamel up to DEJ
- Score three: Demineralization in the outer half of dentin
- Score four: Demineralization in the inner half of dentin.[20]

Statistical analysis

Data were analyzed by SPSS software (Version 25.0. Armonk, NY, USA: IBM Crop). The normality distribution of data was evaluated by Kolmogorov–Smirnov test. Bcl-2 and Bax expression and their ratio were compared between the study groups by one-way ANOVA and Games–Howell *post hoc* test. $P < 0.05$ were considered statistically significant.

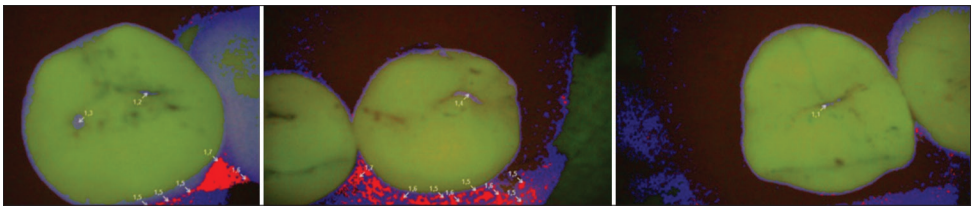

Figure 2: Images taken with Proxi head of VistaCam.

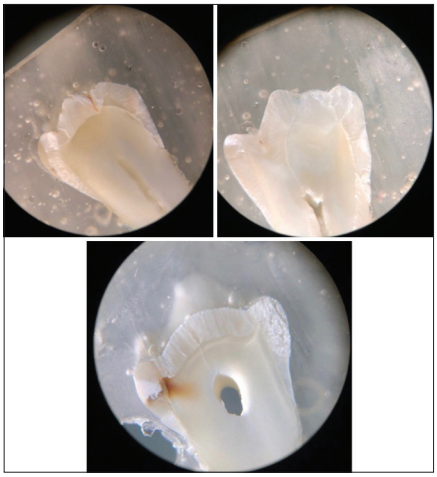

Figure 3: Histology examination.

RESULTS

One hundred and twenty different surfaces were examined in this article. All surfaces were analyzed with the ICDAS II method, bitewing radiography, VistaCam, and histological assessment (gold standard). Table 1 shows the sensitivity, specificity and positive and negative predictive value (NPV) of each approach.

The specificity of ICDAS II, radiography, and VistaCam was 1, 0.957 (95% confidence level: 0.939–0.975), and 0.424 (95% confidence level: 0.334–0.514), respectively.

The sensitivity of ICDAS II, radiography, and Vista Cam was 0.786. (95% confidence level: 0.701–0.831, 0.357 (95% confidence level: 0.313–0.390), and 0.786. (95% confidence level: 0.701–0.831), respectively.

The positive predictive value (PPV) of ICDAS II was 1 while for radiography and VistaCam, it was 0.714 (95% confidence level: 0.673–0.755), and 0.284 (95% confidence level: 0.202–0.316), respectively. PPV means the ratio of diagnosed caries with a specific technique to the carious lesions confirmed by the gold standard (histology). These data show that ICDAS II detected all carious lesions.

Table 1: Sensitivity, specificity, positive and negative predictive value of International Caries Detection and Assessment System II, radiography and VistaCam in 80 extracted human premolars

Diagnostic technique	Specificity (%)	Sensitivity (%)	PPV (%)	NPV (%)
ICDAS II	100	78.6	100	93.9
Radiography	95.7	35.7	71.4	83
VistaCam	42.4	78.6	28.4	86.7
VistaCam	42.4	78.6	28.4	86.7

PPV: Positive predictive value; NPV: Negative predictive value; ICDAS II: International Caries Detection and Assessment System II

Radiography and VistaCam were in the second and third positions.

The NPV of ICDAS II, radiography, and VistaCam was 0.939 (95% confidence level: 0.896–0.982), 0.83 (95% confidence level: 0.762–0.898), and 0.867 (95% confidence level: 0.805–0.929), respectively, for primary occlusal caries. NPV shows the ratio of diagnosed caries-free surfaces to the caries-free surfaces confirmed by histology. ICDAS II had the highest NPV, which means when ICDAS II diagnosed a surface caries free, it was more probably truly caries free. VistaCam and radiography were in second and third place, respectively.

ICDAS II with VistaCam has a repeatability coefficient of 47.4%, radiography with VistaCam has a repeatability coefficient of 44.2%, and ICDAS II with radiography has a repeatability coefficient of 83.4%.

As shown in Figure 4, the diagnoses of teeth surfaces made using histology (gold standard), ICDAS II, radiography, and VistaCam were compared. The specificity of VistaCam was significantly lower than radiography and ICDAS II. The sensitivity of radiography was significantly lower than ICDAS II and VistaCam, but the specificity of ICDAS II and VistaCam did not differ significantly. The PPV of ICDAS II was significantly higher than ICDAS II and radiography. Moreover, the PPV of VistaCam was significantly lower than ICDAS II and radiography.

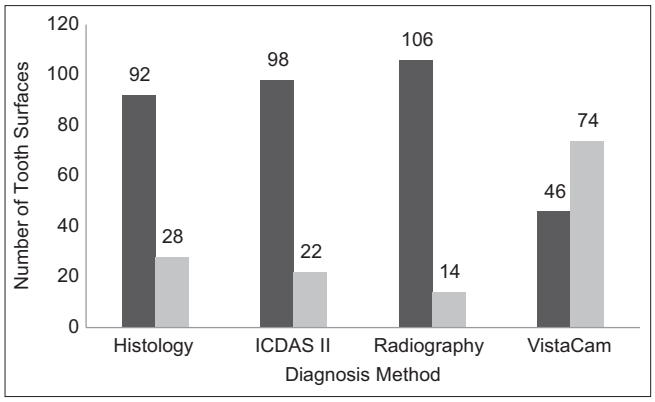

Figure 4: Comparison of the diagnosis results of tooth surfaces using histology, ICDAS II, radiography, and VistaCam. The black bars represent healthy tooth surfaces, and the grey bars represent carious tooth surfaces according to histology (gold standard), ICDAS II, bitewing radiography, and VistaCam. ICDAS II: International Caries Detection and Assessment System.

Finally, the NPV of ICDAS II was significantly higher than radiography and Vistacam, but the NPV of radiography and VistaCam did not show a significant difference (at $P < 0.05$ level of significance).

DISCUSSION

Occlusal lesions are the most common carious lesions.[22] Primary occlusal caries are more difficult to detect than lesions on other surfaces.[23] This is due to the unique morphology of occlusal grooves and hidden cavities inside their depths.[24] As a result, the detection of these lesions is critical, and dentists must use precision, skill, and cutting-edge technologies to improve their diagnoses.[23] Modern dentistry is far more conservative, focusing on preserving healthy tooth structure as much as possible. Therefore, it is critical to make an accurate identification of healthy tissue.

This study employed the Proxi head of a VistaCam iX intraoral camera, a novel and noninvasive approach for detecting occlusal caries. The proxi head is a useful addition to the VistaCam iX and VistaCam iX HD intraoral cameras. It produces infrared light (850 nm) that penetrates translucent enamel and scatters in lesions of enamel and dentin. The goal of the Proxi head, according to the manufacturer, is to detect incipient caries without exposing the patients to radiation. This method uses occlusal photography and is not always compatible with bitewing radiographs.[8]

Our findings revealed that ICDAS II had the highest specificity and VistaCam showed the lowest specificity among the other two. This could be due to false-positive results in VistaCam data caused by misinterpretation of enamel cracks. Enamel Cracks appear as bright areas in VistaCam, which according to the manufacturer's instructions, indicates the presence of cavities. However, histology examination (gold standard) showed no sign of caries.[19] Since our study was *in vitro*, the outcome may not be compatible with *in vivo* situations.

According to Kouchaji, DIAGNOdent had lower specificity than visual inspection in diagnosing occlusal caries. A good caries detection method should have a sensitivity of at least 75% and a specificity of at least 85%.[22] Rodrigues *et al*. found that the ICDAS II and fluorescent cameras had higher sensitivity, while the laser fluorescent cameras and bitewing radiographs had higher specificity in occlusal caries. They also stated that ICDAS with bitewing radiography provided the best results and was the optimum combination for detecting caries on the occlusal surfaces.[24]

ICDAS II had the same sensitivity for the detection of primary caries as VistaCam, however, it was much lower than that of radiography. This suggests that radiography is the best approach in real caries. Similar to this article, Presoto *et al*. found that the VistaCam fluorescence camera had good sensitivity but limited specificity in detecting occlusal caries despite the greater specificity of ICDAS and radiography.[13] In comparison to the other two approaches, the low specificity of the VistaCam camera caused inaccurate detection.

In this study, ICDAS II had a much greater NPV or correct negative results than radiography and VistaCam. The difference between the NPV of VistaCam and radiography was not statistically significant.

The specificity of VistaCam was significantly lower than that of radiography and ICDAS II.

The sensitivity of radiography was much lower than ICDAS II and VistaCam. The ICDAS II approach had the same sensitivity as VistaCam, and the difference was insignificant.

ICDAS II had a significantly higher PPV than radiography and VistaCam. VistaCam had a significantly lower PPV than ICDAS II and radiography. The repeatability coefficient of ICDAS II with VistaCam was 47.4% while it was 44.2% for the

radiography with VistaCam and 83.4% for the ICDAS II with radiography. This demonstrated that the visual inspection with radiography had a high degree of repeatability. Because a test can be inaccurate but repeatable, repeatability is not necessarily crucial. As a result, sensitivity and specificity tests are essential when evaluating a diagnosis method. Kouchaji demonstrated the reproducibility of visual examination and fluorescence laser in a paper similar to this one.[22] ICDAS II with bitewing radiography provided the highest performance and combination for caries detection on occlusal surfaces, according to Rodrigues *et al*.[24] According to the findings, ICDAS II may be the best approach for diagnosing primary occlusal caries among the methods tested in this article.

Further, *in vivo* study is recommended on the diagnostic value of the Proxi head of VistaCam and Bitewing radiographs on occlusal caries of permanent molars compared to the gold standard. Furthermore, the effectiveness of the VistaCam Proxi head should be evaluated compared to other innovative caries detection techniques.

CONCLUSIONS

In the present study, the aim was to evaluate the effectiveness of VistaCam iX in identifying occlusal caries. The specificity and sensitivity were 100% and 78.6% for ICDAS II, 95.7% and 35.7% for radiography, and 42.4% and 78.6% for VistaCam which were notably different. ICDAS II seemed to be the best approach for detecting primary caries followed by bitewing radiography. VistaCam did not show favorable outcomes due to false-positive results in enamel cracks. Bitewing radiography had much lower sensitivity than ICDAS II and VistaCam. ICDAS II and VistaCam had similar sensitivity and did not differ considerably. We suggest practitioners use visual inspection (ICDAS II) first when encountering possible occlusal caries since this method has superior sensitivity and specificity compared to others. Moreover, bitewing radiography can aid in reaching a definite diagnosis if necessary.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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