# Proximal Caries Detection in Permanent Teeth by Using DIAGNOcam: An in Vivo Study

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## Abstract

The greatest challenge in dental practice is diagnosing non cavitated dental caries. Diagnostic tools play a very valuable role in the detection of dental caries. In this study traditional radiographic bitewings and the newer DIAGNOcam were used to identify caries lesions. Bitewing radiography enhances the diagnosis of dental caries in areas that are inaccessible to clinical visual inspection by revealing a radiographic image of the lesions that are present.

The DIAGNOcam is a form of near infra-red (NIR) transillumination that transmits light through the tooth in order to detect the dental caries lesions. It uses a digital camera to capture images of the lesions, from which the extent of demineralization can be determined. Aim: To compare the reliability of DIAGNOcam to that of bitewing radiography in the detection of proximal dentinal caries in permanent teeth.

One hundred eighty-seven teeth were scanned with the DIAGNOcam. Once the DIAGNOcam examinations of the teeth were completed, digital bitewing radiographs were obtained under standardized conditions. The images obtained from the DIAGNOcam and the bitewing radiographs were evaluated by two observers. Statistical analysis was performed to assess the percentage of agreement between the two methods using Statistical Package for Social Sciences (SPSS, IBM, USA); and the inter- and intra-rater reliability were assessed.

The findings from the bitewing radiographs of the class IV proximal dentinal lesions were used as a gold standard, and compared to the corresponding NIR light images that showed 97.3% agreement between the two methods in the diagnosis of dentinal caries. Kappa statistics, used for assessing the agreement between the two observers, indicated an inter-rater reliability of 0.978 (p = 0.00001). Cronbach's Alpha, used to assess the intra- reliability of the findings by the main observer, showed 0.987 (p = 0.00001). The results were based on the correlation of bitewing radiographs and DIAGNOcam images according to a selection of positively validated dentin caries lesions.

DIAGNOcam might be reliable for detecting proximal dentin caries in permanent teeth. The introduction of NIR light transillumination via the DIAGNOcam allow integration of this imaging procedure into everyday dental practice, which could lead to a reduced usage of radiographic bitewings for the detection of proximal caries.

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## Introduction

Dental caries is a microbial disease affecting the hard substance of the tooth, leading to destruction through the process of decalcification. Tooth decay and the destruction of teeth is a complex process[1]. Early detection of dental caries lesions is crucial in ensuring early caries management, as well as in the risk assessment for more serious cavitation on the affected teeth. With early diagnosis, patients can receive proper treatment that can help halt the caries process[2]. Besides the conventional caries detection methods, such as probing, visual inspection, and the use of intraoral film and

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digital sensors, other types of methods are currently used for detection of caries. Nevertheless, 25%−42% of carious lesions remains undetected[3]. The new methods for proximal caries detection that are widely used in clinical practice today include laser fluorescence devices, such as near infra-red transillumination (NIR) DIAGNOcam, digital fiber-optic transillumination (DIFOTI), and electrical caries monitoring (ECM). DIAGNOcam uses a light-based apparatus equipped with a camera that helps to capture caries images using visible light. The light helps to identify the tooth density caused by demineralization. The DIAGNOcam has been demonstrated to be an effective diagnostic tool for detecting proximal caries[4].

**Materials and methods**

The teeth used in this study comprised 12 permanents first molars (6.4%), 5 permanent second molars (2.7%), 74 permanents first premolars (39.6%), and 96 permanents second premolars (51.3%). The 187 teeth (374 proximal surfaces) were viewed using the two imaging modalities: DIAGNOcam method and bitewing dental radiography.
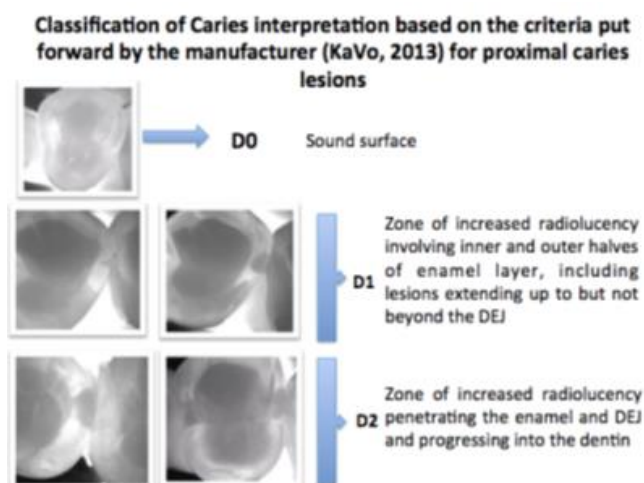


**Figure 1.** DIAGNOcam Proximal Caries Interpretation Criteria.

The procedure and aims of the study were explained to people included in the study and informed consent was obtained. The selected teeth were without obvious cavities, symptoms of pulpitis, proximal restorations, developmental disorders, and missing adjacent teeth. The teeth were scanned with a

DIAGNOcam (780 nm wavelength; Kavo, Biberach, Germany). Each tooth was dried with compressed air for 10 seconds before the DIAGNOcam camera was centered over an area of interest. The optimal position of the intraoral tip with the sensor placed on the teeth was verified from the live image appearing on the screen of the computer (HP, USA) next to the dental unit. The images were interpreted as per the classification of proximal caries lesions guidelines, based on the criteria put forward by the manufacturer[5]. (Figure 1).

Once the DIAGNOcam examinations of the teeth were completed, the bitewing radiographs were carried out with a dental intraoral X-ray machine (POYE, Taiwan) and an adult photo-stimulable phosphor plate (PSP Detector, GENDEX, USA). An extension cone paralleling approach (XCP, KERR, Switzerland) was used; the exposure time was 0.6 seconds at a cathode voltage of 70 kV and 10 mA amperage. The PSP intraoral plate was then placed into the Image Analysis Module Detector (DURR Dental, Germany), which is placed in the digital image analyzing unit (VistaScan DURR Dental, Germany). If any defect, such as overlapping of the teeth occurred, the radiographs were repeated. The radiographs taken were interpreted as per the criteria put forward by Pitts (1984) [6]. Statistical analysis was performed to assess the percentage of agreement between the bitewing radiograph and the DIAGOcam in detecting the dentinal caries using Statistical Package for Social Sciences (SPSS) Version 22 (IBM, USA).

Inter-rater reliability was assessed using Kappa statistics, to assess the agreement between the two observers. Cronbach's Alpha for the main examiner was calculated to determine the agreement and the reliability of the findings by the same examiner between the two techniques with one-week time interval between first and second readings.

**Results**

The result of the DIAGNOcam interpretation showed that from the total of 374 surfaces, 216 surfaces were sound/caries free (D0) (Figure 2), 111 surfaces were enamel caries (D1), and 47 surfaces were dentin caries (D2). The result of the radiographic interpretation showed that from the total of 374 surfaces, 274

surfaces were sound/caries free (R0) (Figure 2), 52 surfaces were enamel caries (R1), and 48 surfaces were dentine caries (R2).
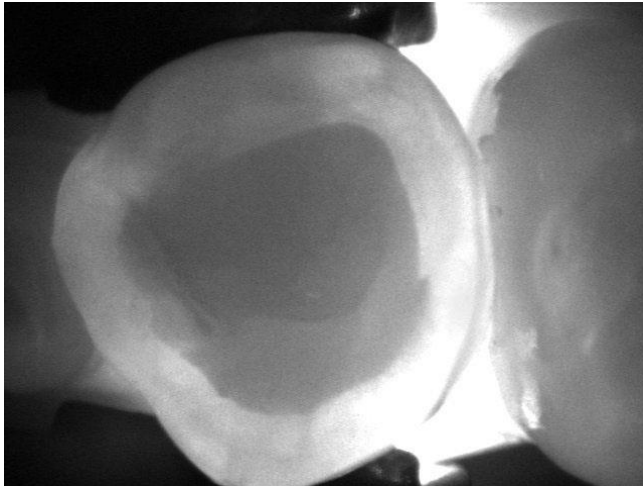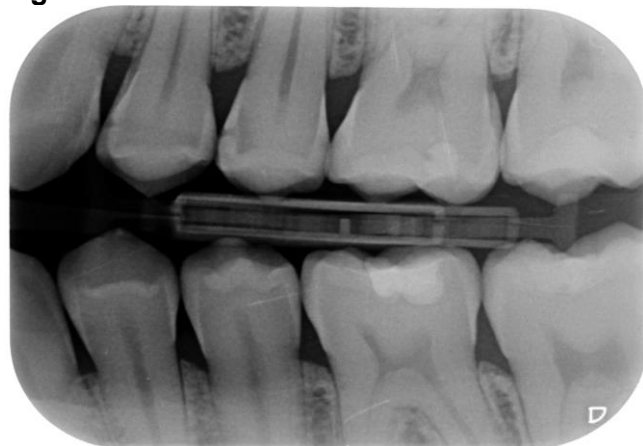


**Figure 2a**



**Figure 2b**
**Figure 2.** DIAGNOcam (**a**) and radiographic (**b**), images of a sound left mandibular first premolar.

DIAGNOcam showed 111 surfaces with enamel caries, while radiography identified 52 surfaces with enamel caries (Figures 3-5).
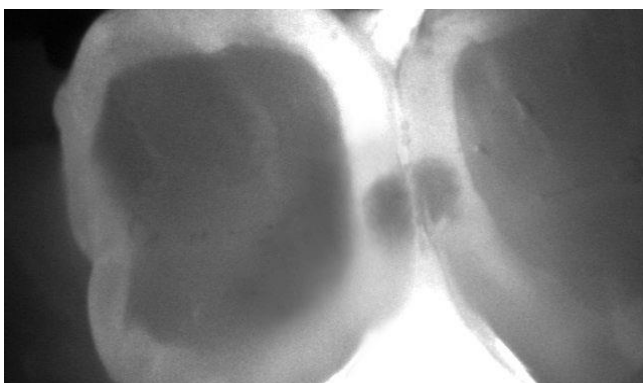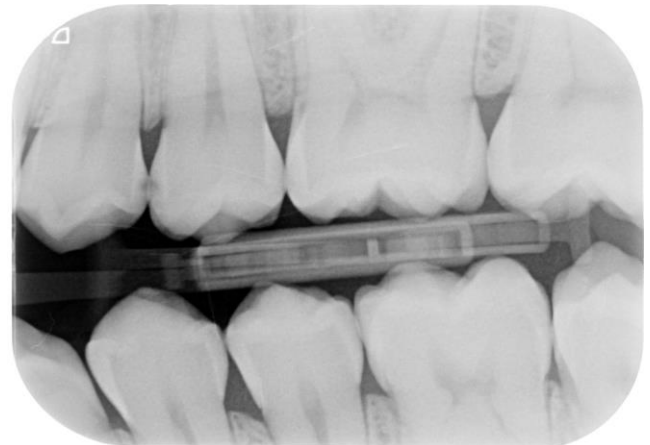


**Figure 3a**



**Figure 3b**
**Figures 3.** DIAGNOcam (**a**) and radiographic (**b**) images of enamel caries in the right maxillary first and second premolars.
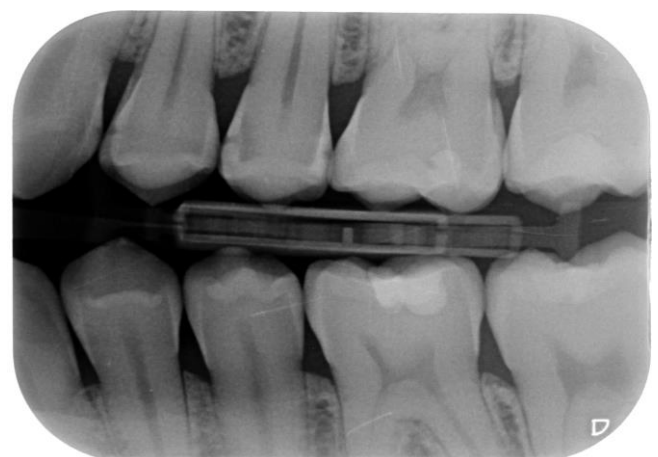


**Figure 4a**



**Figure 4b**
**Figure 4.** shows DIAGNOcam (**a**) and radiograph (**b**) images of enamel caries distally and dentin caries mesially in the same left maxillary second premolar tooth.

**Figure 5a**



**Figure 5b**
**Figures 5.** DIAGNOcam image (**a**) showing enamel caries and a sound radiograph (**b**) image of the same left maxillary first premolar.

Figures 6 shows DIAGNOcam and radiograph images of the right maxillary first and second premolars with dentin caries. Figures 7 shows a DIAGNOcam image of the right mandibular second premolar with enamel caries, while the radiographic image of the same tooth shows dentin caries.
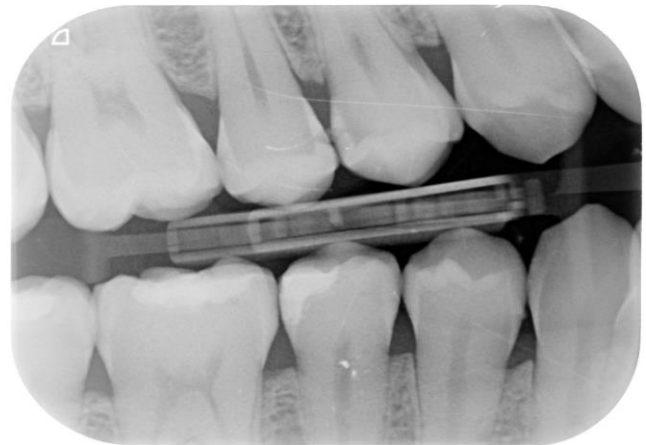


**Figure 6a**



**Figure 6b**
Figures 6. DIAGNOcam (**a**) and radiographic (**b**) images of the right maxillary first and second premolars with dentin caries.
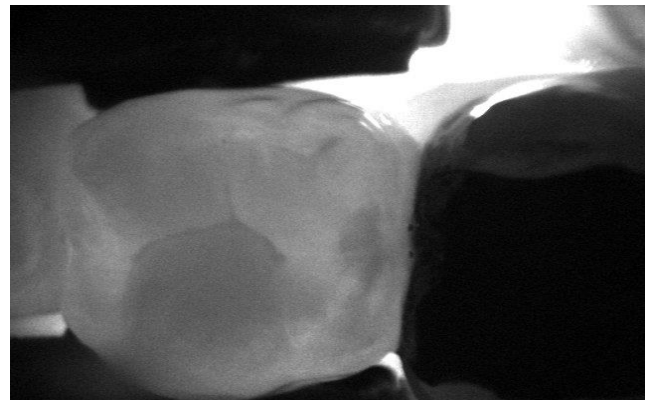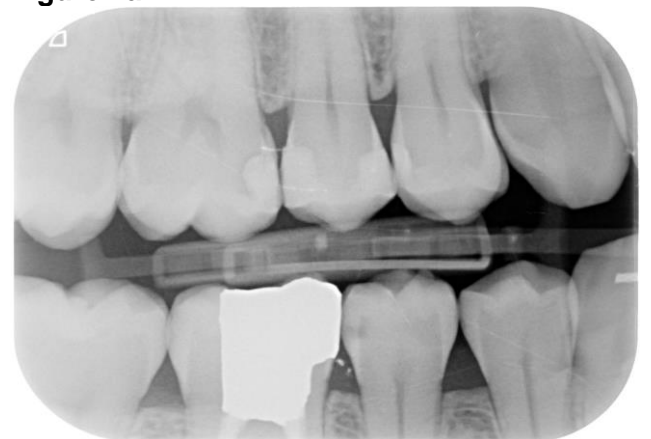


**Figure 7a**



**Figure 7b**
**Figures 7.** DIAGNOcam (**a**) image of the right mandibular second premolar showing enamel caries, while the radiographic image (**b**) of the same tooth shows dentin caries.

The findings from the bitewing radiographs of the proximal dentinal lesions were used as gold standard, and compared to the

corresponding NIR light images that showed 97.3% agreement between the two methods in the diagnosis of dentinal caries (Table 1).

| | DIAGNOcam | | | Radiograph | | |
|---|---|---|---|---|---|---|
| | D0 | D1 | D2 | R0 | R1 | R2 |
| Count | 216 | 111 | 47 | 274 | 52 | 48 |
| % | 57.8% | 29.6% | 12.6% | 73.3% | 13.9% | 12.8% |

**Table 1.** Correlations Between Radiographic & DIAGNOcam Readings.

### Discussion

Radiographic caries detection is the most frequently used diagnostic tool in general dental practice [7]. A previous systematic review and meta-analysis reviewed 947 identified articles, and concluded that radiographic caries detection is highly accurate for dentin caries lesions [8]. Radiography is associated with potentially harmful ionizing; therefore, there is a need for more alternative techniques and the development of new diagnostic methods and instruments for caries detection that are less harmful [9]. Many studies have used the bitewing radiograph as a gold standard for detecting proximal dentinal caries [5]. However, it has been reported that enamel proximal caries lesions are poorly detected by radiography, since at least 40% demineralization must be present before radiographic detection is possible [10]. Near infra-red (NIR) imaging has great potential as a screening tool for the detection of proximal lesions without the use of ionizing radiation. The DIAGNOcam, which uses NIR light for transillumination of the tooth, has been used as diagnostic device for caries detection. The light is transmitted directly through the alveolar process, but not into the proximal space [11].

In the present study, Forty-seven of 48 lesions identified radiologically as (R2) proximal dentin lesions were classified as dentin lesions (D2) by DIAGNOcam. The results of the two methods showed 97.3% agreement in diagnosis of dentin caries. The one lesion that was not observed on DIAGNOcam imaging was probably missed due to tooth overlap, the presence of gingival tissue blocking the contact and bulky gingival tissues, so the usefulness of NIR may be limited [11]. It may also be because the bitewings radiographs are a two-dimensional representation of a three-dimensional tooth mass[12].

Cohen suggested the Kappa result be interpreted as follows: 35 - 63% as moderate, 64-81% as strong, and 82-100% as almost perfect agreement [13]. Accordingly, Inter-rater reliability in this study was almost perfect (97.3%). Chronbach's alpha results are interpreted as follows: The acceptable values of alpha, ranges from 70-80%, values between 80-90% are good, and values more than 90% are excellent [14]. Based on that, the intra-rater reliability Cronbach's alpa of this study was excellent (98.7%).

This finding was in consistent with the results of the study conducted by Sochtig *et al.* (2014) who found that bitewing radiographs and NIR transillumination via DIAGNOcam (780 nm wavelength) showed 95.3% agreement in the diagnoses of dentin caries. Thus, employing NIR transillumination may help to avoid the use of bitewing radiographs for diagnosis of caries in everyday clinical practice.

The results of this study were also compatible with the results of a study conducted by Kuhnisch *et al.* (2015) who demonstrated a comparably high diagnostic validity of NIR transillumination with the DIAGNOcam in comparison to bitewing radiographs for the detection of proximal dentin caries. That study showed 99% agreement between the two methods, and also concluded that NIR transillumination could reduce the usage of bitewing radiographs.

In a study conducted by Abdelaziz and Krejci (2015), it was found that NIR transillumination technology using the DIAGNOcam was useful in the detection of proximal caries and, less importantly, for occlusal caries, fissures, and secondary decay around amalgam and composite restorations. The study found that the dentinal lesions depicted on the DIAGNOcam image correlates very closely with radiographic images. Our findings validated the usefulness of the DIAGNOcam device for evaluation of proximal caries in dental practice, as compared to bitewing radiographs, as also reported by other studies [16]. A study by Błażejewska *et al.* (2016) has confirmed the usefulness of detecting primary caries with the DIAGNOcam, but still the effectiveness of detecting carious lesions remains lower than with radiovisiography. However, there was no significant difference between the two methods in the detection of dental caries [17].

The results of this study were in agreement with those of a study by Marinova-Takorova *et al.* (2015) who showed that the results obtained by DIAGNOdent and DIAGNOcam were highly similar, but DIAGNOcam results correlated better with the clinical results [18]. A study conducted by Staninec *et al.* (2010) concluded that NIR imaging has great potential as a screening tool for the detection of proximal lesions without the use of ionizing radiation [11]. Our study agreed with their findings regarding dentinal proximal caries lesions; however, our study used DIAGNOcam, which uses NIR 780 nm wavelength, while their study used NIR 1310 nm wavelength. The result of our study may be supported by a study conducted by Russotto *et al.* (2016) which concluded that NIRT should be used in caries diagnosis in combination with radiographic images to correct a false positive diagnosis of enamel caries. Moreover, NIRT could be used to detect caries in patients for whom non-urgent radiographic exposition is contraindicated and to monitor enamel caries in medically treated patients [19].

## Conclusions

Based on the results of this study, the following conclusions can be drawn: the DIAGNOcam might be reliable for detecting proximal dentin caries in permanent teeth and might yield reproducible results. The introduction of NIR light transillumination using the DIAGNOcam allows the integration of this imaging procedure into everyday dental practice, which may lead to a reduced usage of radiographic bitewings for detecting proximal caries. That study also concluded that NIR transillumination may become a highly welcomed alternative to bitewing radiography in proximal caries detection.

## Declaration of Interest

The authors report no conflict of interest and the article is not funded or supported by any research grant.

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