

## Sensitivity and Specificity of Different Diagnostic Methods in Occlusal Caries Detection of Permanent Teeth Among Paediatric Patients

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### ABSTRACT

Dental caries is a commonly progressive disease that proceeds through various degrees of severity that a dentist can detect. The aims of the in vivo study were to assess the accuracy of the individual model (near-infrared light transillumination [NILT] device, visual and radiographic examinations) in detecting occlusal caries, and to evaluate the performance of visual and NILT device combination for occlusal caries detection in deciding the treatment options. Fifty-two non-cavitated occlusal surfaces from 16 patients were assessed with three different diagnostic devices in random order. Identified lesions were prepared and validated. Logistic regression analysis was performed for each method. The sensitivity and specificity values for each method and the combined models were statistically measured using RStudio version 0.97.551. At the enamel level, visual detection was the most sensitive method (0.88), while NILT was the most specific (0.93). NILT scored the highest for sensitivity (0.93) at the dentine level and visual detection scored the highest for specificity (0.88). Visual detection + NILT model was significantly better ( $p = 0.04$ ) compared to visual detection or NILT alone ( $df = 1$ ). The visual-NILT combination is a superior model in detecting occlusal caries on permanent teeth. The model provided surplus value in caries detection hence improving the treatment decision-making in occlusal surfaces.

**Keywords:** Diagnostic imaging; near-infrared light transillumination; occlusal caries; paediatric; permanent teeth

## INTRODUCTION

There had been a parallel effort to detect caries lesion as early as possible even before the non-cavitated stage along with the development of a quantitative method for caries lesion detection (Pitts, 2004). This effort has been driven by the acceptance that early identification provides better estimations of the disease and improves the possibility for successful preventive intervention. However, from a clinical perspective, this is an arguable statement as a low diagnostic threshold may lead to the detection of discoloured surfaces, thus increasing false-positive diagnosis (Nyvad, 2004). On the other hand, the creation of the International Caries Detection and Assessment System (ICDAS) in 2002 strengthens the idea of early detection of caries lesion. ICDAS shows a significant correlation with lesion depth in the histological examination (Shoaib *et al.*, 2009; Gomez, Tellez *et al.*, 2013). It has shown to be an accurate and reproducible method to detect early lesions and changes during longitudinal follow-up (Braga *et al.*, 2009). The use of bitewing radiographs provides supportive information to complete the clinical diagnosis in proximal and occlusal tooth surfaces (Hintze *et al.*, 1998; Espelid *et al.*, 2003; Schaefer *et al.*, 2018).

The range of caries diagnosis options has expanded considerably in recent years, especially in X-ray free diagnostics. The application of various technologies provides clinicians with affordable options, some of which prove to be equal or superior to radiography. The objective should be to detect carious lesions in the initial stage with optimum efficiency. A variety of non-invasive technologies for incipient, intermediate and hidden caries detection have been investigated and made available such as fibre-optic transillumination (FOTI), laser fluorescence (LF) and electrical conductance (EC) (Yang & Dutra, 2005; Gomez, Tellez *et al.*, 2013; Tassery *et al.*, 2013; Schaefer *et al.*, 2018). Most of the published studies on the detection systems mentioned above

have shown acceptable performance and reproducibility for the detection and quantification of dentinal lesions (Gomez, Zakian *et al.*, 2013), incipient and hidden caries (Gomez, Tellez *et al.*, 2013), early and intermediate occlusal caries (Gomez, Zakian *et al.*, 2013), and monitoring the disease in assessing the efficacy of anti-caries dental care products (Gomez, 2015). Each performance of clinical testing is evaluated in terms of specificity and sensitivity to ensure the method effectiveness.

In the context of caries, sensitivity refers to the test's ability to identify evidence of caries formation correctly. In contrast, specificity refers to the ability to rule out caries correctly or to identify surfaces that are non-caries (Martin, 2007). Although it was evident that both properties should be maximised in a test, an increase in one means a decrease in the other and vice versa.

Transillumination with light has been further developed into cold visible light (Wenzel *et al.*, 1992; Schneiderman *et al.*, 1997; Young & Featherstone, 2005). This technique allows images from tooth surfaces to be digitally captured and stored. Moreover, it has made this technology accessible for practitioners and sophisticated enough for longitudinal evaluation of individual caries lesions. The package's special software allowed the diagnosis to be made on a computer screen and visualised by a live video. The device established a good agreement with the clinical status and information beyond the radiograph (Bin-Shuwaish *et al.*, 2008) and can be useful in detecting incipient and hidden carious lesions (Yang & Dutra, 2005). The DIAGNOcam<sup>®</sup> is the most recent developed near-infrared light transillumination (NILT) device (KaVo<sup>®</sup> Dental, Lake Zurich, IL, United States). It is a fibre-optic transillumination (excitation wavelength of 780 nm) device with a camera. The device is placed directly on the tooth and the transilluminating light positioned on either side of the tooth shines through the tooth. A video camera captures the light where a

carious lesion appears as dark spots. The software allows storage of the images.

A previous *in vivo* diagnostic study had shown signifying correlation of utilising visual inspection, bitewing radiographs and NILT as diagnostic strategies to avoid over-diagnosis (Schaefer *et al.*, 2018). Additionally, NILT is shown as suitable for detecting early caries lesion (Elhennawy *et al.*, 2018). There are numerous reports on ICDAS studies, but there were only a few DIAGNOcam® studies that focused in detecting the occlusal caries (Marinova-Takorova *et al.*, 2016; Simon *et al.*, 2017; Schaefer *et al.*, 2018; Tassoker *et al.*, 2020).

Therefore, the aims of the present *in vivo* study were twofold: (1) To assess the accuracy of the individual model (NILT device, visual and radiographic examinations) in detecting occlusal caries and (2) To evaluate the performance of visual and NILT device combination for occlusal caries detection in deciding treatment options.

## MATERIALS AND METHODS

### Study Design and Sampling

For the present *in vivo* study, the proposed minimum sample size required for diagnostic values (prevalence of 30%, *p* value 0.05 and power of 80%) was 31 samples for sensitivity test and 13 samples for specificity test (Bujang & Adnan, 2016). The study engaged 16 new patients (7–15 years old) with informed verbal and written consent from October 2016 to March 2017 who attended the Paediatric Dental Clinic. The methods were tested on 52 occlusal surfaces of identified molars or premolars. The patients had or would have had at least one fully erupted first permanent molar and/or premolars with ICDAS 1 (first visual change in enamel) or ICDAS 2 (distinct visual change in enamel). All patients recruited were diagnosed with high caries risk based on the medical model of risk for dental caries (Kutsch, 2014). Exclusions were made for

cases that exhibited uncooperative patients, special needs children, teeth with apparent dentine caries (ICDAS 3, 4 and 5), enamel/dentine anomalies, smooth surface caries (based on a visual inspection and bitewing radiograph) and any other types of teeth restorations. All procedures performed in this study were approved by the Ethical Committee of Research Management Institute (RMI), Universiti Teknologi MARA (UiTM) (600-IRMI (5/1/6) REC/115/17). The study was carried out in accordance with the Declaration of Helsinki 1964. Informed consent was obtained from each of the individual participants included in the study.

### Examiners' Calibration and Validation

A total of three calibrated examiners with a minimum of five years of professional qualification and experience took part in the validation process. Furthermore, all examiners were calibrated for studied detections methods; Visual-ICDAS photographs, digital bitewing radiographs and NILT images. Data was presented in Microsoft PowerPoint version 2003 (Microsoft Corporation, New Mexico, United States) for the evaluation process. The evaluation was carried out according to an agreed environment setting and procedure of conduct by all evaluators. A total of 10 photographs and images were evaluated and scored based on the criteria described further in the article. The intra/inter-examiner reproducibility was expressed by the kappa statistic, where 10 non-cavitated, discoloured molar and/premolar surfaces were examined in the mean of ICDAS, NILT and bitewing radiographs scores and repeated two weeks later. The intra- and inter-examiner reproducibility interpretation was calculated based on previous studies (Landis & Koch, 1977; McHugh, 2012).

The newly developed NILT scores were assembled and validated by all three calibrated examiners. The scores were defined based on the device image shadow extension, broadening and intensity. It had been divided into five scores (0 to 4),

translating into the sound surface, two dissimilar surface levels of enamel involvement and two distance surface levels of dentine involvement.

The study involved two stages of scoring. The initial stage consisted of scoring the records according to the defined criteria. The second stage was to validate operator's treatment based on clinical photographs, bitewings radiograph and NILT images, and a combination of clinical photographs and NILT images. The included lesions were validated as the reference standard.

## Examination Methods

### Visual Inspection

The principal investigator (IWM) was the sole operator for all the examinations process. Possible confounding factors such as plaque or calculus were eliminated using strict inclusion criteria and consistent cleaning procedure of the occlusal surfaces. All selected occlusal surface sites were brushed using a rotary brush and slow handpiece, rinsed (5 seconds), air-dried (5 seconds) and visually examined using a

dental light and mirror. The occlusal surfaces of the teeth were photographed using Nikon D90 (Nikon Corporation, Thailand). The region of interest (ROI) was virtually outlined using the groove-fossa system. The basis of validation was topographical position and enamel spectrum changes on the occlusal surface of a tooth. ICDAS was used for the scoring (Ismail *et al.*, 2007) (see Table 1). These were labelled as the model of the Visual-ICDAS photograph.

### Bitewing Radiography

Bitewing radiograph was performed using CMOS sensor (EzSensor, pixel size 35 µm, Vatech, Hwaseong, Korea) with plastic bitewing holder (Kwik-bite, Kerr United Kingdom) coupled to an intraoral machine (Satelec X-Mind AC/DC, Satelec ACTEON Tuusula, Finland). The system automatically registered all digital radiographic examinations. The images were collected and evaluated on EasyDent V4<sup>®</sup> viewer software version 4.1.4.5 (Vatech, Hwaseong, Korea). The radiographs classification was adopted from a previous study (Anttonen *et al.*, 2003) (see Table 2). This method was designated as the digital radiographs model.

**Table 1** ICDAS scores (as adopted from Ismail *et al.*, 2007)

Score	Visual (ICDAS)
0	No or slight change in enamel translucency after prolonged air drying.
1	First visual change in enamel (after drying) or restricted to within the confines of a pit or fissures.
2	Distinct visual change in enamel (on wet surface).
3	Localised enamel breakdown in opaque or discoloured enamel without visual change of dentinal involvement.
4	Underlying dark shadow from dentin with or without localised enamel breakdown.

**Table 2** Digital bitewing radiographs scores (as adopted from Anttonen *et al.*, 2003)

Score	Digital radiograph
0	No radiolucency.
1	Radiolucency of the enamel.
2	Radiolucency extending to enamel-dentine junction or superficial dentine.
3	Radiolucency extending to the middle third of dentine.
4	Radiolucency extending to deep inner third of dentine.

### NILT Procedure

The NILT investigation was carried out using DIAGNOcam® (KaVo® Dental GmbH, Germany), where the camera arm was placed as perpendicular as possible to embrace most of the occlusal anatomy surface. The digital images captured were labelled and recorded accordingly. A newly developed and validated score was used to rank the NILT images (Table 3). This method was categorised as the NILT images model.

### Clinical Validation Criteria

Based on the ICDAS, the surface discolouration was evaluated and scored as 1 or 2; both were treated either with topical fluoride, fissure sealant or fissure sealant applied through enameloplasty in caries-active individuals (Smallridge *et al.*, 2000; Bader *et al.*, 2001; Deery, 2013). The selection of patients was retrieved from the Integrated Dental Record and Management System (Universiti Teknologi MARA, Malaysia) where operators indicated each patient's treatment needs, based on their professional assessment after taking into account the individual's caries risk assessment. Later, the primary and second researcher (IWM and APV) validated the treatment selection and decided based on the binary presence or absence of caries lesion. Afterwards, they performed the chosen treatment procedure accordingly. Fissures were cleaned, prepared and assessed. Surfaces with discolouration that did not invade beyond the fissure system would be sealed using preventive resin

sealant, and the tooth was classified as enamel caries and labelled as (E). Based on the newly developed NILT scores in Table 3, enameloplasty was proposed on the surfaces which scored 1 to 4 and not on the sound surfaces, which scored 0. Surfaces with deeper demineralisation at the occlusal surface (scores 3 and 4) dictated the preparation of cavity using a small round bur diamond (size 8), medium (size 10) or large (size 12) as necessary to remove the undermined or/and overhanging enamel to allow self-cleansing of the lesion. The prepared cavity then was observed for the lesion's soft surface layer became worn away, leaving a hard and pigmented surface (Deery, 2013). The cavity later was warranted as caries-free through visual inspection; the tooth would be classified as dentine caries and labelled as (D).

### Statistical Analysis

Data were analysed using RStudio version 0.97.551 ©2009–2012 Inc. software (RStudio, PBC, Boston, MA). Intra- and inter-examiner values for all detection models were calculated using a weighted kappa statistic. Visual examination after tooth preparation served as the standard reference in calculating sensitivity and specificity. The enamel and dentine caries were used as the binary response, while Visual-ICDAS photographs, NILT images and digital radiographs were used as predictors. Logistic regression analysis was performed for each model. A likelihood ratio test (LRT) was used to compare nested models. This test yields chi-square ( $\chi^2$ )

**Table 3** Newly developed NILT scores

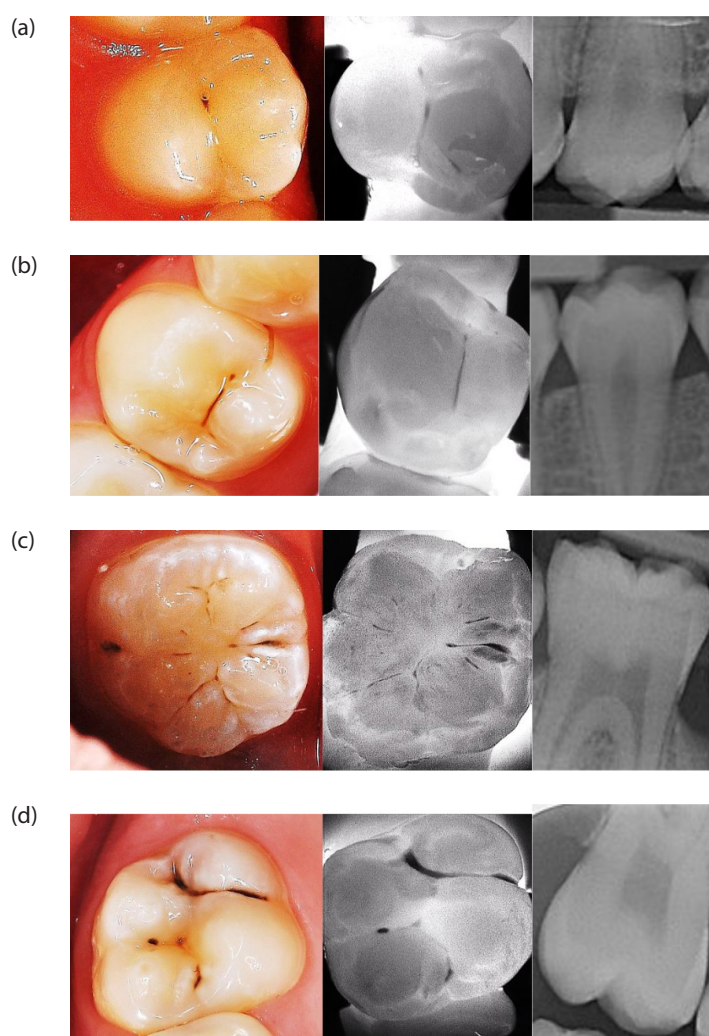
Score	DIAGNOcam®
0	Normal shadow of fissures.
1	Continuous pencil thin-line, less intense grey shadow appears when transilluminated.
2	Broadening of the shadow restricted to the fissure, more intense grey shadow appears when transilluminated.
3	Wide, dark-greyish and expecting dentine perforation shadow appears when transilluminated.
4	Wide, dark-greyish shadow and expecting dentine perforation includes groove—fossa cusp system appears when transilluminated.

value and a  $p$  value. If two nested models are compared and the LRT produces  $p \leq 0.05$ , the model being compared fits the data better than the base model. The area under receiver operating characteristic (AUROC) was calculated at the enamel and dentine threshold level. The optimum performance of each model's threshold values for enamel and dentine were determined from the AUROC analysis. The optimum value was defined by the visual measure of the predictive ability of the logistic regression model. The optimal cut-off points corresponding to the maximum combination sensitivity and specificity

observed were dichotomised into two cut-offs: 0 = enamel and 1 = dentine.

### Image Investigation and Assessment

Fig. 1 illustrates the Visual-ICDAS photographs, NILT images and bitewing radiographs of different demineralisation degree of enamel and occlusal caries. The images represent the stages of caries invasion and extension starting from; (a) sound surface with discoloured fissure, (b) early enamel caries, (c) discoloured fissures of the groove-fossa system with dentine penetration and finally (d) obvious dentine involvement.



**Fig. 1** The visual-ICDAS photographs, NILT digital images and bitewing radiographs of different demineralisation degree of enamel and occlusal caries. The images represent the stages of caries invasion and extension starting from (a) sound surface with discoloured fissure, (b) early enamel caries, (c) discoloured fissures of the groove-fossa system with dentine penetration and finally (d) obvious dentine involvement.

## RESULTS

A total of 52 teeth (16 children) of 44 molars and eight premolars were examined and treated accordingly. When conferred to the standard reference, 28 teeth had caries into the dentine and restored with resin material. In comparison, 24 teeth had caries restricted to the enamel and sealed with preventive resin restoration. The gender distribution was equal with eight female and eight male children. The intra-examiner reproducibility (weighted kappa) was as follows; 0.85 (IWM), 0.91 (APV) and 0.93 (MYPMY) for Visual-ICDAS, 0.91 (IWM), 0.89 (APV) and 0.90 (MYPMY) for NILT, 0.83 (IWM), 0.91 (APV), 0.93 (MYPMY) for bitewing. Accordingly, the inter-examiner reproducibility (weighted kappa) of NILT examinations between primary examiner (IWM) and experienced examiner one (APV) and two (MYPMY) were 0.92, 0.95 respectively and 0.72 for all three evaluators. For reliability interpretation, the present study's weighted kappa values were based on previous studies (Landis & Koch, 1977; McHugh, 2012). In general, all kappa values were varied between the substantial (61–80) and had an almost perfect agreement (81–100).

Table 4 shows the correlation between cut-offs, sensitivity, specificity and AUROC at enamel and dentine threshold level. The AUROC curves scaled 0.90 (Visual-ICDAS), 0.93 (NILT), 0.73 (digital radiograph) and 0.98 (combination model Visual-NILT) to discriminate the caries detection either in enamel or in dentine (Fig. 2). Sensitivities

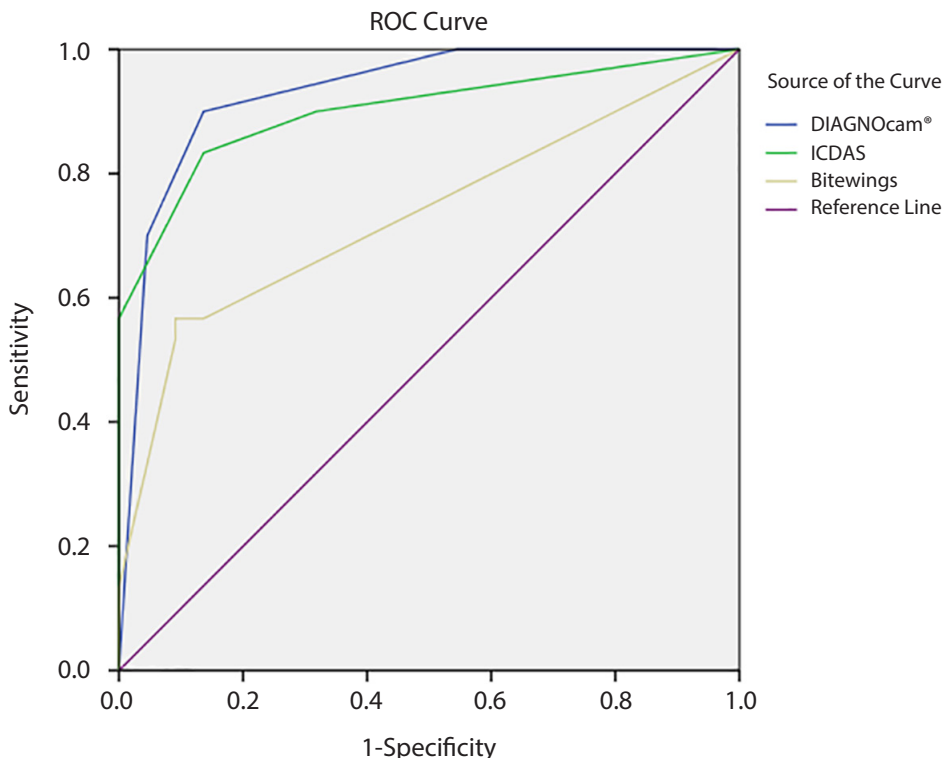
on enamel level varied between 0.88 (Visual-ICDAS), 0.83 (NILT) and 0.83 (digital radiograph); specificities varied from 0.89 (Visual-ICDAS), 0.93 (NILT) and 0.61 (digital radiograph). At the dentine level, sensitivity ranged between 0.89 (Visual-ICDAS), 0.93 (NILT) and 0.61 (digital radiograph) and specificity from 0.88 (Visual-ICDAS), 0.83 (NILT) and 0.83 (digital radiograph). The study expressed that visual detection was the most sensitive method (0.88), while NILT was the most specific (0.93). NILT scored the highest for sensitivity (0.93) at the dentine level and visual detection scored the highest for specificity (0.88). On the other hand, the combination-model Visual-NILT method reported a sensitivity of 0.92 and specificity of 0.93 at the enamel level. The model also reported high sensitivity and specificity at the dentine level with 0.93 and 0.92, respectively. The full logistic regression model of Visual-ICDAS and NILT was statistically significant ( $p \leq 0.05$ ) compared to the reduced model of both Visual-ICDAS and NILT separately ( $df = 1$ ). This finding suggested that Visual-NILT was a better model in detecting occlusal caries on permanent teeth (Fig. 3).

## DISCUSSION

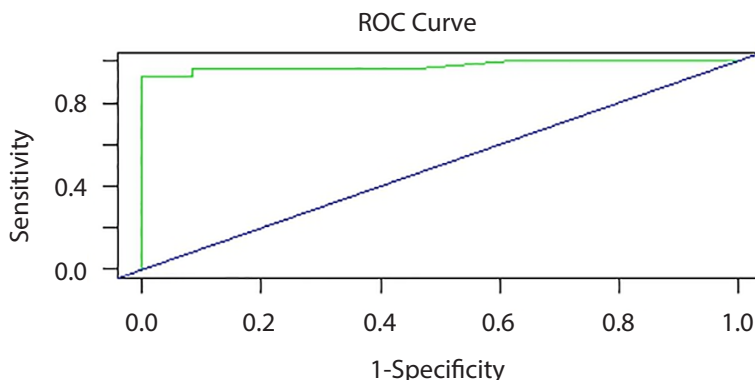
Early detection of occlusal caries plays a significant role in dental practice and minimally invasive management. Since the 1990s, clinical trials worldwide have provided evidence that clinically diagnosed caries lesions, at the non-cavitated stage,

**Table 4** Sensitivity, specificity and AUROC between the caries detection methods

Methods	Cut-off points				AUROC (98% CI)
	Enamel		Dentine		
	Sensitivity	Specificity	Sensitivity	Specificity	Enamel/Dentine
Visual (ICDAS photograph)	0.88	0.89	0.89	0.88	0.90 (0.82;1.00)
DIFOTI (DIAGNOcam®)	0.83	0.93	0.93	0.83	0.93 (0.86;0.99)
Digital radiograph (Bitewings)	0.83	0.61	0.61	0.83	0.73 (0.60;0.87)
Combination model visual-ICDAS and DIFOTI	0.92	0.93	0.93	0.92	0.92 (0.90;0.98)



**Fig. 2** The area under ROC curve for all three predictors.



**Fig. 3** The area under the ROC curve for the full model (visual-ICDAS and NILT images).

in particular, may be successfully treated by non-operative strategies (Carvalho *et al.*, 1992; Machiulskiene *et al.*, 2001, 2002; Maltz *et al.*, 2003; Marinho *et al.*, 2003; Ismail *et al.*, 2013). However, when the diagnostic process is related to management strategies, it becomes a major challenge for dental professionals (Machiulskiene & Carvalho, 2018). Moreover, there is a need to detect or quantitatively monitor such lesions to support treatment decisions.

The narrow and deep fissure system increased the susceptibility to occlusal caries in children and young adolescents and should regularly be inspected for caries signs (Dodds, 1996; Muller-Bolla *et al.*, 2009). Visual inspection may underestimate occlusal dentin caries in teeth without cavitation (Lussi, 1993; Gimenez *et al.*, 2015). Moreover, there is a need to detect or quantitatively monitor such lesions to support treatment decisions. The present



sample consists of children in their mixed dentition with at least one discoloured pit-fissure system of first permanent molar and premolar. During this post-eruptive period, the tooth is most susceptible to caries. Thus, all samples were entitled to a preventive sealing or preventive resin restoration concerning the patient's individual caries risk assessment and caries history. All the tooth surfaces scored 1–4 had undergone enameloplasty which revealed the high sensitivity of visual examination in discriminating the lesion extension in the enamel.

The intra- and inter-examiner reliability revealed substantial to an almost perfect agreement for all the performed methods. Specifically, for the DIAGNOcam® device, obtaining reproducibility was very promising even though all the examiners had different experience lengths. Nevertheless, the practitioners tend to develop individual concepts based on experience regarding caries detection and the subsequent preventive or restorative treatment options. Therefore, a learning curve in using the device must be taken into consideration. Schneiderman *et al.* (1997) concluded that the real-time analysis images enable the practitioners to obtain NILT images under controlled and repeatable conditions. This value contributed significantly to the reproducibility properties of the device.

A valuable feature of quantitative caries diagnostic tools is the possibility to establish cut-off levels to determine caries penetration (Huth *et al.*, 2008). In the perspective of this *in vivo* study, the cut-off points for lesion depths were defined as enamel or dentine based on the visual examination. The distinction between the enamel and dentine level cannot be quantified entirely using DIAGNOcam®. Such findings were in concordance with the other previous studies (Pretty & Maupome, 2004; Schaefer *et al.*, 2018). Since the captured images are not directly quantified and the clinician must perform the analysis within all the advantages and disadvantages that such analyses require,

a learning curve is expected in mastering the device (Sidi & Naylor, 1988).

The results demonstrated a potential significance of the NILT (DIAGNOcam®) model for detecting occlusal caries with high sensitivity to conventional models. The NILT images indicated early incipient caries on the discoloured groove-fossa system even when digital radiograph images failed to show their presence and that NILT provided clear signatures of occlusal caries on premolars and molars.

The principle behind a tooth's transillumination is that demineralised areas of enamel or dentine scatter light more than sound areas (Angelino *et al.*, 2017). Thus, the NILT captured images were interpreted as follows:

1. The darker the shadows of light projected onto the tooth surface, the deeper caries invasion to be anticipated.
2. If the shadows were estimated to be beyond the groove-fossa system of the fissure, the widening/broadening of the cavitation was presumed, and therefore more chances of dentine perforation could be expected.

The above criteria used were correlated with one of the earliest *in vitro* study on near-IR imaging performance (Staninec *et al.*, 2010). The detection was significantly based on subjective interpretation of the lesion appears as such. On the other hand, an occlusal surface with deep fissures with no demineralised activity detected visually might be projected by a fine line shadow and possibly considered as demineralised surfaces. This restriction might contribute to the increase in the over-scoring tendency of discoloured sites.

The findings described in Table 4 show that DIAGNOcam® performed best when observing the dentine caries and to detect no caries in the enamel surface. The diagnostic performance established by the receiver

operating characteristic (ROC) curve of both Visual-ICDAS and NILT images gave an almost perfect result. Bitewing radiography performance was found to be in substantial agreement with the samples. However, when compared with the other two detection methods, it might be giving the lowest efficiency in detecting the occlusal caries. The variability in sensitivity is high, compared to specificity when occlusal surfaces with different depths of the lesion was evaluated using a bitewing radiograph (Dove, 2001).

In this study, the sensitivity values for Visual-ICDAS could have been influenced negatively due to the assessment performed using images instead of direct in vivo scoring. The quality of the taken photographs of the occlusal surface can also be debatable. Although enamel caries cannot be validated in a clinical study (Anttonen *et al.*, 2003) and the present study, the images of V-NILT suggest that an experienced and well-trained clinician can differentiate between enamel or dentine caries in the pit-fissures system. The NILT images can considerably contribute to making the diagnosis and treatment decision. The present study adopted the bitewing radiograph scores from another in vivo study by Anttonen *et al.* (2003) because it resembles similarity in nature with our investigated lesion.

The NILT images obtained indicated equal low sensitivity in the enamel level and specificity in dentine level when compared to bitewing radiography. However, the anatomic configuration of the occlusal surface also explaining the low sensitivity in bitewing radiographs. The sensitivity in dentine level and specificity in enamel level, however, were higher. This finding is also supported by a previous study (Sidi & Naylor, 1988) that compared visual inspection with FOTI and various image modalities, suggesting superior sensitivity of FOTI compared with radiological imaging. These findings may be explained by many different factors that can affect the ability

to accurately detect these lesions such as exposure parameters, type of image receptor, image processing, display system, viewing conditions, and eventually the training and experience of the human observer (Dove, 2001). Despite the low dose of radiation exposure from taking bitewing radiographs in caries detection, according to the linear-no-threshold nature of radiation effect, theoretically, there is no safe dose in radiographic acquisition (Yusof *et al.*, 2017).

The NILT images exhibit lesion extension in horizontal plane angle surface but there is no substantiation of lesion activity towards the pulpal region. The caries invasion depth cannot be determined with the device since the light transilluminate only in two-dimensional (2D) perspectives. Hence the combination with a Visual-ICDAS method which has been validated based on the quantitative correlation between the clinical assessments of tooth surfaces with the histological presence or extent of demineralisation in enamel and dentin (Ekstrand *et al.*, 1997; Ricketts *et al.*, 2002) possibly will aid to overcome this setback.

Detection of a lesion at a very early stage requires a diagnostic method with high sensitivity. However, that may result in more false-positive diagnoses (Kühnisch *et al.*, 2006) and lower specificity. Due to the lack of a single detection method that provides high sensitivity and high specificity, combining some methods is recommended to increase detection accuracy. We found that the combination method resulted in an almost perfect sensitivity and specificity value on enamel and dentine levels. The proposed model, namely the Visual-NILT, is superior in differentiating caries lesions in the inner half of enamel from those in the outer third of dentine (Côrtes *et al.*, 2003) and is effective in the diagnosis of lesion both involving only the enamel as well as enamel-dentine (Marinova-Takorova *et al.*, 2016). Therefore, the combination method would facilitate treatment decision-making, thereby preventing overtreatment.

## CONCLUSION

The NILT presented a similar efficiency to visual inspection and was superior compared to bitewing radiography. The NILT device can provide satisfactory information for the diagnosis and treatment selection of occlusal caries, and it has significantly adds value when combined with a visual inspection. Moreover, this method may avoid the use of bitewing radiography, minimising the chance of radiation exposure of the children, thus increasing safe practice.

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