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Evaluation of near-infrared digital imaging transillumination compared with bitewing radiography for proximal caries detection in children

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Abstract

Background: Limitations in traditional caries detection tools have driven the development of alternatives methods, focused on the early lesion detection such as near-infrared digital imaging transillumination (NIDIT).

Aim: The aim of this study was to evaluate the performance of NIDIT compared with bitewing radiography (BWR) in the detection of interproximal carious lesions in children.

Design: A retrospective audit of data from children who had NIDIT, BWR and intraoral photographs was conducted. Carious lesions were scored on a tooth surface level with BWR acting as the primary reference for comparison. Accuracy was determined using multi-class area under the curve (AUC), and correlation was determined using Fleiss' Kappa.

Results: Data from 499 tooth surfaces involving 44 children were included in this study. The average age across the participants was 86 months (~7 years) with an average dmft (decayed, missing and filled teeth in primary dentition) of 5.29. Multi-class AUC comparing NIDIT to BWR was 0.70. The correlation between NIDIT and BWR was moderate (0.43), whereas the correlation between photographic examination and BWR was 0.30, which is fair.

Conclusion: When compared to BWR, NIDIT showed a high specificity but a low sensitivity for proximal caries detection in primary teeth.

KEYWORDS

bitewing radiography, dental caries detection, DIAGNOcam, near-infrared digital imaging transillumination

1 | INTRODUCTION

Dental caries is the most common chronic condition of childhood with an estimated 573 million children globally suffering from untreated caries.[1] When left unmanaged, caries can have a significant impact on the quality of life of children and their families ranging from pain and discomfort through to reduced self-esteem and guilt.[2] By and large, dental caries is a preventable disease and early detection and management is critical towards preventing the need for invasive and costly operative intervention. Currently, the most common caries detection modalities are visual detection and bitewing radiography (BWR) but these have their limitations. Visual examination is best positioned for occlusal surfaces of teeth as the proximal surface is often hidden with caries tending to occur at or below the contact points of teeth.[3] BWR can visualise both occlusal and interproximal carious lesions; studies, however, show that this method underestimates the actual depth of the carious lesion.[4] Furthermore, 30%–40% of the enamel must be demineralised before an enamel lesion is visible on radiographic images.[5] Radiographs are also technique-sensitive as improper angulation can result in overlapping of interproximal surfaces and hence provide limited diagnostic value.[6] Moreover, there is an increasing push towards limiting exposure to ionising radiation, especially in young children. The limitations and inherent subjectivity of these traditional caries detection methods have encouraged research and development into more conservative, accurate and safer methods, particularly aiming to detect carious lesions at earlier stages.

Transillumination was introduced to dentistry in the mid-1980s as an adjunctive tool in caries detection.[7] It takes advantage of the difference in optical properties between natural and demineralised tooth structure. When visible light is shone onto a tooth, carious lesions scatter and absorb more light photons than healthy tooth structure, allowing a dark shadow to be visualised. This process is referred to as 'fibre-optic transillumination (FOTI)'. An extension of this is digital imaging fibre optic transillumination (DIFOTI), a technology introduced in the late 1990s, which allows the image of the transilluminated tooth to be digitally recorded allowing for improved lesion surveillance and monitoring.[8] In 2012, DIAGNOcam was released, which is a near-infrared digital imaging transillumination (NIDIT) device.[6] This device is very similar to DIFOTI, but instead of using visible light, DIAGNOcam uses two near-infrared laser diodes operating at a wavelength of 780 nm, illuminating the tooth from the cervical area.[8] A wavelength of 780 nm is considered the 'optical window of tissues' compared with visible light, which has a wavelength range of 380–750 nm. It allows for more efficient light penetration of biological tissue with less scatter and absorption.[9] A complementary metal–oxide–semiconductor chip captures live images of the tooth allowing for real-time visualisation, and these images are able to be saved onto a computer or laptop.[8] DIAGNOcam is claimed to be a revolutionary tool in the field of dentistry due to its unique features, which included as follows: no exposure to ionising radiation; ability to detect incipient lesions; less risk of proximal overlap as seen on radiographs; images are able to be viewed live and saved digitally; and both occlusal and proximal caries can be detected.[8]

Given the potential for NIDIT to be a non-invasive, non-ionising, easy-to-use caries detection system, this study aimed to evaluate the performance of NIDIT (DIAGNOcam) in detecting interproximal carious lesions in children compared with conventional visual and BWR examination.

Why this paper is important to paediatric dentists

- Near-infrared digital imaging transillumination (NIDIT) is a non-invasive, non-ionising tool designed to support the early caries detection.
- NIDIT demonstrated a high specificity (detecting sound tooth surfaces) but low sensitivity (detecting true carious lesions) in comparison with bitewing radiography for proximal surfaces in primary teeth.
- NIDIT can concomitantly visualise and digitally capture the early carious lesions, hypomineralised tooth structure and restorations in primary teeth and is a promising adjunctive diagnostic tool.

2 | MATERIALS AND METHODS

Children presenting to the paediatric clinic at the Oral Health Centre of Western Australia typically undergo a comprehensive oral examination including BWR, clinical photographs and NIDIT where appropriate. A retrospective audit of children who had all three modalities undertaken was conducted, and a de-identified database was generated. Variables including patient demographics (date of birth, age and gender), date of examination, tooth number, tooth surface and severity of carious lesions (scored using International Caries Detection and Assessment System-II [ICDAS-II]) were collated. The unit of measurement was at the tooth surface level. A decayed, missing and filled teeth in primary dentition (dmft) score was also calculated for each patient based on clinical examination. Ethics approval for this study and a waiver of consent were approved by the University of Western Australia's Human and Research Ethics Committee (Ref: RA/4/20/4442), and all clinical and radiographic images were stored in a centralised, secure research data store. Tooth surfaces were excluded if they contained restorations or were unable to be scored due to poor or unacceptable image quality as defined by the criteria shown

TABLE 1 Scoring system for the quality of bitewing radiography (BWR) and near-infrared digital imaging transillumination (NIDIT) images.

	BWR	NIDIT
Grade	Description	Description
1: Excellent	No overlap of interproximal surfaces, all primary molar teeth visible	100% of the contact point and occlusal table, well exposed and minimal noise
2: Diagnostically acceptable	1–2 teeth with interproximal overlap; some noise	At least 70% of the contact point and occlusal table visualised and moderate noise
3: Unacceptable/ poor	>2 teeth with interproximal overlap; moderate to severe noise	Less than 70% of the contact point and occlusal table visualised and high noise
4: N/A	Tooth/surface not captured on BW	Tooth/surface not captured on NIDIT

TABLE 2 Scoring systems for the assessment of bitewing radiography (BWR),[10] near-infrared digital imaging transillumination (NIDIT) images[6] and intraoral visual photographs.[28]

	BWR		NIDIT		Photographic inspection (ICDAS-II)
Score	Description	Score	Description	Score	Description
0	No visible radiolucency	0	Sound surface	0	No evidence of caries
1	Radiolucency in the outer half of enamel	1	First visible signs restricted to the enamel	1	Initial caries
2	Radiolucency in the inner half of enamel +/− the dentinoenamel junction	2	Established caries lesion	2	Distinct visual change in enamel
3	Radiolucency limited to the outer one third of dentine	3	Established enamel caries with an isolated spot reaching DEJ	3	Localised enamel breakdown due to caries with no visible dentine
4	Radiolucency reaching the middle one third of dentine	4	Dentine caries penetrating the DEJ linearly	4	Underlying dark shadow from dentine
5	Radiolucency reaching the inner one third of dentine	5	Deep dentine caries lesion	5	Distinct cavity with visible dentine
6	Radiolucency into the pulp	O	Occlusal caries lesion	6	Extensive distinct cavity with visible dentine
		H	Hypomineralisation		

in Table 1. Only primary first and second molar tooth surfaces were included in this study. Owing to the limited availability of comparable studies, an a priori sample size calculation was not feasible. Therefore, a purposive sample, guided by the existing literature, was employed to enable a subsequent post hoc power calculation.

2.1 | Radiography

BWR and NIDIT images were taken by dental students under the guidance of a registered paediatric dental supervisor. Radiographs were taken with the Heliodent Plus Intraoral X-ray unit (Sirona, USA) with parameters set at 70 kV, 7 mA and 0.16–0.20s. Sizes 0 and 2 of standard PSP plates were used implementing the paralleling technique using Kwik-Bite™ (Kerr) holders. The quality of the BWR was graded using the criteria in Table 1. Carious lesions identified on BWR were scored as per the International Caries Classification and Management System (ICCMS™) as seen in Table 2.[10]

2.2 | NIDIT

DIAGNOcam 2170 U (KaVo) was used in conjunction with the KaVo DIAGNOcam desktop software V3.0.1. Images were captured by a paediatric dentist by drying the tooth surface and positioning the probes perpendicular to the tooth surface to best capture the interproximal surfaces of the primary molars. Both small and large tips were used depending on the comfort of the patient and the size of the dentition. Images were taken at each proximal contact beginning from the distal of the primary canine and moving distally to the distal surface of the second primary molar. The quality of NIDIT images was graded using the criteria set in Table 1. During the initial review of the data, both occlusal carious lesions and hypomineralised areas were identified on the tooth surfaces. Since these were not covered in the classification system by Sochtig et al., as illustrated in Figure 1,[6] two new subcategories were introduced for completeness. These additions were made to distinguish between occlusal caries lesions and hypomineralised enamel, as detailed in Table 2 and illustrated in Figure 2.

2.3 | Photographic examination

Standardised intraoral clinical photographs taken by the supervising paediatric dentist were used to score each tooth surface using the ICDAS-II as detailed in Table 2. These photographs included the facial/buccal and occlusal views of each patient's dentition and any photographs of questionable quality were retaken to ensure all surfaces were adequately captured and exposed. Images were obtained using a Canon EOS 70D (Canon Inc.), a macro lens 100 mm f/2.8 macro lens and a MR-14EX II ring flash. All photographs were taken in the same clinic under the same lighting with the following settings: a shutter speed of 1/200 s, an aperture value of f/22 and ISO of 200.

2.4 | Data interpretation

Three investigators underwent calibration and training to score teeth using ICDAS-II, NIDIT and BWR under the guidance of a previously calibrated examiner (JP). Calibration included a workshop on caries diagnosis and detection, interpretation of NIDIT and radiographs followed by scoring a set of 35 previously standardised images. A feedback session was held immediately after this session. A 2 weeks washout period was observed, and the calibration exercise was performed again with sufficient inter-rater reliability (0.91). Formal scoring was performed separately by two investigators (AV and YG), and disagreements were settled by a third investigator (YF). Carious lesions were scored based on the criteria shown in Table 2 for each imaging modality, and a quality score was also assigned to BWR and NIDIT images (Table 1). Figure 3 illustrates a case example of BWR, NIDIT and clinical photography for the same patient with a focus on Tooth 54. In this case, Tooth 54 received a score of 4 across all three modalities as defined by the criteria in Table 2.

2.5 | Statistical analysis

Statistical analysis was performed using the 'R' statistical computing software (R Core Team). Sensitivity (SE), specificity (SP) and overall accuracy (ACC) were calculated for the diagnostic findings of BWR, NIDIT and photographic assessment. Multi-class area under the curve (AUC) was also calculated as defined by Hand and Till.[11] The agreement between modalities was also calculated and represented by Fleiss' Kappa scores. The agreement values were graded as follows: poor (<0.00), slight (0.00–0.20), fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80) and almost perfect (0.81–1.00). The inter-rater reliability of both image quality and carious lesion severity was assessed using an intra-class coefficient. To facilitate further statistical analysis, the scoring criteria to classify carious lesions in BWR and NIDIT images were categorised into 'sound', 'enamel' or 'dentine' lesions (as seen in Table 4). For the purposes of this study, BWR was the gold standard for comparison given that histological assessment or physical separation of the teeth was not feasible.

3 | RESULTS

A total of 44 children were included in this study comprising 18 females and 26 males. Table 3 summarises the demographic and dental characteristics of the study sample including the caries experience. The average age across the participants was 7 years with an average dmft of 5.29 and SiC_{30} (Significant Caries Index representing the mean dmft score among the top 30% of the population with the highest dmft scores) of 11.4. A total of 662 interproximal surfaces from 331 primary molars were included. One hundred and sixty-three tooth surfaces were excluded as they were restored or deemed to be of poor or unacceptable quality as defined in Table 1. A final sample of 499 tooth surfaces were suitable for analysis. This included 129 maxillary first molar surfaces, 133 maxillary second molar surfaces, 121 mandibular first molar surfaces and 116 mandibular second molar surfaces. Subcategorisation revealed the final sample to include a total of 264 mesial surfaces and 235 distal surfaces. As seen in Table 3, no statistically significant differences were found across gender, tooth or surface type. Inter-rater reliability for scoring carious lesions for both BWR

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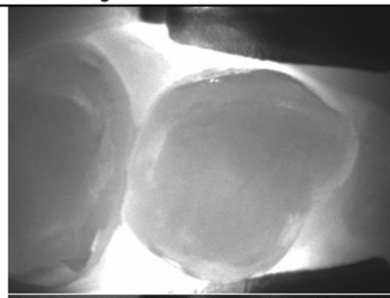
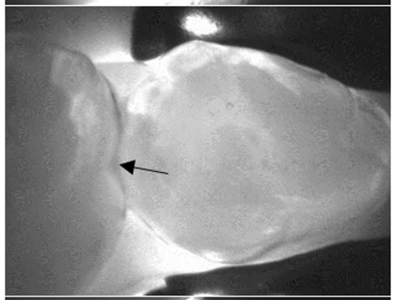
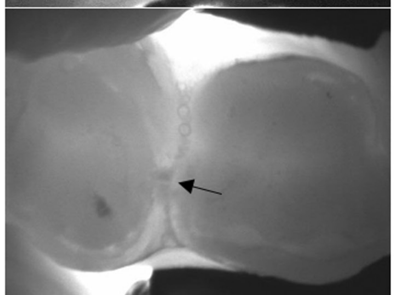
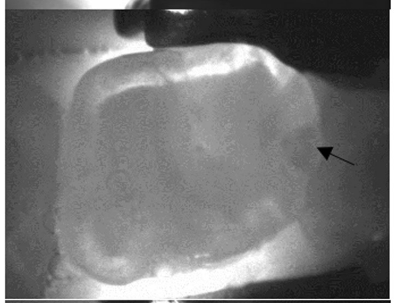
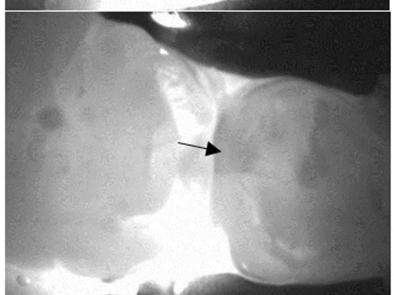
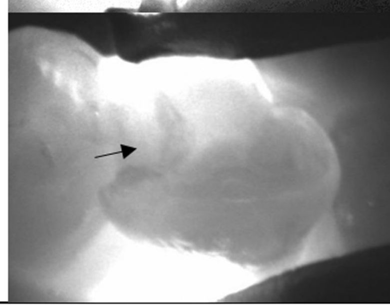
Score	*Description*	*NIDIT Image*
0	Sound surfaces	
1	First visible signs of enamel caries	
2	Established carious lesion in enamel	
3	Established enamel lesion approximating the DEJ	
4	Carious lesions penetrating the DEJ linearly	
5	Deep dentine carious lesion	

FIGURE 1 Classification of proximal caries lesions using near-infrared digital imaging transillumination (NIDIT).

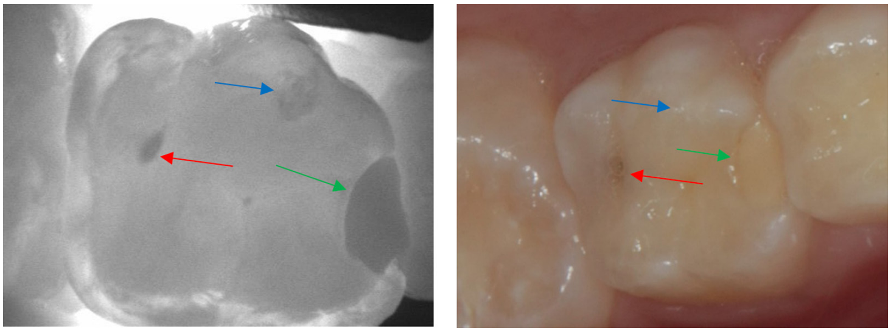


FIGURE 2 Comparison of occlusal carious lesion (red arrow), hypomineralised lesion (blue arrow) and restoration (green arrow) between near-infrared digital imaging transillumination (NIDIT) (left) and clinical photography (right).

FIGURE 3 Case example showing bitewing radiography (BWR), clinical photograph and near-infrared digital imaging transillumination (NIDIT) image of the same patient with a focus on Tooth 54, demonstrating a distal carious lesion extending to the middle third of dentine.

and photographic images was good (0.80 and 0.88, respectively). The reliability, however, was moderate for the scoring image quality of BWR and NIDIT, as well as the scoring of carious lesions using NIDIT (0.53, 0.56 and 0.64, respectively).

A post hoc power analysis with a 0.05 significance level indicated that this study has the potential to detect effects with an AUC of up to 0.56 in a two-class classification scenario at a 90% statistical power. Notably, the multi-class AUC between BWR and NIDIT was 0.70 and 0.69 between BWR and photographic examination. Fleiss' Kappa value between BWR and NIDIT was 0.43 (moderate), compared with 0.30 (fair) between BWR and photographic examination. The class-based specificity, sensitivity and accuracy between both NIDIT and photographic examination when compared to BWR are presented in Table 5. The multi-class AUC and agreement for each tooth type and surface, when comparing BWR and NIDIT, are stratified and detailed in Table 6. Whilst there was no significant association between agreement (BWR and NIDIT) and the quality of radiographic images ($p = 0.11$), a significant association was observed between agreement (BWR and NIDIT) and NIDIT image quality ($p = 0.04$). There were also no major discrepancies in NIDIT's ability to detect carious lesions between tooth types or tooth surfaces as reflected by the multi-class AUC ranging from 0.68 to 0.75 and agreement ranging from 0.36 to 0.43 as shown in Table 6.

4 | DISCUSSION

Early detection and diagnosis of caries is critical in preventing future progression and the need for invasive and operative care. NIDIT is marketed as a tool that enables the early detection of carious lesions whilst reducing the need for ionising radiation. Nevertheless, as BWR and visual examination remain the mainstay for proximal caries detection this study sought to explore the effectiveness of NIDIT when compared to these conventional modalities in primary teeth. Numerous studies have examined the effectiveness of NIDIT on permanent teeth[6,12–17] there, however, have only been a handful examining its use in primary teeth.[13,14,18] Studies on permanent teeth have had varying conclusions included as follows: (1) NIDIT can replace BWR in proximal caries detection[6,12,19,20]; (2) NIDIT should only be used as an adjunct to conventional BWR;[13–15,21] (3) NIDIT is comparable to/has similar efficacy as BWR;[21–24] and (4) NIDIT is more suitable for the detection of superficial/enamel lesions.[15–17,25] Several anatomical distinctions between primary and permanent teeth can impact both NIDIT imaging and interpretation, as well as the pattern and progression of carious lesions. These differences restrict the applicability of results from studies on permanent teeth to primary teeth: (1) Enamel and dentine are thinner in primary teeth than in permanent teeth; (2) the direction of enamel rods in the cervical area of primary teeth is angled occlusally compared with

TABLE 3 Demographics of the study cohort.

	n (%)	p-value
Gender		.228
Male	26 (59.1%)	
Female	18 (40.9%)	
Dental development age (years)		<.001
Primary (<6)	8 (18.2%)	
Early mixed dentition (6–9)	32 (72.7%)	
Middle mixed dentition (9, 10)	4 (9.1%)	
Late mixed dentition (10–12)	0	
Caries experience (dmft)		<.001
Caries free (0)	9 (20.5%)	
Low (0 < 2.6)	7 (15.9%)	
Moderate (2.7–4.4)	5 (11.4%)	
High (>4.4)	23 (52.3%)	
Tooth type		.702
Maxillary first Primary Molar	129 (25.9%)	
Maxillary second Primary Molar	133 (26.7%)	
Mandibular first Primary Molar	121 (24.2%)	
Mandibular second Primary Molar	116 (23.2%)	
Tooth surface		.194
Mesial	264 (52.9%)	
Distal	235 (47.1%)	

TABLE 4 Categorisation of the scoring criteria between imaging modalities.

Classification	NIDIT score	BWR score	Photographic score
Sound	0	0	0
Enamel	1,2,3	1,2	1,2,3
Dentine	4,5	3,4,5,6	4,5,6

apically in permanent teeth; and (3) there is a significant cervical constriction of primary teeth with broad flat proximal contacts compared with point contacts in permanent teeth.

A study by Błażejewska and colleagues examined 100 children using BWR, NIDIT and visual examination with visual examination as the gold standard. It found that BWR was more accurate than NIDIT and that NIDIT cannot replace BWR.[13] Similarly, De Zutter and colleagues examined 127 primary and 65 permanent surfaces using BWR, NIDIT and visual examination with BWR as the gold standard. They found a moderate-to-substantial correlation between NIDIT and BWR radiography for primary teeth, however, concluded that NIDIT cannot be recommended to replace BWR and must be used complementarily.[14] By comparison, Almoudi and colleagues examined 236 proximal primary tooth surfaces using NIDIT, BWR and visual examination with visual examination after temporary tooth separation as the gold standard. The authors found that NIDIT had higher sensitivity than BWR in diagnosing cavitated proximal carious lesions and concluded that NIDIT can be considered as an alternative to BWR to detect cavitation.[18]

In the present study, BWR was used as the gold standard for comparison, since placing separators between all primary molars for direct visual examination was not feasible or a standard clinical practice. Nevertheless, given that 30%–40% of the enamel must be demineralised before an enamel lesion is visible on radiographic images,[5] BWR is not the ideal choice for diagnosing early carious lesions. Whilst NIDIT does not have this drawback, any early carious lesions diagnosed by NIDIT that were not diagnosed on BWR would be classified as a false-positive reading, hence reducing the accuracy of NIDIT. This is reflected in the results obtained, in which sensitivity of NIDIT in detecting enamel lesions was only 0.36. An interesting finding, however, is that in 16% of the cases, NIDIT reported sound surfaces whilst BWR showed a radiolucency. On the contrary, in 5% of the cases, BWR reported sound surfaces whilst a lesion was observed using NIDIT. These variations in detection underscore the clinical complexities in accurately diagnosing early carious lesions, highlighting the need for a comprehensive approach that considers multiple diagnostic modalities.

This study revealed that NIDIT exhibited high sensitivity (0.92) for sound surfaces, meaning that a sound surface identified using BWR would also likely be detected as such by NIDIT. Additionally, NIDIT demonstrated high specificity (0.98) for dentine lesions, indicating that NIDIT and BWR were in agreement when identifying lesions that did not extend into dentine. The overall multi-class AUC was 0.70 and agreement between NIDIT and BWR was calculated using Fleiss' Kappa. This calculation does not use BWR as the gold standard but simply compares the correlation between a particular NIDIT score and the corresponding BWR score. The agreement was only 0.43 (moderate), which is similar to that found by De Zutter and co-workers (average agreement across two examiners of 0.58–moderate) who also analysed primary teeth using BWR as the reference standard.[14] This study found an association between the agreement of NIDIT and BWR scores and the quality of NIDIT images ($p = 0.04$). This underlines the importance of a good-quality NIDIT image to accurately diagnose carious lesions. The addition

TABLE 5 Near-infrared digital imaging transillumination (NIDIT), photographic assessment and bitewing radiography (BWR) scores with sensitivity, specificity and accuracy per class.

		NIDIT			Photographic		
	Count (%)	**0**	**E**	**D**	**0**	**E**	**D**
BWR	0	289 (57.9%)	23 (4.6%)	3 (0.6%)	299 (59.9%)	2 (0.4%)	14 (2.8%)
	E	61 (12.2%)	39 (7.8%)	7 (1.4%)	88 (17.6%)	2 (0.4%)	17 (3.4%)
	D	19 (3.8%)	24 (4.8%)	34 (6.8%)	28 (5.6%)	1 (0.2%)	48 (9.6%)
	Sensitivity	0.92	0.36	0.44	0.95	0.02	0.62
	Specificity	0.57	0.88	0.98	0.37	0.99	0.93
	Accuracy	0.79	0.77	0.89	0.74	0.78	0.88

TABLE 6 Table for the multi-class area under the curve (AUC) and agreement between near-infrared digital imaging transillumination (NIDIT) and bitewing radiography (BWR) for each tooth type and tooth surface.

	Tooth types				Tooth surface	
	Upper Ds	**Upper Es**	**Lower Ds**	**Lower Es**	**Mesial**	**Distal**
Multi-class AUC	0.68	0.74	0.72	0.75	0.70	0.69
Agreement	0.42 (mod)	0.51 (mod)	0.38 (fair)	0.36 (fair)	0.43 (mod)	0.42 (mod)

of noise, overexposure of the image and irregular proximal contacts drastically affect the interpretability of the image. The inter-rater reliability for scoring of NIDIT images was only 'moderate' compared with scoring of carious lesions on photographic images and BWR, which were both 'good'. This can be attributed to the fact that analysing NIDIT images is a new skill that is not routine practice for most dental professionals, and there was also a relatively high proportion of 'unacceptable/poor' quality NIDIT images (13%).

This study used photographic images rather than direct visual examination, which follows a rising trend in the use of clinical images and teledentistry to diagnose caries since the COVID-19 pandemic. The literature suggests diagnosis from photographs to have a high specificity; the inherent limitations of the photographic method such as focusing, improper illumination and the two-dimensional view of photographs, however, can result in variable sensitivity.[26,27] Nevertheless, unlike the wider teledental literature, which includes photographs taken on smartphones, fluctuating lighting and non-dental personnel, this study employed standardised DSLR photography with photographic mirrors taken by a specialist to ensure all images were of good diagnostic quality. The agreement between photographic examination and BWR was found to be moderate (0.30), and the photographs only detected enamel lesions on five surfaces. As a result, a significant proportion of enamel lesions identified by BWR (83%) were classified as sound in the photographs. This discrepancy could be attributed to the inability to dry the tooth surface during photographic examination, which likely led to early enamel lesions on primary molars being undiagnosed. In contrast, photographic assessment showed a higher accuracy for dentine lesions (0.88) compared with enamel (0.78) or sound lesions (0.74). This increased accuracy may be due to the broader spectrum (ICDAS-II 4–6) and more clinically noticeable nature of dentine lesions, which likely reduces subjectivity and improves diagnostic accuracy relative to enamel lesions.

An interesting finding from this study was the ability of NIDIT to visualise hypomineralised enamel as seen in Figure 2. Yellow, brown opacities that may be missed visually were more obvious on NIDIT images and were not visible on BWR. This may be a useful adjunct to assist documentation and patient communication for teeth affected by hypomineralisation. Although this is beyond the scope of this study, the ability to use NIDIT to detect development defects of enamel is an interesting concept and studies exploring variations in the lucency between caries and hypomineralisation using NIDIT would be useful to ascertain the validity of this technique.

This study is limited by its retrospective nature in that any NIDIT images that were not of excellent quality could not be retaken. Several limitations were observed during the study period for example a latency between pressing the DIAGNOcam handpiece's capture button and final image acquisition on the laptop often necessitated multiple attempts to capture a stable image of the same tooth. Additionally, slight deviations in positioning produced an over or under-exposed image and multiple images were often taken of the same surface. The DIAGNOcam probes also needed to be pushed down firmly to engage the cervical constriction of primary teeth to obtain the correct exposure and choosing the correct tip size was important. Furthermore, the DIAGNOcam software did not allow tooth numbers to be corrected or edited after the image was taken and it did not have the ability to adjust the image settings such as brightness, contrast and sharpness.

The findings of this study suggest moderate agreement between BWR and NIDIT in proximal caries detection for primary teeth. In comparison with BWR, NIDIT showed a high specificity but low sensitivity and therefore can only be considered an adjunctive tool for caries detection in primary molars. Nevertheless, it can be a useful tool for patient communication and monitoring proximal surfaces. In addition, the ability to concomitantly visualise and capture hypomineralised tooth structure and restorations in primary teeth is a promising additional feature of NIDIT that requires further investigation.

AUTHOR CONTRIBUTIONS

J.P., A.V., Y.J.G. and Y.F. collected the data, conducted the data analysis and drafted the manuscript. J.P. and R.A. developed the research plan, guided the data collection and analysis, and contributed to the writing and review of the final manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

The authors confirm that the data supporting the findings of this study are available within the article. Raw data are not publicly available due to ethical restrictions and patient confidentiality.

ETHICS STATEMENT

Ethics approval for this study was received from the UWA Human Research and Ethics Committee (Ref: RA/4/20/4442).

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