

Title: *In Vitro* Performance of Near Infrared Light Transillumination at 780-nm and Digital Radiography for Detection of Non-Cavitated Approximal Caries

Short title: Non-Cavitated Approximal Caries Detection *in Vitro*

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Abstract:

Objectives: To evaluate the ability of a Near Infrared Light Transillumination (NILT) device to detect non-cavitated approximal caries lesions; and to compare its performance to Digital Radiography (DR).

Methods: Thirty human extracted premolars (sound to lesions into the outer one-third of dentin) were selected. Lesion depth was confirmed by micro-computed tomography (μ -CT). Teeth were mounted in a custom-made device to simulate approximal contact. DR and NILT (CariVu™, DEXIS, LLC, Hatfield, PA, USA) examinations were performed and repeated by three trained and calibrated examiners. Sensitivity, specificity, area under ROC curve (A_z), inter- and intra-class correlation coefficients (ICCs) for each method, and correlation among the methods were determined.

Results: ICCs for intra-/inter-examiner agreement were substantial for NILT (0.69/0.64), and moderate for DR (0.52/0.48). Sensitivity/specificity for NILT and DR were 0.68/0.93 and 0.50/0.64, respectively. A_z for NILT was 0.81, while for DR it was 0.61. Spearman correlation coefficient with μ -CT for NILT (0.65, $p < 0.001$) demonstrated moderate association, while that of DR suggested no association (0.19, $p = 0.289$).

Conclusion: Within the limitations of this *in vitro* study, NILT demonstrated a potential for early approximal caries detection. NILT and DR performed the same regarding the accuracy for non-cavitated approximal caries detection; however, NILT was superior to DR in terms of repeatability, agreement and correlation with μ -CT.

Clinical significance: A commercial version of NILT was recently introduced as a non-irradiative adjunctive caries detection method. It uses near infrared (NIR) light at 780-nm to transilluminate teeth and captures live images from the occlusal surface. This study demonstrates that NILT can be used as an alternative to radiography for non-cavitated approximal caries detection.

Key words:

Approximal Caries, Caries Detection, Near Infrared Transillumination, Transillumination,
Bitewing Radiography, CariVu™, DIAGNOcam.

Introduction:

It has been known that demineralization and remineralization of tooth structure occur over time. More importantly, the net balance between the pathologic and protective factors will determine the rate of caries lesion progression to a state that can be detected visually or by other caries detection methodologies [1, 2]. Because of the widespread use and availability of fluoride, caries lesion behavior has changed significantly and a lower progression rate has been observed [3]. The slow progress of the caries lesion gives the dental professional a substantial opportunity to diagnose and manage dental caries at an early stage, as non-cavitated lesions can be arrested or remineralized before irreversible destruction of the tooth structure occurs. Hence, early caries detection and monitoring can have a profound effect on the success of preventive treatment of non-cavitated caries lesions [2].

First described by Raper in 1925 [4], bitewing radiography in combination with visual examination has become the traditional method for approximal caries detection [5]. Radiographs also help to estimate approximal and occlusal caries lesion depth and enable detection of lesions on visually inaccessible surfaces. A major limitation of radiographic caries detection is that image interpretation may vary significantly within or between examiners [5]. Furthermore, two recent systematic reviews with meta-analysis evaluated the performance of visual examination and radiography for caries lesion detection [6, 7]. They demonstrated that these two conventional methods have low sensitivity but high specificity for early approximal caries detection. This means that the conventional methods have high risk to miss detection of approximal lesions.

An argument has been raised to re-evaluate clinicians' over-reliance on using radiography for caries detection because of the following reasons: 1) decrease in caries prevalence; 2) the risk associated with low-dose radiation, especially for children [5]; and 3) slow progression rate of approximal caries lesions as the result of the widespread use of fluoride [3]. Although there is no

conclusive evidence that dental radiographs taken during childhood increase the risk of malignant diseases [8], it is still difficult to justify the repeated use of bitewing radiography to monitor lesions and consequently to evaluate the effectiveness of non-invasive dental preventive treatments [5, 9]. Therefore, because of these concerns, it is of vital importance to continue the development of new caries detection techniques with improved sensitivity, specificity, and reliability, while decreasing risk to the patients.

The search for a highly accurate caries detection method has resulted in many attempts. Methods based on visible and near infrared (NIR) light transillumination have been under development since the early 1990s [10]. Thereafter, Digital Imaging Fiber Optic Transillumination (DIFOTI) (Electro-Optical Sciences Inc., NY, USA) was introduced as a more sensitive, non-irradiative adjunctive method for early caries detection [11]. Its principle is based on transilluminating the tooth with a visible light (wavelength between 400-nm to 700-nm) and the caries lesion will appear as a dark shadow due to differences in light scattering and absorption of light photons. However, visible light cannot penetrate deep into enamel because of high light scattering by tooth tissues. NIR light can penetrate deeper into enamel due to reduced scattering in tooth enamel [12]. NIR transillumination for caries detection has been under further development since early last decade [12-20]. NIR light at 1310-nm has shown an enhanced image contrast over 830-nm for approximal caries transillumination. However, both have shown highly improved image contrast compared to wavelengths in the visible range (400-nm to 700-nm) [19]. Furthermore, two *in vivo* studies evaluated a prototype of NIR transillumination [16, 18]. Staninec et al., illustrated that lesions appearing in radiographs were also detected in NIR transillumination [16]. Simon et al. investigated the performance of NIR transillumination and radiography clinically on premolars planned for extraction with microradiography as a gold standard. The NIR transillumination showed higher sensitivity than radiography for approximal caries detection [18].

A commercial near infrared light transillumination (NILT) device was introduced in Europe as DIAGNOcam (KaVo, Biberach, Germany) in 2012, and a year later, in the United States as CariVu™ (DEXIS, LLC, Hatfield, PA, USA) [21]. This device uses a near infrared (wave length ~ 780-nm) light to transilluminate the tooth. This system consists of a charged coupled device (CCD) sensor to capture images, connection to a computer, special software, and elastic arms containing a NIR light source that transmits light through the gingiva, the alveolar bone, the root of the tooth, and up to the crown. The image displays and saves from the occlusal surface [21]. To our best knowledge, no study has evaluated and compared the commercially available NILT to a histological reference method that can identify the severity of caries lesions. Hence, there is a need for further evaluation of NILT regarding the detection of early non-cavitated caries lesions. For practical reasons, we designed an *in vitro* model to simulate the clinical situation as close as possible in terms of allowing the near infrared light to be transmitted through a certain material thickness, the roots and up to the crown of the tooth. We employed non-destructive micro-computed tomography (μ -CT) as the histological reference method to confirm lesion depth extension. The objectives were to evaluate the ability of NILT to detect non-cavitated approximal caries lesions; and to compare between NILT and digital radiography (DR). The null hypothesis was there was no a difference in the ability of caries detection between NILT and DR.

Materials and Methods

Teeth Selection

Eighty-five sound and carious human premolars were selected from a pool of extracted teeth. The non-cavitated caries lesions were located on approximal surfaces and they were surrounded by sound enamel. The presence of caries was determined by visual tooth surface changes [22, 23]. The extracted human teeth were collected from dental practitioners across the United States and transported in 0.1% thymol solution. The collection of human teeth for use in dental laboratory research studies has been approved by the Indiana University (IU) Institutional

Review Board. All specimens were kept in 0.1% thymol solution at 4° C until used. Teeth were cleaned using Robinson's brush with water on a slow speed handpiece.

Initial Microfocus Computed Tomography (μ -CT) Image Acquisition

The teeth were mounted and secured on plastic Lego® bricks (The LEGO Group, Billund, Denmark) using utility wax (Heraeus Kulzer Inc., Lafayette, IN, USA). The teeth were scanned using microfocus computed tomography (μ -CT) for lesion depth determination and to establish a gold standard assessment. The μ -CT images were acquired using Skyscan μ -CT machine (Skyscan 1172, Kontich, Belgium) at 80 kV, 134 μ A, 8.9 μ m pixel size resolution. An Al + Cu filter was used. The specimens were rotated at 180° with rotation step of 0.7° and frame average of 4. Two-dimensional image reconstructions were done using NRecon version 1.6.6 software (Bruker microCT, Kontich, Belgium) and stored in 16-bit TIFF files. Visual interpretation of sagittal views of the μ -CT images was performed using image display software (CT-Analyzer, Bruker microCT, Kontich, Belgium) in a dark room on a digital screen (DELL, U2412Mb, Limerick, Ireland). The images were evaluated by two examiners (NA, MA) according to the criteria previously prescribed [24] as described in Table 1. For each specimen, the image with the deepest lesion was considered for score determination. In case of disagreement, the examination was performed again until consensus agreement was achieved.

Model Assembly

Carious teeth with lesion extension into the inner two-thirds of dentin (D₂: Score 4 lesions, Table 1) were excluded. Also, cracked teeth and teeth with obvious fluorosis were excluded. Eventually, twelve extracted premolars were selected based on lesion depth extension according to μ -CT for training and calibration, and thirty teeth for the main examination. The sample distribution for training and calibration/main examination was as follows: sound surface [E₀ (Score 0): n=3/12];

lesion in the outer half of the enamel [E₁ (Score 1): n=3/6]; lesion in the inner half of the enamel [E₂ (Score 2): n=3/6]; lesion in the outer one-third of the dentin [D₁ (Score 3): n=3/6], respectively.

The teeth were mounted on plastic Lego[®] bricks (The LEGO Group, Billund, Denmark) with the test surface adjacent to a sound tooth. The height of contact, lesion and marginal ridge were standardized at the same level for all specimens. Triad[®] visible light cure resin (DENTSPLY International, Inc., York, PA, USA) was applied around the root and the cervical part of the teeth at the level of the cemento-enamel junction resembling the anatomy of the gingiva. The selection of Triad[®] visible light cure resin was based on a pilot study. Several extracted premolars were mounted using different imbedding materials. NILT images were acquired and evaluated in order to obtain images with contrast comparable with *in vivo* NILT images available in public sources [21, 25-27]. Dental floss was used to confirm the presence of the proximal contact (Figure 1). The assembled models were kept in a sealed plastic container with wet gauze to maintain humidity. After model assembly, the mounted teeth (specimens) were again scanned using μ -CT with the same setting as described previously to standardize μ -CT image quality.

Digital Radiography (DR) Image Acquisition

The mounted teeth were placed on a custom film holder with a beam-aiming device. The DR images were obtained using Schick 33 CDR sensor (Sirona Dental Inc., Long Island City, NY, USA) at 60kV, 7 mA/ 0.20 seconds (Sirona, Heliodont DS. Bensheim, Germany). Plexiglass, 10×2.5×10 cm, was placed to simulate the soft tissue effect between the x-ray tube head and the tooth. The images were saved using dedicated software (CDR[®]DICOM, Schick Technologies Inc., Long Island City, NY, USA). The images were extracted and stored in uncompressed TIFF format.

Training and Calibration

Prior to the main examination, three examiners (MA, AH, AG), who had more than 10 years of clinical teaching and research experience, were trained on DR and NILT examinations. The training course included theoretical elements in a PowerPoint presentation for one hour, and hands-on training on previously obtained specimens for NILT and DR images for three hours.

The primary and repeated calibration examinations were performed during separate sessions. One examiner (NA) randomly ordered the samples between examiners and before each examination for each method using the random function of Microsoft Excel software (Microsoft® Excel® version 14.6.0, Microsoft Corporation, Redmond, WA, USA).

DR Calibration

The images were displayed randomly on a digital screen in a dark room (DELL, U2412Mb, Limerick, Ireland) via image viewer software (Windows Photo Viewer, version Windows 7, Microsoft, Redmond, WA, USA). The images were evaluated by the three examiners according to the criteria previously prescribed [24] in Table 1.

NILT Calibration

After air-drying, each specimen was examined with NILT (CariVu™, DEXIS, LLC, Hatfield, PA, USA) in a dark room. The examiners were instructed to place the light aperture and make it contact the resin that resembled the gingiva; the NILT camera was centered perpendicularly over the test tooth. The live picture was monitored on the digital screen (DELL, U2412Mb, Limerick Ireland) and when the examiners were satisfied with a viewed image, they were asked to capture it and report the score. The images were saved through the software (DEXIS, version 9.4.0, Hatfield, PA, USA). The scoring criteria are described in Table 1.

Repeated Calibration

Each examiner performed DR and NILT calibration again on the same specimens at least two days after the initial calibration and in the same manner as previously described.

Statistical Analysis for Calibration

Intra-examiner repeatability and inter-examiner agreement of all methods were assessed using intraclass correlation coefficients (ICCs). Two-way tables were also used to provide additional information about the repeatability and agreement.

Calibration Results

The intra-examiner repeatability ICCs after calibration were as follows: DR (0.86) and NILT (0.71). The inter-examiner agreement ICCs were as follows: DR (0.86) and NILT (0.71). Since the ICCs values was not satisfactory for NILT a second training and calibration exercise was performed only for NILT as previously described. The intra-examiner repeatability ICC for the second NILT calibration was 0.81, and the inter-examiner agreement ICC was 0.81.

Main Examinations

Main DR and NILT examinations were performed on the thirty teeth (n=30) as previously prescribed in “model assembly.” It was performed in the same manner as in calibration for each method. Repeated examination was performed one week after the first main examination on all teeth (n=30).

Sample Size Justification

Data from previous studies indicated a correlation of approximately 0.7 between methods. With a sample size of 10 sound teeth and 5 teeth for each of E₁, E₂, and D₁, the study had 80% power to detect a difference in the area under Receiver Operating Characteristic (ROC) curve (A_Z) of 0.23 (0.67 vs. 0.90), assuming a two-sided test with a 5% significance level.

Statistical Analysis

Intra-examiner repeatability and inter-examiner agreement of all methods were assessed using intraclass correlation coefficients (ICCs). Two-way tables were also used to provide additional information about the repeatability and agreement. Comparisons between the DR and NILT methods for sensitivity, specificity, and A_z were performed using bootstrap analyses. The bootstrap analysis method employed in this study allowed us to use the individual data from all three examiners, which is more clinically relevant than using a rule to combine scores across multiple examiners, such as using the maximum score, majority rule, or forced consensus. The bootstrap methodology uses resampling techniques to estimate statistics and perform comparisons for values that are not normally distributed. In this case, the bootstrap also provides a way to properly account for the correlations between examiners, between repeats, and between methods when all were assessed on the same sample. The sensitivity was determined further based on three μ -CT thresholds: lesion in the outer half of the enamel [E_1 (μ -CT= E_1)]; lesion in the inner half of the enamel [E_2 (μ -CT= E_2)]; and lesion in the outer one-third of the dentin [D_1 (μ -CT= D_1)]. The correlations among the measurements and the correlations of the measurements with the μ -CT were also calculated using bootstrap methods.

Results

The intra-examiner repeatability and inter-examiner agreements are presented in Figure 2. Intraclass correlation coefficients (ICCs) of the intra-examiner repeatability and inter-examiner agreements were interpreted based on Landis and Koch [28]. The repeatability and agreement were substantial for NILT and moderate for DR. Overall sensitivity, specificity, area under the ROC

curve (A_z) and correlation with μ -CT scores are presented in Table 2. For overall sensitivity, although DR was not significantly different from NILT ($p=0.25$), NILT presented a higher value. As for the sensitivity at three μ -CT thresholds, again there were no statistically significant differences found between the methods (μ -CT= E_1 $p=0.68$, μ -CT= E_2 $p=0.73$ and μ -CT= D_1 $p=0.06$), but numerically NILT was higher for μ -CT= E_1 and μ -CT= D_1 , and lower for μ -CT= E_2 . While specificity and A_z were also not significantly different ($p=0.09$ and $p=0.052$, respectively), NILT presented higher values. For correlations of NILT and DR with μ -CT, NILT was moderately associated with μ -CT (correlation= 0.65 , $p<0.001$) while DR was not associated with μ -CT (correlation= 0.19 , $p=0.29$, Table 2).

Discussion

When dental caries is detected before surface cavitation occurs, preventive therapy can arrest the progression of active caries lesions before they reach the cavitation stage [29]. This preventive treatment approach requires valid as well as reliable early caries detection methods in order to successfully detect and monitor the changes in lesion progression, especially at non-cavitated stages [2, 30]. Our research interest is early detection of dental caries so that it can be remineralized and arrested. Therefore, in this current study, we selected extracted premolars with approximal non-cavitated lesions that extended at most into the outer one-third of dentin. Teeth with lesions extending into the inner two-thirds of dentin were excluded mainly because deep dentin lesions are more often subjected to surgical intervention [31] and more time consuming to remineralize in *in vitro* models [32]. Also, deep non-cavitated dentin lesions are not commonly available.

For practical reasons, we designed this *in vitro* study to compare NILT and DR with the use of μ -CT as the reference standard for the determination of the presence of caries lesions on extracted human premolars. This was done in order to provide a detailed investigation of the

performance of the new commercially available NILT device (CariVu™) in comparison to DR regarding non-cavitated approximal caries detection. Model assembly was carefully designed. We conducted a pilot study to determine the most suitable medium for the NIR light to travel through. Using the medium chosen in this current study, NILT images of *in vitro* model resembled clinical NILT images based on available public sources [21, 25-27]. The results of *in vitro* study cannot be always transferred to those of *in vivo*. As NILT images were obtained in ideal laboratory conditions, they may differ from the clinical environment. Tooth hydration, stains and presence of gingiva may impact the performance of the NILT. Working in a laboratory environment may improve performance of any caries detection method in *in vitro* settings. Another challenging limitation of *in vitro* models for caries detection is selection and distribution of an optimal representative sample of extracted teeth. Extracted teeth are part of an inherently biased group [33]. Specificity values for radiography were reported in systematic reviews to range from 0.87 to 0.96 [7] for dentin caries lesions and lower for lesions limited to enamel (ranged between 0.76 to 0.80 in *in vitro* studies) [34]. In this current study, the specificity value for DR was surprisingly low (0.64). There is no clear explanation for this. Examiners were trained and calibrated with almost perfect agreement and repeatability among them. Also, an independent examiner ensured randomization of the samples between examinations and between the examiners who performed the caries detection. A potential explanation may be due to under representation of more severe lesions.

The null hypothesis was not rejected, as no significant difference was found between the DR and NILT regarding A_z values. The available scientific data for NILT are limited. Kuhnisch et al., [27] performed an *in vivo* study to compare the performance of visual examination, radiography, Laser Fluorescence pen (LF pen, DIAGNOdent Pen, KaVo Biberach, Germany) and the European version of NILT (DIAGNOcam, KaVo, Biberach, Germany) for detection of dentin-involved approximal caries lesions. The reference standard was established after clinical caries excavation using radiography for lesion depth measurement. They found that the sensitivity values were 0.992

for NILT, and 0.961 for radiography. However, one of the limitations of Kuhnisch et al. [27] study can be attributed to the unavoidable selection bias in any *in vivo* diagnostic study. For ethical reasons, only teeth that showed visual and radiographic signs of dentin-involved approximal caries lesions were included in their sample. This may result in high sensitivity values, as the probability of detecting dentin lesion is high. Also, due to absence of negative controls, specificity values could not be calculated. Our current study showed sensitivity values at the dentin threshold in agreement with Kuhnisch et al. [27]

Near infrared (NIR) light (wavelength: 700-2000-nm) can penetrate deeper enamel due to enamel's reduced scattering coefficient (μ_s) within the NIR wavelength spectrum. The scattering coefficient of enamel in the visible wavelength is 60 cm^{-1} at 632-nm and decreases as the wavelength increases to the NIR spectrum ($\mu_s = 2 \text{ to } 3 \text{ cm}^{-1}$ at 1310-nm and 1550-nm) [10, 20]. Fried *et al.* [17] demonstrated that when NIR light was delivered close to the cemento-enamel junction, the approximal lesions could be viewed from the occlusal. This is because light with wavelength in the NIR range can penetrate deeper enamel thicknesses [10, 17, 20]. Staninec *et al.*, [16] evaluated the performance of a prototype device that used NIR light from buccal, lingual and occlusal views at 1310-nm for approximal caries detection *in vivo*. Thirty-three lesions were included based on bitewing radiography that served as the reference standard. The NIR prototype device detected thirty-two lesions when all views (occlusal, buccal and lingual) were used to evaluate the approximal sites. The NIR prototype device buccal and lingual views detected thirty lesions, while the occlusal view detected twenty-seven lesions [16]. This can be explained as the emitted light in NIR needed to travel through a large amount of surrounding enamel to reach the occlusal surface. Moreover, it was determined that NIR light at 1310-nm is optimal, as the enamel is highly transparent at this wavelength and stains do not interfere [13, 14, 16, 17, 20]. However, manufacturer of the NILT device adopted 780-nm NIR light source to reduce the cost and to enhance clinical use [27]. Also, the device includes only occlusal tips to acquire the images from

the occlusal view. Development of an approximal tip to allow imaging from the buccal and lingual view as well as using longer wavelength light as previously reported [13, 14, 16-18, 20] may improve NILT performance for approximal caries detection.

In this current study, NILT demonstrated that lesions involving the inner half of the enamel were more detectable than lesions in the outer half. This is in agreement with Ando's [35] observations regarding occlusal and smooth surface caries detection *in vivo* using DIFOTI. A possible explanation is that increased demineralization may lead to increased light scattering and absorption [36]. This indicates the potential of light transillumination methods to quantify caries lesions. NILT showed higher repeatability and agreement than DR as well as superior correlation with μ -CT depth scores. This could be attributed to the ability of the NILT to detect early changes in the optical properties of demineralized enamel [23]. The detectable optical changes are earlier than radiographic changes as 30% to 40% mineral loss is necessary for the radiographic detection of enamel caries [37]. Furthermore, DR failed to show any association with μ -CT depth scores, while NILT showed a moderate association. Radiographs usually underestimate the depth of the lesion; the location, shape and extent of the lesion, as well as the anatomy of the tooth, can influence radiographic depiction [5].

Arguments have been raised regarding when the use of bitewing radiography for caries detection is justified and how long the intervals between radiographic examinations should be [38, 39]. The concern associated with bitewing radiography for caries detection is primarily due to the radiation risk and low sensitivity for detecting non-cavitated lesions [8]. Therefore, it is still difficult to justify the repeated use of bitewing radiography to detect lesions and consequently supports the need to evaluate the effectiveness of non-invasive preventive treatments [5, 9]. Although the absorbed radiation dose from bitewing radiography is very low [8], further reduction or elimination of ionizing radiation is desirable.

NILT offers several advantages over bitewing radiography. The major advantage is elimination of the radiation hazard associated with bitewing radiography. Using the NILT method, images can be viewed in real time, and no film is required, which reduces patients' discomfort associated with the use of intra-oral films or sensors. Also, images can be saved and used for longitudinal observation over multiple visits. Another advantage of NILT is the ability to determine lesion extension. Also, it can detect approximal and occlusal caries from one view saving time and effort of obtaining images from both views. The results of this *in vitro* study demonstrated the potential of NILT for approximal non-cavitated caries detection. NILT can be used as an adjunct method to detect and monitor non-cavitated approximal caries lesions. However, its performance needs clinical validation with a well-accepted reference standard (for example, *in vitro* validation after primary tooth exfoliation).

One of the disadvantages of NILT is that it cannot delineate the dental pulp because of the strong light scattering of the dentin [27] Consequently, it is difficult to estimate the lesion depth in dentin in relation to the pulp. Therefore, the probability of approximal cavitation based on lesion depth cannot be estimated with the same confidence as in radiography [40]. Further study is needed to identify possible quantitative or qualitative indicators that can be used to determine or estimate dentin lesion depth.

A concern regarding additional diagnostic yield is that it may lead to more false-positive diagnoses and consequently over-treatment, especially in populations regularly exposed to fluoride [5]. However, the key for appropriate caries detection is found in the outcomes of the caries diagnosis process. False positive diagnosis of an active non-cavitated caries lesion should not result in operative treatment, but in preventive non-surgical intervention, such as plaque control, topical fluoride and dietary modification. Although, this means a cost to the patient, it does not result in a

harmful health outcome. On the other hand, there are consequences of missing an active caries lesion. If the patient is caries-active with irregular dental visits, there is a risk of progression of non-cavitated lesions to irreversible tooth cavitation before they are detected, thus requiring surgical intervention, such as restoration [41, 42]. However, if the patient has a low caries risk with regular dental visits, the lesion will probably be detected at a later visit before it progresses to the cavitation stage [43].

Conclusion

Within the limitations of this *in vitro* study, it can be concluded that NILT showed the potential of the method to serve as a useful non-irradiative method for non-cavitated approximal caries detection in place of DR. However, the performance of NILT for detection of early non-cavitated caries requires further *in vivo* validation using a well-accepted gold standard.

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Figure 1. Sample assembly on Lego® bricks. a. Adjacent sound tooth; b. Examined/Test tooth.

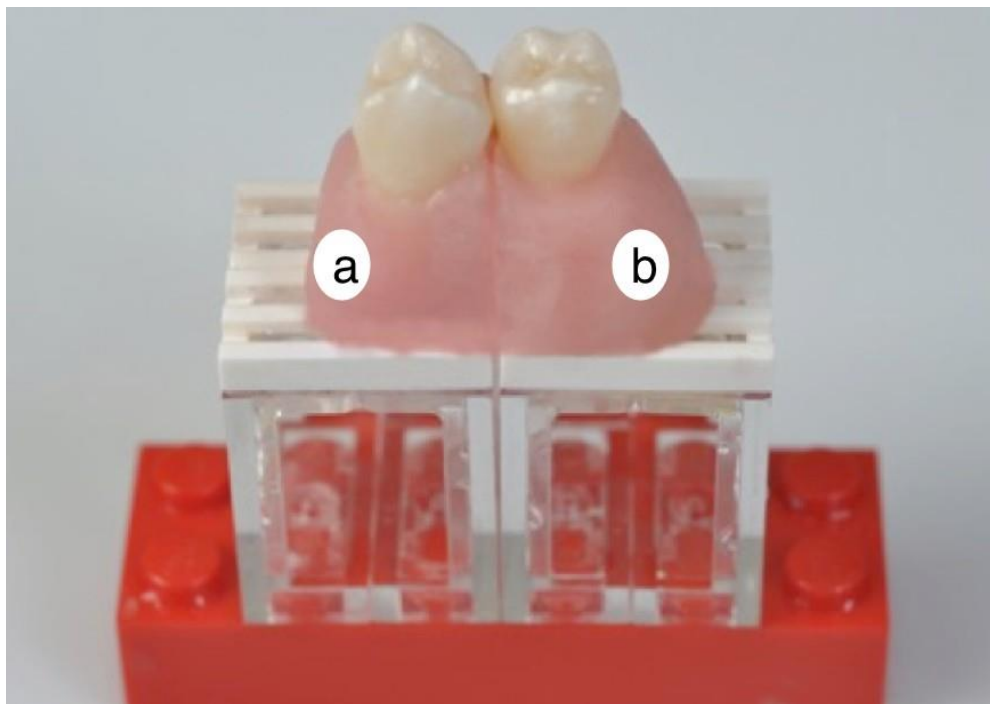


Figure 2. Intra-examiner repeatability and inter-examiner agreements using intra-class correlation coefficient from three examiners. NILT= Near Infrared Light Transillumination

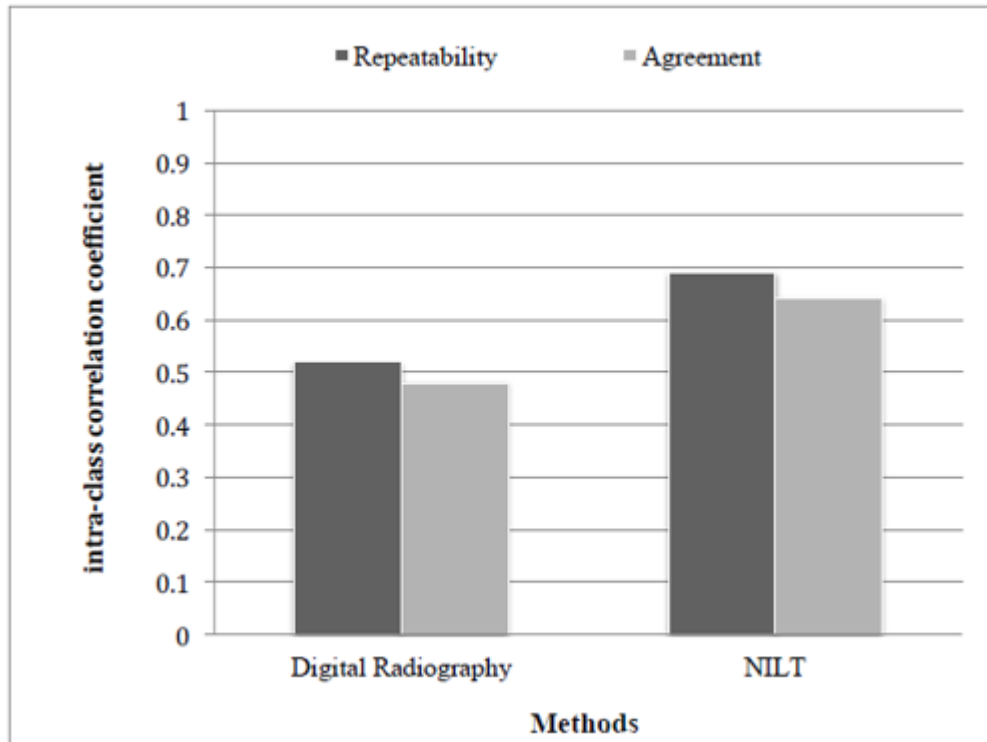


Table 1. Criteria used in this study. Circles and arrows indicate location of caries lesion.

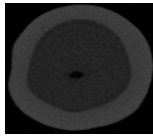
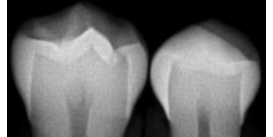
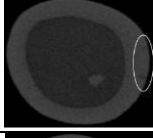

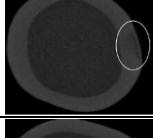
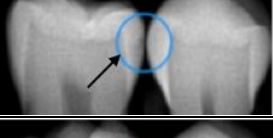
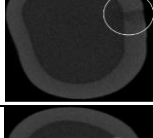
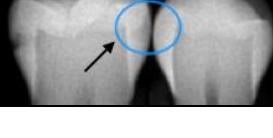
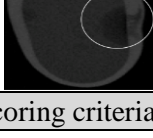
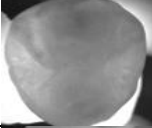

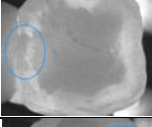

Score	Microfocus computed tomography (μ -CT) and radiography scoring criteria	μ -CT Images	Radiographs
0 (E ₀)	No radiolucency present.		
1 (E ₁)	Radiolucency extends to the outer half of the enamel.		
2 (E ₂)	Radiolucency extends to the inner half of the enamel and does not extend beyond the dentino-enamel junction (DEJ).		
3 (D ₁)	Radiolucency extends to the outer one-third of the dentin.		
4 (D ₂)	Radiolucency extends to the inner two-thirds of the dentin (Excluded in this study).		
Score	Near Infrared <u>L</u> ight <u>T</u> ransillumination (<u>N</u> ILT) scoring criteria	<u>N</u> ILT Images	
0	No shadowing.		
1	Shadow in outer half of enamel.		
2	Shadow in inner half of enamel, but not to DEJ.		
3	Shadow extended to DEJ, but not beyond outer one third of dentin.		

Table 2. Specificity, Sensitivity, Area under ROC curve and correlation of the methods with μ -CT scores.

Method	Sn	Sp	Sn for μ CT =E ₁	Sn for μ CT=E ₂	Sn for μ CT=D ₁	A _z	Correlation with μ CT scores
Digital Radiography	0.50	0.64	0.39	0.67	0.44	0.61	0.19
<u>NILT</u>	0.68	0.93	0.50	0.61	0.92	0.81	0.65

Sn = Sensitivity.

Sp = Specificity.

A_z = Area under Receiver Operating Characteristic (ROC) curve.

μ CT= Microfocus computed tomography.

E₁= lesion in the outer half of enamel.

E₂= Lesion in the inner half of enamel.

D₁=lesion in the outer one-third of dentin.

NILT = Near Infrared Light Transillumination.