Accuracy of Extraoral Bitewing Compared with Histopathology in Proximal Caries Detection of Primary Molar Teeth

Piyanut Khummoon[1], Sirilawan Tohnak[2]*, Chutamas Deepho[2], Saran Worasakwutiphong[3,4] and Supanya Naivikul[1]

[1]Department of Preventive Dentistry, Faculty of Dentistry, Naresuan University, Phitsanulok, 65000, Thailand

[2]Department of Oral Diagnosis, Faculty of Dentistry, Naresuan University, Phitsanulok, 65000, Thailand

[3]Department of Surgery, Faculty of Medicine, Naresuan University, Phitsanulok, 65000, Thailand

[4]Naresuan University Cleft and Craniofacial Center, Phitsanulok, 65000, Thailand

* Corresponding author. E-mail address: sirilawant@nu.ac.th

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Abstract

An accurate diagnosis of dental caries leads to a suitable treatment plan and prevents premature loss of primary teeth. Intraoral bitewing radiography helps caries determination but has limitations in pediatric patients with severe gag reflexes while the extraoral bitewing radiograph resolved the patients who refused to undergo intraoral radiographs. The research objective was to compare the accuracy of extraoral bitewing radiography and the gold standard histopathological examination for proximal caries detection in the primary molars. Twenty-four extracted primary molars with and without proximal caries were divided into three groups and arranged in the mimetic alveolar sockets of a 3D-printed skull and mandible. Two observers evaluated extraoral bitewing images separately twice at one-week intervals. The weighted kappa coefficients showed excellent intra-observer and inter-observer agreements between each session of the extraoral bitewing radiographic assessments. The Mann-Whitney U test showed no difference between the radiographic grading scores of extraoral bitewing images and the gold standard. The sensitivity, positive predictive value (PPV), negative predictive value (NPV), and the area under the receiver operating characteristic (ROC) curve in cavitated carious lesions were higher than in non-cavitated carious lesions. In conclusion, extraoral bitewing is an alternative radiography for pediatric patients who are either uncooperative or intolerant to intraoral radiography.

Keywords: extraoral bitewing radiographs, proximal caries, primary teeth, caries diagnosis

Introduction

Dental caries is a complex disease that is caused by an imbalance between demineralization and remineralization. Untreated dental caries in children can lead to infection, discomfort, and premature loss of teeth (Selwitz et al., 2007; Wong et al., 2017). Clinical examinations combined with bitewing radiography are the most used method for the detection of proximal caries. However, intraoral bitewing radiography requires a skilled operator and may cause discomfort to some patients (Abdinian et al., 2015; Terry et al., 2016; Wenzel, 2014). Respiratory diseases, such as the common cold, influenza, tuberculosis and coronavirus disease (COVID-19) can transmit saliva via evaporation, respiratory secretions, and droplets while the receptor and film holder is in the uncooperative pediatric patient's mouth (MacDonald et al., 2020; Villoria et al., 2021). Due to the stated limitations, an extraoral bitewing radiograph has been proposed as an alternative to an intraoral bitewing radiograph.

The extraoral bitewing image can display the left and right posterior teeth, and the crown-root structures of the maxilla and mandible in a single exposure (Abdinian et al., 2015; Chan et al., 2018; Felemban et al., 2020; Johnson et al., 2021; Little et al., 2020; Terry et al., 2016). The principle of the extraoral bitewing radiography is similar to conventional panoramic radiography, but its interproximal angulation projection is improved to ensure that the perpendicular X-ray beam travels through the proximal surface of the teeth (Mallya & Lam, 2018; Whaites & Drage, 2020). The ability of the extraoral bitewing technique for initial proximal caries detection is comparable to the intraoral technique (Abu El-Ela et al., 2016). While intraoral bitewing radiography is the common diagnostic tool for caries detection, the focus on histopathological validation allows the detailed assessment of caries status (Diniz et al., 2012).

The anatomy of primary teeth differs from that of the permanent teeth due to the enamel and dentin thickness, pulp-crown ratio, and their contact surfaces. As a result, the prevalence of dental caries in primary teeth may differ from that found in permanent teeth (De Menezes Oliveira et al., 2010; Susan, 2015; Turner & Dean, 2015). Due to the limited knowledge available, we hypothesized that the extraoral bitewing radiograph could reveal proximal caries. Therefore, the objective of this study was to compare the accuracy of extraoral bitewing for the detection of proximal caries in primary molars, with the gold standard histopathologic examination.

Methods and Materials

This experimental research was approved by the Naresuan University Institutional Review Board (IRB No. P1-0076/2565) before it began at the Dental Hospital, Faculty of Dentistry, Naresuan University. The sample size was calculated at 85% power of test and 95% level of confidence by using the G*power program version 3.1.9.7 (Franz Faul, University Kiel, Germany). A total of 24 primary molars, representing 48 surfaces, were used in this study. All sample sizes consisted of teeth extracted because of pathological root resorption, whether or not they had dental caries. The teeth were visually and tactilely examined to determine whether there was cavitation. There were 30 surfaces with cavitated lesions, 11 without, and 7 with sound surfaces. The teeth were cleaned and preserved in a 0.1% thymol solution at a standard ambient temperature of 25 °C before the crown and root sections of the teeth were separated using a high-speed diamond bur. A CBCT data set of a 7-year-old male patient, that had been taken for orthodontic reasons, was edited and adjusted using the Meshmixer™ software version 3.5.474 (Autodesk, California, USA, Inc.), to create a 3D printed model using polylactic acid (PLA) (Anet ET4+ printer: ANET Co., Ltd., Bangkok, Thailand). Eight of the primary molar crowns were fixed in the mimetic alveolar sockets of the 3D-printed skull and mandible model. Dental baseplate wax was used to fill the alveolar sockets up to the cementoenamel junction and retain the teeth in position.

Extraoral bitewing images were taken using a Veraview X800 X-ray machine (J. Morita Mfg. Corp., Kyoto, Japan) with 6 mA, 80 kVp, and an exposure time of 11.99 sec, as recommended in the instruction manual. The 3D model was placed on the chin rest and positioned on the line of the X-ray detector (laser beam). The facial midline of the model lined up with the vertical laser beam, while the horizontal laser beam lined up with the model's orbitale, as illustrated in Fig. 1.

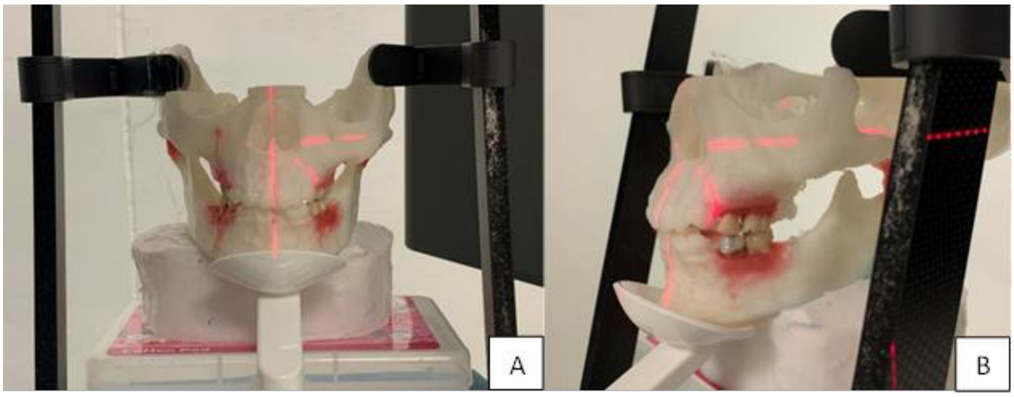

Figure 1 Position of the skull and mandible during extraoral bitewing exposing. (A) coronal view, (B) sagittal view

A general practitioner, and a dental radiologist with 8 years' experience, randomly evaluated three extraoral bitewing radiograph images. (Fig. 2)

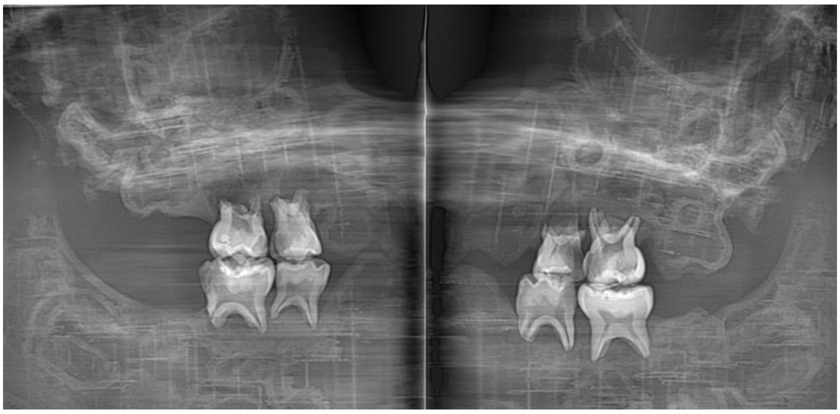

Figure 2 Examples of extraoral bitewing images

The extraoral bitewing images were displayed using the Uniweb server program on a 21-inch high-definition light-emitting diode screen computer monitor (OptiPlex 3050, Dell®, Round Rock, Texas, USA) in a room with ambient light. Each observer independently evaluated the images twice at one-week intervals, to minimize the possibility of recalling previous assessments. The complete evaluation of the images may take several sessions of 30 min each, and a 15-min break between them to prevent eye fatigue. To improve the interpretation of the radiographs, the observers are free to adjust the brightness and contrast of the images.

Following the radiographic evaluation, the primary molar teeth were embedded into acrylic up to the occlusal surfaces, then cut into 3 to 6 sections, in a mesiodistal direction along the axis of the crown using a macrotome (Isomet 5000; Buehler, Lake Bluff, IL, USA). For each of the 500 μm thickness sections, proximal surfaces were evaluated at the front and back sides of the slice using a stereomicroscope (Olympus SZX16, Hatagaya, Shibuya-ku, Tokyo, Japan) at x 12.5 magnification. When multiple caries categorization scores were present on a single microscopic slice, the caries score was determined by identifying the deepest decay extent within a given data set. One observer, who passed the calibration with the pathologist, assessed the decay extent twice at one-week intervals. The criterion for enamel caries is an opaque-white to dark-brown discoloration. In the part of the dentin that was interpreted at the upper border of the sclerosis dentin layer, there was a dark yellow or brownish discoloration. If there was a discrepancy between the first reading and the second reading, the pathologist resolved the discrepancy. Fig. 3 illustrates the front and back sides of an example section.

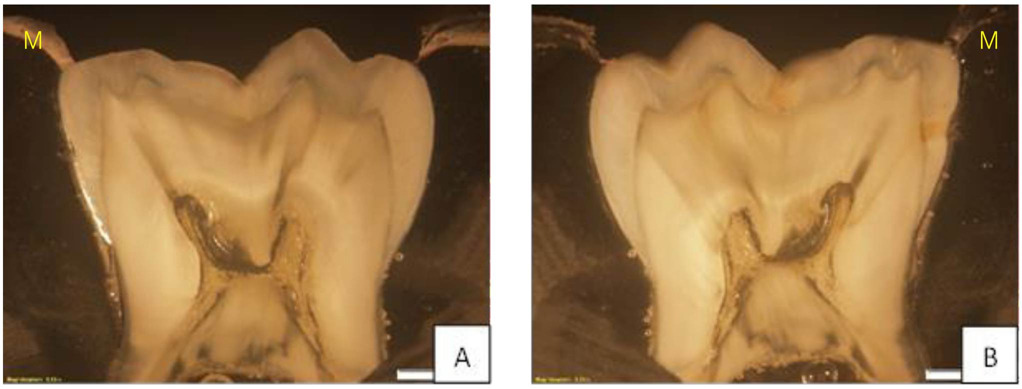

Figure 3 The same microscopic slice as on the front (A) and back (B) sides. A caries score of 2 is shown on the front, and a score of 3 is shown on the back of the medial surface (M), which represents various caries categorization scores. The caries score will be determined using the deepest extent of decay in each slice. As a result, this instance gets a caries score of 3

Data assessment

The observers scored the radiographic images and histological sections by using the Russell and Pitts criteria, where 0 indicates no proximal caries or sound surface; 1 indicates proximal caries in the outer half of the enamel; 2 indicates proximal caries in the inner half of the enamel; 3 indicates proximal caries in the outer half of the dentine; and 4 indicates proximal caries in the inner half of the dentine (Russell & Pitts, 1993). The interproximal overlapping areas that are shown on the radiographic images were excluded from the assessment.

Data analysis

The radiographic interpretations and the histological examinations were analyzed by using IBM SPSS v26 software (IBM Corp., New York, NY; SPSS Inc., Chicago, IL, USA). A weighted kappa was used to calculate the inter-observer and intra-observer agreements of the radiographic images by the observers. The Kappa statistics were calculated according to the following criteria: (1) poor agreement (< 0.20); (2) fair agreement (0.21-0.40); (3) moderate agreement (0.41-0.60); (4) substantial agreement (0.61-0.80); and excellent agreement (0.81-1.00). The Mann-Whitney U test determined a statistically significant difference between the radiography grading scores of the extraoral bitewing and the gold standard histological examination grading scores. The receiver operating characteristic (ROC) analysis evaluated the observers' ability to differentiate between teeth with varying degrees of dental caries. The area under the ROC curve values (Az value) was used to interpret the Az values, < 0.50 indicates no diagnostic value; 0.50-0.75 indicates a poor diagnostic value; 0.75-0.90 indicates a good diagnostic value; and > 0.9 indicates an excellent diagnostic value (Ray et al., 2010). The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were used to assess the diagnostic accuracy of the radiographic images.

Results

We used 24 primary molars, which represented 48 surfaces in this study. Six teeth surfaces were excluded from the statistical analysis, due to the outer layer of the tooth enamel being overlapped by more than half of its thickness by another tooth. There was a total of 42 surfaces in this study, and Table 1 shows the descriptive data of their dental conditions. The presence of carious lesions was confirmed by histological examinations.

Table 1 The frequency and percentage of dental conditions confirmed by histological examinations

Dental condition	Sound surface (%)	Carious lesions		Total (%)
		Non-cavitated lesions (%)	Cavitated lesions (%)	
Frequency (surfaces)	6 (14.30)	11 (26.20)	25 (59.50)	42 (100.00)

The weighted kappa coefficients showed excellent intra-observer and inter-observer agreements between each session of the extraoral bitewing radiographic assessments, which ranged from 0.876 to 0.912 and 0.916, respectively.

The Mann-Whitney U test showed no difference between the radiographic grading scores of the extraoral bitewing images and the gold standard histological examination of each tooth surface. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and the area under the ROC curve (Az value) of carious lesions, cavitated carious lesions and non-cavitated carious lesions for each observer are presented in Table 2. The sensitivity, PPV, NPV, and area under the ROC curve of both readings were higher for cavitated carious lesions than for non-cavitated carious lesions. The Az value of the cavitated carious lesions was 0.80. Fig. 4 (A-C) shows the ROC curve of the two observers for carious lesions, cavitated carious lesions and non-cavitated carious lesions, respectively.

Table 2 The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and the area under the ROC curve (Az value) of extraoral radiography for detection of proximal caries by the condition of caries cavitation for each observer

Observer 1						
Dental condition	Sensitivity	Specificity	PPV	NPV	Az value	SE
Carious lesions	0.53	0.83	0.95	0.23	0.68	0.11
Cavitated carious lesions	0.76	0.83	0.95	0.46	0.80	0.10
Non-cavitated carious lesions	0.00	0.83	0.00	0.31	0.42	0.15

Table 2 (Cont.)

	Observer 2					
Dental condition	**sensitivity**	**specificity**	**PPV**	**NPV**	**Az value**	**SE**
Carious lesions	0.58	0.83	0.96	0.25	0.71	0.11
Cavitated carious lesions	0.76	0.83	0.95	0.46	0.80	0.10
Non-cavitated carious lesions	0.18	0.83	0.67	0.36	0.51	0.15

PPV, positive predictive value; NPV, negative predictive value; SE, standard error

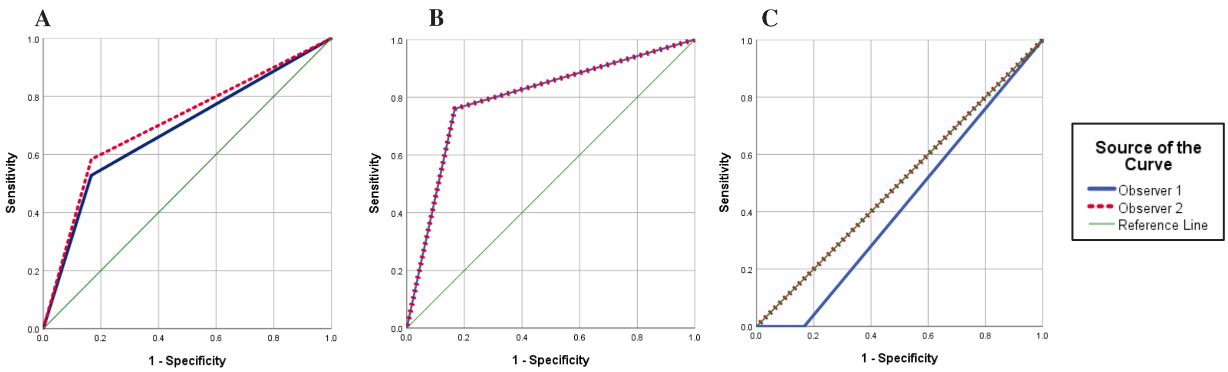

Figure 4 The ROC curve of two observers for detecting proximal caries by extraoral bitewing radiography in conditions of (A) carious lesions, (B) cavitated carious lesions, (C) non-cavitated carious lesions

Discussion

Dental caries, which is one of the most prevalent oral diseases in children, can be diagnosed based on direct visual examination and intraoral radiographs. Proximal carious lesions commonly occur and can be determined by the discoloration of a tooth or its rough surface. Intraoral radiography is a valuable method for the detection of caries, especially the proximal dental caries that are difficult to detect (Tyndall et al., 1998). Extraoral bitewing radiographs show both left and right posterior teeth in a single radiation exposure, which is beneficial for pediatric patients who are either resistant to intraoral radiographs, or have a severe gag reflex (Abdinian et al., 2015; Abu El-Ela et al., 2016; Johnson et al., 2021; Kamburoğlu et al., 2012; Mallya & Lam, 2018). The information from the extraoral bitewing images of proximal caries in permanent teeth can overcome the limitations of the intraoral radiograph assessment. Our hypothesis of the proximal carious lesions shows that the extraoral bitewing radiographs correspond with the histological examinations. The investigations of the accuracy of extraoral bitewing were carried out using either human skulls and their mandibles, or the heads of cadavers (Abu El-Ela et al., 2016; Felemban et al., 2020; Kamburoğlu et al., 2012). In our study, a 3D-printed skull was constructed from the dataset of a 7-year-old male patient, thereby simulating a real child's skull and mandible. The primary teeth were arranged in open contact and set in the sockets along the alignment of the upper and lower jaws. Our results found that six teeth surfaces (12.5%) overlapped, which was similar to the proximal overlapping (18.3%) reported in the clinical studies by Terry et al. (Terry et al., 2016).

The primary teeth have different morphology and mineral composition compared to permanent teeth. This study experimented on primary molars with various depths of caries, whereas other studies utilized permanent premolars and molars (Abu El-Ela et al., 2016; Felemban et al., 2020; Kamburoğlu et al., 2012). A histopathological examination is regarded as an accurate assessment of the presence and extent of dental caries. This is a valid test to assess the accuracy of the diagnostic tool. The results of the observations showed a similarity between radiographic grading scores and the histological examinations in our investigations. An inspection of non-cavitated caries in the primary molars differed from the extraoral bitewing images of the permanent teeth, due to their thinner enamel layer (Abu El-Ela et al., 2016; Kamburoğlu et al., 2012).

The sensitivity of extraoral bitewing used in the detection of proximal caries in our study, was similar to Kamburoğlu and Felemban's study (Felemban et al., 2020; Kamburoğlu et al., 2012). We divided the teeth with carious lesions into cavitated and non-cavitated groups, which revealed a higher sensitivity of approximately 76% in the cavitated ones, while the specificity was constant in all the groups. The Az value was found to be 0.80, which indicated that the diagnostic value was good. Extraoral bitewing radiographs are recommended for dental examination during the COVID-19 pandemic (Little et al., 2020; MacDonald et al., 2020; Villoria et al., 2021). In the present situation, we suggested that extraoral bitewing could be used to detect non-cavitated or cavitated proximal caries when the conventional intraoral bitewing was limited. Intraoral bitewing had higher sensitivity than extraoral bitewing in the incipient proximal caries detection because of smaller pixel size and better resolution (Abu El-Ela et al., 2016). However, previous studies showed no significant difference between the radiographic grading scores of both modalities in diagnostic accuracy of proximal caries detection in permanent molars (Abdinian et al., 2015; Felemban et al., 2020; Terry et al., 2016). The accuracy of proximal caries detection using extraoral bitewing depends on several factors, including the presence of cavitation, the alignment of the teeth, the size and form of the dental arch, and the patient's position and cooperation (Aps, 2020). The limitations were that extraoral bitewing was inferior to intraoral bitewing in that it was more expensive, required a longer exposure time, and resulted in a higher radiation dose. Our study shows a correlation between the presence of cavitation and the detection of proximal caries from extraoral bitewings. This present study also disclosed a lack of correlation between the variables associated with patients and caries detection. The limitation of this study is the small sample size which may expose a weakness in the overall conclusions.

Conclusion and Suggestions

The difference in the grading of caries between extraoral bitewing images, and the gold standard histological examination was insignificant. Extraoral bitewing can detect cavitated carious lesions on the proximal contact surfaces of the primary teeth, while non-cavitated lesions should be carefully interpreted and an additional examination should be performed. Therefore, this process is a good alternative to conventional bitewings for pediatric patients, who are uncooperative or are intolerant to intraoral radiography.

Further studies should be conducted with larger sample sizes and compared with other radiographic techniques, to determine the possibility of using it for the detection of proximal caries.

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Author Contributions

Author 1 (Piyanut Khummoon): Design of methodology, Investigation, Collection of data, Data analysis and interpretation, Manuscript writing-original draft

Author 2 (Sirilawan Tohnak): Conceptualization, Design of methodology, Manuscript review and editing, Supervision

Author 3 (Chutamas Deepho): Conceptualization, Design of methodology, Manuscript review and editing, Investigation, Supervision

Author 4 (Saran Worasakwutiphong): Providing of materials (3D-printed model)

Author 5 (Supanya Naivikul): Conceptualization, Design of methodology, Manuscript review and editing, Supervision

Conflict of Interests

All authors declare that they have no conflicts of interest.

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