RESEARCH ARTICLE

Intraoral *versus* extraoral bitewing radiography in detection of enamel proximal caries: an *ex vivo* study

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Objective: To compare the diagnostic accuracy of digital intraoral and extraoral bitewing (EO BW) radiography in the detection of enamel proximal caries regardless of their ability to separate contacts.

Methods: Artificial caries with different degrees of decalcification was induced in 80 human sound premolars and molars using formic acid. Intraoral radiographs were taken with photostimulable phosphor plate (PSP) and complementary metal oxide semiconductor (CMOS), using the paralleling bitewing technique. Extraoral bitewing radiographs were obtained using Sirona digital panoramic X-ray unit (Sirona Siemens, Bensheim, Germany). In total, 160 proximal surfaces were assessed by 2 observers twice. Area under the receiver operating characteristic curve (Az) values for each image type, observer and reading were compared using z-tests, with a significance level of $p \leq 0.05$. Sensitivity, specificity, positive-predictive value and negative-predictive value for each observer and reading were calculated.

Results: Spearman's test showed a strong positive correlation between the duration of demineralization and histological grading of carious teeth surfaces. For the three radiographic techniques, intraobserver reliability was strong to excellent. Moreover, interobserver agreement was strong. The differences between all detection methods were not statistically significant ($p > 0.05$). Intraoral bitewing using CMOS sensor had the highest sensitivity while EO BW had the highest specificity in the detection of incipient proximal caries.

Conclusions: Within the limits of the *ex vivo* design, the difference in diagnostic accuracy between the three radiographic techniques was not significant. EO BW could be used in the detection of enamel proximal caries with results comparable with intraoral bitewing with PSP plate and CMOS sensor.

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Introduction

Today, dental caries is a major health problem and one of the most common chronic diseases throughout the world. It has a great effect on people's quality of life and high indirect impact on the economy.¹ Incipient proximal caries produces a big challenge for the patients and the dentists, as the clinical

examination of tightly contacting proximal surfaces is very difficult and results in an unacceptable proportion of false-negative results.²⁻⁴ Therefore, clinical examination should always be supplemented with radiographic examination.⁵

Among the various methods used today in the diagnosis of caries, intraoral bitewing radiography (IO BW) is the most frequently used examination for the detection of proximal carious lesions,⁶ and it is more accurate than periapical radiography in the diagnosis of

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Table 1 Grouping of samples

Group	Number of surfaces	Time of demineralization
Control group	40	0 h
Experimental group 1	40	10 h
Experimental group 2	40	20 h
Experimental group 3	40	30 h

proximal caries.⁷ Currently, there are three purchasable intraoral digital sensors: charge-coupled device (CCD), complementary metal oxide semiconductor (CMOS) and photostimulable phosphor plate (PSP).⁸

Extraoral bitewing (EO BW) images are more comfortable to the patients than IO BWs, and they are useful in imaging problematic patients who have troubles with intraoral imaging.⁹ Hence, some manufacturers have recently introduced EO BW radiography in their panoramic machines. The technique provides bitewing-like images for the premolar and molar areas including parts of maxilla, mandible and rami. It uses Selective Compliance Assembly Robot Arm (SCARA) technology to overcome the drawbacks of panoramic radiography in caries detection, as it provides better interproximal separation between contacts. The SCARA robot was first developed under the guidance of Professor Hiroshi Makino from University of Yamanashi in 1979.¹⁰ SCARA is a revolutionary electromechanical construction, providing flexible, precise and complex movements required in rotational maxillofacial radiography. It uses two parallel horizontal joints to rotate in *X–Y* axis and move vertically in *Z*-axis. This *XYZ* Cartesian system with a rotary angle delivers a broad movement range and flexibility to accomplish virtually any diagnostic requirement in maxillofacial dentistry.^{11,12} EO BW using the SCARA technology was first introduced by Planmeca ProMax.¹²

To the best of our knowledge, no previous studies assessed the diagnostic accuracy of EO BW radiography produced by Sirona ORTHOPHOS XG 5 panoramic machine (Sirona Siemens, Bensheim, Germany) in the detection of enamel proximal caries. Therefore, the aim of the present study was to compare the diagnostic accuracy of EO BW produced by Sirona ORTHOPHOS XG 5 with that of PSP and CMOS IO BW in the detection of enamel proximal caries.

Methods and materials

The study was expedited from review by the Faculty's research ethics committee. 80 human sound premolar and molar teeth that were extracted for periodontal or orthodontic reasons (40 maxillary and 40 mandibular) were obtained from the archives of the surgery department. Teeth were cleaned of debris and calculus by scaling, disinfected in 2% sodium hypochlorite solution for 20 min and stored in distilled water.

Sample preparation and grouping

The teeth were divided into 4 groups (3 experimental and 1 control groups) of 40 surfaces each (Table 1). Control group surfaces were left sound and were distributed randomly with the experimental groups. Circular pieces of rubber were prepared with a rubber dam punch and applied to the proximal surfaces of the test teeth just below the contact area in order to produce standard circular windows for acid application. Then the teeth were coated with a fast-drying acid-resistant nail polish except for the rubber circle. After the varnish dried, the rubber circles were removed from the proximal surfaces leaving circular windows of 2 mm diameter of exposed enamel (Figure 1). The specimens of the experimental groups were kept individually immersed in

Figure 1 Steps of tooth preparation. (a) Application of circular piece of rubber to the proximal surface of the test tooth just below the contact area. (b) The tooth was coated with a fast-drying acid-resistant nail polish except for the rubber circle. (c) After the varnish dried, the rubber circle was removed from the proximal surface leaving a circular window of 2-mm diameter of exposed enamel.

Figure 2 Acquisition of intraoral bitewing.

8 ml of 5% formic acid and incubated at 37° C for 10 h, 20 h and 30 h.

To obtain one proximal surface of the same tooth exposed to 10-h and the other surface exposed to 20-h demineralization, we prepared a circle of exposed enamel on the proximal surface that was intended to have 20-h demineralization through application of a rubber circle and coating the tooth with nail polish; after it dried, the rubber was removed from the surface leaving exposed enamel. The tooth was then placed in the demineralizing solution for 10 h. Later, the nail polish was removed and rubber circles were placed on both proximal surfaces then the nail polish was reapplied. The rubber circles were removed after the nail polish dried, and the tooth was placed again in 5% formic acid for another 10 h with both proximal surfaces having exposed circles of enamel.

After completion of demineralization time, the teeth were cleaned by acetone to remove the varnish. Only the primary investigator had the key of the time of demineralization on the surfaces of teeth. Five skull and mandible assemblies were borrowed from the department of anatomy. 16 teeth were adapted to each skull and mandible, so that each quadrant received 2 premolars and 2 molars. "The alveolar sockets were widened to accommodate the roots. The teeth were then maintained in their position by softened pink wax".

Image acquisition

- (1) IO BW radiographs were taken using the Digora®-Optime system (Orion Corporation Soredex, Helsinki, Finland) and reusable PSP plate size two. The specimens were exposed using Trophy® X-ray unit (Trophy Radiologie, Vincennes, France) operating at 70 kVp, 8 mA, 2.5-mm aluminium filtration, rated value of focal spot 0.7 mm, and the exposure time selected was 0.22 s. The paralleling technique was applied using bitewing XCP film/plate holder (Dentsply-Rinn Corporation, Elgin, IL) to stabilize the intraoral receptor in position (Figure 2). One

premolar and another molar bitewing radiographs were taken for each quadrant.

- (2) Then the skulls and mandibles were further imaged by cabled CMOS sensor size two (Digora®, Soredex Toto, Orion Corporation). The specimens were exposed using the same X-ray machine, exposure factors and the same film holder.
- (3) EO BW images were taken with the Bitewing Program of Sirona ORTHOPHOS XG 5 digital panoramic machine (Sirona, Siemens). The exposure parameters were adjusted at 7 mA, 60 kVp and 8.8 s (Figure 3).

Image evaluation

All digital images were evaluated by two calibrated observers using the same computer monitor (15.6-inch high definition light-emitting diode screen), and the lights were subdued during observations. Observers were two oral radiologists with 15 and 12 years' experience. They independently rated the proximal surfaces of each tooth using a four-graded scale:¹³

- R0: no radiolucency
- R1: radiolucency in the outer half of enamel
- R2: radiolucency in the inner half of enamel up to the dentinoenamel junction (DEJ)
- R3: radiolucency beyond the DEJ and in the outer half of dentin.

Observers were instructed to assess only proximal surfaces coronal to the cemento-enamel junction. The images of each system were presented in a separate viewing session with intervals of at least 1 week to minimize viewer fatigue and to decrease the chance of recalling previous decisions on similar images and comparing images of other systems. A total six separate viewing sessions were performed (two sessions for each system). The observers were given the option to perform

Figure 3 Skull and mandible positioning during exposure of extraoral bitewing.

Figure 4 Examples of intraoral and extraoral bitewing radiographs. (a) Intraoral bitewing with photostimulable phosphor plate showing the lower right first molar with R1 (radiolucency in outer half of enamel) in the mesial surface and R2 (radiolucency in the inner half of enamel up to the dentinoenamel junction) in the distal surface. (b) Intraoral bitewing with complementary metal oxide semiconductor sensor showing the lower right first molar with R1 in the mesial surface and R2 in the distal surface. (c) Extraoral bitewing showing the lower right first molar with R0 (no radiolucency) in the mesial surface and R2 in the distal surface.

any needed image adjustments to improve radiographic interpretation (Figure 4). A total of 45 digital radiographs (20 radiographs with PSP, 20 with CMOS and 5 with EO BW) with a total of 160 proximal surfaces and 60 contacts were rated by each observer for each system twice.

Microscopic examination

Histological validation served as the gold standard. After the radiographic assessments were completed, each tooth was sectioned mesiodistally parallel to the long axis of the crown by a diamond disc on Strong 90 micromotor (Saeshin Precision Co., Ltd., Daegu, Korea). Both sides of each section were examined under a stereomicroscope (Olympus DP 10, SZ-PT; Olympus Corporation, Tokyo, Japan) with 10× magnification at the oral pathology department. Two observers, with

3 years' experience in histological examination and blinded to the radiographic appearance of the surfaces, evaluated the sections by consensus (Figure 5). The caries level was scored according to the criteria given by Russell and Pitts:¹⁴

H0: no caries apparent

H1: carious lesions in the outer half of enamel only

H2: various lesions in the inner half of enamel up to the DEJ

H3: carious lesions penetrating the DEJ and in the outer half of dentin.

Data analysis

All the data were tabulated, compared and statistically analyzed using IBM SPSS v. 20 (IBM Corp., New

Figure 5 Stereomicroscope image of the lower right first molar showing H1 (cariou lesions in outer half of enamel only) in the mesial surface and H2 (cariou lesions in inner half of enamel up to the dentinoenamel junction) in the distal surface.

York, NY; formerly SPSS Inc., Chicago, IL) for Windows. Spearman's rank correlation test was used to evaluate the correlation between duration of demineralization and histological results. Weighted kappa coefficients were calculated to assess the intraobserver and interobserver agreement. Kappa statistics was interpreted as: <0.10, no agreement; 0.10–0.40, poor agreement; 0.41–0.60, moderate agreement; 0.61–0.80, strong agreement; and 0.81–1.00, excellent agreement.

Friedman test was used to find whether there was a significant difference between caries grading by the three imaging modalities and the histological gold standard followed by Wilcoxon signed-ranked test to show which radiographic technique differed significantly from the histological gold standard. The receiver operating characteristic analysis (ROC) was used to assess the diagnostic accuracy of the three imaging modalities by comparing the caries score by PSP, CMOS and EO BW with the histological gold standard. The Az values for each image type, observer and reading were compared using z-tests, with a significance level of $p \leq 0.05$. Sensitivity, specificity, positive-predictive value and negative-predictive value for each observer and reading were calculated.

Results

Spearman's test showed a strong positive correlation between duration of demineralization and histological grading of carious teeth surfaces ($R = 0.87$) (Figure 6). The intraobserver agreement for the three radiographic techniques was strong to excellent (Table 2). The interobserver agreement of the three radiographic techniques was strong (Table 3). Friedman test showed significant difference between caries scoring by PSP, CMOS, EO BW and histology (Table 4). Wilcoxon signed-ranked test showed a significant difference in caries scoring between PSP and histology as well as between EO BW and histology, whereas there was no difference in caries scoring between CMOS and

Figure 6 Scatter chart illustrating the correlation between the duration of demineralization and histological grading of carious teeth surfaces.

Table 2 Intraobserver kappa coefficients for each observer

Radiographic technique	Observer 1 (Reading 1–Reading 2)			Observer 2 (Reading 1–Reading 2)		
	Weighted kappa	SE	95% CI	Weighted kappa	SE	95% CI
PSP	0.862	0.031	0.924–0.812	0.735	0.034	0.803–0.667
CMOS	0.790	0.032	0.854–0.726	0.814	0.030	0.874–0.754
EO BW	0.780	0.034	0.848–0.712	0.810	0.030	0.870–0.750

CI, confidence interval; CMOS, complementary metal oxide semiconductor; EO BW, extraoral bitewing; PSP, photostimulable phosphor plate; SE, standard error.

histology (Table 5). Caries grading by IO BW and EO BW had nearly similar Az values (Table 6 and Figure 7). The differences between the three radiographic methods were not statistically significant ($p > 0.05$) (Table 7). Sensitivity, specificity, positive-predictive value and negative-predictive value of the two readings of the two observers are presented in (Table 8).

Discussion

Early diagnosis of incipient proximal caries prevents further loss of tooth structure, function, aesthetics and general health problems.¹⁵ EO BW provides enhanced patient experience and comfort for trismus, disabled, claustrophobic patients or patients with severe gag reflex. It also provides 50% dose reduction compared with the normal panoramic program.¹² Moreover, it provides enhanced clinical efficiency because the apices of the teeth and distal surfaces of third molars can also be captured. So if it is as accurate in diagnosis of incipient proximal caries, then its use must be recommended.

In the present study, for IO BW, two size two receptors were used for each quadrant to obtain a premolar and a molar BW radiographs. This allowed accurate adjustment of the horizontal angulation and prevented horizontal overlapped contacts.¹⁶ On the other hand, Kamburoglu *et al*⁹ captured the premolars and molars of each side using only one Kodak bitewing insight film size two.

Our study sample consisted of extracted human premolars and first and second molars as >90% of all radiographic caries lesions are found in those teeth.¹⁷ We did not use the canine as its proximal caries is usually detected by periapical radiography.^{18,19} Similarly, Kamburoglu *et al*⁹ and Peker *et al*²⁰ did not assess the canine. On the other hand, Abdinian *et al*²¹ and Haiter-Neto *et al*²² used the canines as non-test teeth

just to produce proximal contact with the first premolar, while Berkhout *et al*²³ used human premolars only.

Similar to Onem *et al*,²⁴ we used sound human premolars and molars teeth to precisely induce artificial proximal caries with different depth so that we can assess the ability of radiographic grading of caries and accuracy of incipient proximal caries detection. On the other hand, Castro *et al*²⁵ and Haiter-Neto *et al*²² used posterior teeth sample with normal natural caries with varying lesion depth.

Dry human skulls and mandibles were used, and the teeth were adapted with their roots into the empty sockets to simulate a real dental arch as much as possible. This is in accordance with Kamburoglu *et al*,⁹ who adapted the crowns of teeth sample to the alveolar sockets of a skull and mandible. While Berkhout *et al*²³ mounted the teeth in plaster blocks and each two blocks were placed over each other to simulate upper and lower arch to take a bitewing radiograph.

In accordance with Dias da Silva *et al*,²⁶ we used histological examination as a gold standard for proximal caries grading as it is considered an ideal reproducible validation method and considered scientifically acceptable for *in vitro* research.²⁷ Although Ferreira *et al*²⁸ used extracted human teeth, they preferred to use the Knoop cross-sectional micro-hardness profiling as a validation method for the experimentally induced enamel demineralization, as it provides information on the physical property of enamel hardness and depth of demineralization. On the other hand, Akarslan *et al*⁷ examined 20 patients who needed bitewing, periapical and panoramic radiographs. The true disease status of the teeth in their study was determined with the consensus of the three observers' simultaneous interpretation of all radiographic images.

In the present study, there was a strong positive correlation between duration of demineralization and histological grading of caries. Similarly Ferreira *et al*²⁸ found that the enamel caries depth increased with

Table 3 Interobserver kappa coefficient among observers for the first and second readings

Radiographic technique	Reading 1 (Observer 1–Observer 2)			Reading 2 (Observer 1–Observer 2)		
	Weighted kappa	SE	95% CI	Weighted kappa	SE	95% CI
PSP	0.690	0.038	0.766–0.614	0.758	0.038	0.834–0.682
CMOS	0.693	0.035	0.763–0.623	0.664	0.037	0.738–0.590
EO BW	0.730	0.038	0.806–0.654	0.680	0.037	0.754–0.606

CI, confidence interval; CMOS, complementary metal oxide semiconductor; EO BW, extraoral bitewing; PSP, photostimulable phosphor plate; SE, standard error.

Table 4 Friedman test comparing caries scores by the three imaging modalities and histological gold standard

Modality	Mean	IQR	SD	p-value
PSP	1.190	2	1.080	<0.001
CMOS	1.300	2	1.120	
EO BW	1.05	2	1.070	
Histology	1.300	1.750	0.980	

CMOS, complementary metal oxide semiconductor; EO BW, extraoral bitewing; IQR, interquartile range; PSP, photostimulable phosphor plate; SD, standard deviation.

increased duration of demineralization. However, it was not perfect correlation to illustrate; 20-h demineralization caused H1, H2 and H3 histological caries depth. This might be attributed to the difference in proximal enamel thickness.

Strong intraobserver and interobserver agreement were found for the three radiographic techniques. Similarly, Senel *et al*¹⁵ reported excellent intraobserver agreement and strong interobserver agreement among experienced observers for CCD and PSP in the detection of proximal caries. In addition, Holt *et al*²⁹ and Peers *et al*³⁰ reported excellent interobserver agreement and strong intraobserver agreement, using IO BW films in the detection of proximal caries. On the other hand, Kamburoglu *et al*⁹ found that IO BW had higher interobserver and intraobserver agreement than EO BW. The strong interobserver and intraobserver agreement in the present study reflects the observer experience and calibration as well as good quality of the IO and EO BW images.

Considering the calculated Az values for all methods, there was no significant difference in the diagnostic accuracy of IO BW and EO BW images in the detection of incipient proximal caries. However, the comparable diagnostic accuracy of the three techniques is a function of their image resolution without taking into consideration their ability to separate contacts. Similarly, Abdinian *et al*²¹ found that the diagnostic accuracy of

Table 5 Difference between caries scoring using each radiographic technique and the histological gold standard

Radiographic technique	Mean	SD	Histology		p-value
			Mean	SD	
PSP	1.190	1.080	1.300	0.980	0.020 ^a
CMOS	1.300	1.120			0.868
EO BW	1.050	1.070			<0.001 ^a

CMOS, complementary metal oxide semiconductor; EO BW, extraoral bitewing; PSP, photostimulable phosphor plate; SD, standard deviation.

^a*p* ≤ 0.05 significant.

EO BW and IO BW with PSP were almost similar. Moreover, Senel *et al*¹⁵ reported no difference in the diagnostic accuracy of CCD and PSP images in the detection of proximal caries. On the other hand, Kamburoglu *et al*⁹ declared that IO BW was superior to EO BW radiography in diagnosing proximal caries of premolar and molar teeth. This difference might be due to the presence of superimpositions in EO BW radiography.

Sensitivity of a radiograph refers to its ability to correctly identify an existing carious lesion. High sensitivity allows early detection of incipient caries, thus allows early treatment and preventing of any further tooth loss. In our study, IO BW using CMOS had the highest sensitivity in the detection of incipient proximal caries in comparison with PSP and EO BW. Moreover, in the present study, radiographic caries grading by CMOS was the only technique that did not show a significant difference from histopathological grading. The high sensitivity of CMOS may be due to its high resolution 26.3 lp mm⁻¹³¹ in comparison with 17 lp mm resolution of PSP.³² The CMOS sensor is a silicon-based semiconductor and has an array of X-ray sensitive pixels. The smaller the pixel size the higher the resolution. On the other hand the PSP is composed of polyester base coated with a crystalline halide emulsion. The thickness of the phosphor layer and the diameter of laser beam used to scan the PSP

Table 6 Az values for each reading of each observer

Radiographic technique	Observer 1		Observer 2	
	First reading	Second reading	First reading	Second reading
PSP				
Az	0.896	0.865	0.913	0.903
SE	0.021	0.025	0.021	0.024
95% CI	0.838–0.939	0.802–0.914	0.858–0.951	0.847–0.944
p-value	<0.0001	<0.0001	<0.0001	<0.0001
CMOS				
Az	0.888	0.912	0.871	0.876
SE	0.024	0.022	0.033	0.031
95% CI	0.829–0.933	0.857–0.951	0.809–0.919	0.815–0.923
p-value	<0.0001	<0.0001	<0.0001	<0.0001
EO BW				
Az	0.866	0.859	0.906	0.920
SE	0.022	0.024	0.024	0.0120
95% CI	0.803–0.914	0.795–0.909	0.850–0.946	0.866–0.957
p-value	<0.0001	<0.0001	<0.0001	<0.0001

Az, area under the curve; CI, confidence interval; CMOS, complementary metal oxide semiconductor; EO BW, extraoral bitewing; PSP, photostimulable phosphor plate; SE, standard error.

Figure 7 Receiver operating characteristic curves for each observer and each reading. CMOS, complementary metal oxide semiconductor; EO BW, extraoral bitewing; PSP, photostimulable phosphor plate.

plate inversely affect the resolution. Similarly, Anas et al,³³ Mesgarani et al³⁴ and Kamburoglu et al³⁵ found that CCD had higher sensitivity than PSP. On the contrary, Wenzel et al³⁶ revealed that PSP (Digora-Optime; Soredex) and a solid-state CMOS sensor (Digora Toto; Soredex) had similar sensitivity in the detection of proximal surface cavitation. In addition, Abesi et al³⁷ revealed that both film and PSP had higher sensitivity than CCD in the detection of early and deep enamel caries. Moreover, Abdinian et al²¹ found that the sensitivity of IO BW using PSP plate was superior to that of EO BW radiography.

Specificity of a radiograph refers to its ability to correctly detect when the tooth is sound and no carious lesion is present. High specificity in detection of proximal caries means a decrease in false positive results which help prevent unnecessary cavity preparation and tooth loss. We found that EO BW

radiography had the highest specificity followed by PSP then CMOS. This is in accordance with Abdinian et al,²¹ who reported that EO BW had higher specificity than IO BW with PSP.

One of the limitations of this study is that it was performed *in vitro*. This eliminated tight and overlapping contacts, patient positioning errors and allowed absolute reproducibility. However, perfect tooth positioning without rotations or overlaps might falsely increase the diagnostic accuracy of the tested methods. In addition, no soft tissue equivalent was used, thus decreasing the image noise due to scatter radiation and increasing caries detection by the three techniques. Further studies should test the ability of EO BW in separating contacts. Other studies should be performed *in vivo* to further assess and compare incipient caries detection by IO and EO BW.

Table 7 Pairwise comparison of areas under the receiver operating characteristic curve using *z* test

Radiographic technique	Observer 1		Observer 2	
	First reading	Second reading	First reading	Second reading
PSP-CMOS				
z-statistics	0.283	1.855	1.536	0.986
p-value	0.777	0.064	0.125	0.324
PSP-EO BW				
z-statistic	1.219	0.213	0.231	0.685
p-value	0.223	0.832	0.818	0.493
CMOS-EO BW				
z-statistic	0.748	1.912	0.962	1.306
p-value	0.455	0.056	0.336	0.192

CMOS, complementary metal oxide semiconductor; EO BW, extraoral bitewing; PSP, photostimulable phosphor plate.

Table 8 Sensitivity, specificity, positive-predictive value (PPV) and negative-predictive value (NPV) for the each observer and each reading

Radiographic technique	Observer 1		Observer 2	
	First reading (%)	Second reading (%)	First reading (%)	Second reading (%)
PSP				
Sensitivity	82.50	80.83	90.00	93.33
Specificity	92.50	82.50	85.00	78.38
PPV	97.06	93.27	94.74	93.33
NPV	63.79	58.93	73.91	78.38
CMOS				
Sensitivity	84.17	91.67	92.50	94.17
Specificity	87.50	77.50	72.50	67.50
PPV	95.28	92.44	90.98	89.68
NPV	64.81	75.61	76.32	79.41
EO BW				
Sensitivity	75.83	75.83	92.50	93.33
Specificity	95.00	92.50	77.50	77.50
PPV	97.85	96.81	92.50	92.56
NPV	56.72	56.06	77.50	79.49

CMOS, complementary metal oxide semiconductor; EO BW, extraoral bitewing; PSP, photostimulable phosphor plate.

Conclusions

Within the limits of the *ex vivo* design, the difference in diagnostic accuracy between the three radiographic techniques was not significant. The ability of EO BW

to detect proximal enamel caries was assessed regardless its skills to separate contacts so it could be used in the detection of incipient proximal caries with results comparable with IO BW with PSP and CMOS sensor.

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