Original Article

Comparison of Diagnostic Ability of Conventional Film and Storage Phosphor Plate in Detecting Proximal Caries with Direct Measurements by Stereomicroscope: A Diagnostic Test Evaluation

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Abstract

Background: Radiography plays an important role in detection of interproximal caries. The aim of study is to compare diagnostic ability of conventional film and photostimulable phosphor (PSP) with direct measurement using stereomicroscope in detecting proximal caries. **Methodology:** In this descriptive study – diagnostic test evaluation, 200 proximal surfaces of 100 extracted human posterior teeth were radiographed with dental X-ray unit. Evaluation of conventional and digital radiographs was performed twice by three observers. Carious lesions were classified based on a four-point scale (R0–R3) suggested by Abesi *et al*. Weighted kappa coefficients were calculated to assess intra- and interobserver agreement for each image set. Indices of diagnostic ability calculation were based on the first readings of the three observers. The scores were compared with the histological gold standard using receiver operating characteristic (ROC) analysis to evaluate diagnostic ability. **Results:** Intraobserver kappa coefficients calculated for each observer for each method of detecting caries ranged from 0.914 to 0.956. Interobserver kappa coefficients for each image set ranged from 0.8788 to 0.9583. The sensitivity and specificity of film for the first observer were 77.5% and 78.3% and for PSP were 77.5% and 80%, respectively. ROC analysis revealed that there were no statistically significant results ($P > 0.05$) between Az values for the two detection methods. **Conclusion:** PSP plate should be preferred over conventional films in detecting cavitated proximal caries. Further studies with more noncavitated proximal surfaces are required to conclusively establish the diagnostic ability of PSP over conventional film.

Keywords: *Conventional film, incipient caries, proximal caries, stereomicroscope, storage phosphor plates*

Introduction

Dental caries continues to be a major health concern for worldwide population. The fundamental caries diagnosis depends on visual-tactile-radiographic procedures.[1] Diagnosis of noncavitated caries is of high significance as the disease state can be halted at an early stage with minimal intervention.[2,3] In clinical setting, intraoral radiography is mainly used for the diagnosis of proximal carious lesions.[2-4] Environmental concern and concerns regarding artifacts during chemical processing necessitated development of digital radiographic systems. Digital radiographic systems have the additional advantage of reduced radiation dose and easy archiving and retrieval. Conventional dental film is the most widely used image receptor for intraoral radiography. The digital sensors used for image acquisition are complementary metal–oxide–semiconductor, charge-coupled device (CCD), and photostimulable phosphor (PSP) (photostimulable storage phosphor plate).[5-7] Storage phosphor plates are small, tough, and less expensive in addition to the advantage of being similar in size to conventional film, enabling easy and similar positioning.[8-10]

Conventional film systems even though routinely used have the disadvantage of relatively high radiation dose requirement.[1,5] Moreover, it involves time consuming, chemical processing, and difficulties in storage and retrieval of old records. Digital radiography systems based on storage phosphor plates has the advantage of being more sensitive to radiation than conventional film and thereby requiring less dose for similar image

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production. The advantage of storage phosphor plates over conventional films in accurately detecting incipient caries is debatable.[1,5,9]

Stereomicroscope in research environment offers the three-dimensional view of the carious process which makes it an ideal instrument for *in vitro* comparison of the extent of carious process with other methods.[11,12]

This study compares the diagnostic accuracy of storage phosphor plates and conventional films with direct measurement by stereomicroscope as gold standard in detecting proximal caries.

Methodology

The study material comprised 200 proximal surfaces from 100 extracted teeth. Sound and carious premolar and molar teeth were collected which were extracted for treatment purposes such as periodontal problems and orthodontic treatment. The teeth were visually inspected for the presence or absence of caries on proximal surfaces. Teeth were randomly divided into 25 groups for the purpose of mounting with four teeth in each group. Teeth in each group were embedded in plaster of Paris from apex to cementoenamel junction, with their approximal surfaces in contact [Figure 1]. These teeth were numbered serially from no. 1 to 100. The teeth were radiographed under standardized condition with GNATUS dental radiographic unit (RAIOS X TIMEX 70C), 70 kVp, and 7 mA. The image receptors used were (1) E-speed film (size 2 Kodak) at 0.8 s and (2) VistaScan Durr Dental storage phosphor plate (size 2) at 0.4 s. The films were manually processed using freshly prepared developer and fixer solutions in well-equipped, light proof darkroom and were interpreted by mounting on a viewer (single tube). Digital images were scanned immediately and viewed on a 15-inch monitor (ViewSonic) with a resolution of 1366 × 768 in a well-illuminated room. Radiographs were interpreted by three observers, and carious lesion was classified based on a four-point scale (R_0–R_3).The teeth were subsequently sectioned using a 400-μ diamond disc mounted in a low-speed saw (MARATHON-4) and were examined under a stereomicroscope (OLYMPUS) with ×20 magnification, and caries lesions were classified based on a four-point scale R0, sound; R1, radiolucency restricted to the enamel; R2, radiolucency reaching the dentinoenamel junction and the outer half of the dentin; and R3, radiolucency into the inner half of the dentin by an oral pathologist.

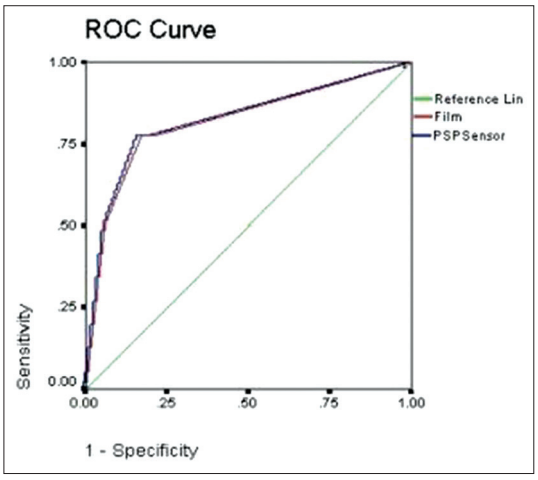

Figure 1: Area under the curve value for the first observers, film, and photostimulable phosphor against gold standard

Ethical issues

Informed consent was taken from the participants from whom the tooth was extracted. Institutional ethical clearance was obtained.

Statistical analysis

Weighted kappa coefficients were calculated to assess interobserver, intraobserver, and test–retest agreements. Kappa values were assessed according to the following criteria: <0.10 – no agreement, 0.10–0.40 – poor agreement, 0.41–0.60 – significant agreement, 0.61–0.80 – strong agreement, and 0.81–1.00 – excellent agreement. When interobserver, intraobserver, and test–retest coefficients were assessed, observers were blinded. Measures of diagnostic accuracy sensitivity, specificity, positive predictive value, negative predictive value, likelihood ratio for a positive test and a negative test, and accuracy were calculated based on the formulae. Receiver operating characteristic (ROC curve) analysis was done, and sensitivity and specificity were analyzed at different cut points. Area under the curve (Az) was calculated using SPSS 10 statistical software. The lower bound for the ROC curve area is 0.5. The closer the ROC curve area is to 1.0, the better the diagnostic test. Az vales and measures of diagnostic accuracy of the two radiographic modalities were compared using Chi-square test with a significance level of 0.05, and $P < 0.05$ was considered statistically significant.

Results

This study was conducted in the department of oral medicine and radiology after obtaining institutional ethical clearance. This *in vitro* study was done on 200 surfaces of 100 extracted teeth to detect the diagnostic ability of conventional film and storage phosphor plate with direct measurements by stereomicroscope as gold standard in detecting proximal caries. The carious lesions were scored based on a four-point scale (R_0–R_3) in both radiographic and histologic examinations.

Two hundred dental surfaces were evaluated with conventional film and PSP, and the results were tabulated along with that obtained from stereomicroscope readings of the same teeth [Table 1]. Comparison of results of conventional film and PSP plate with gold standard stereomicroscopic observations of 200 proximal surfaces revealed that with conventional film, 156 surfaces were

comparable, and with PSP plates, 158 surfaces were comparable.

Weighted kappa coefficients were calculated to assess intra- and interobserver agreement for both conventional film and PSP. Intraobserver kappa coefficients calculated for each observer for the two caries detection methods ranged from 0.914 to 0.956. Considering the very high intraobserver coefficients suggestive of strong intraobserver agreement, interobserver kappa coefficients were based on the first readings of three observers. Interobserver kappa coefficients for each image set ranged from 0.8788 to 0.9583. A strong interobserver agreement was also found for the two detection methods.

Indices of diagnostic accuracy – sensitivity, specificity, positive predictive value, negative predictive value, accuracy, positive likelihood ratio, and negative likelihood ratio – were calculated [Tables 2 and 3]. Considering the very high intraobserver kappa coefficients, indices of diagnostic ability calculation were based on the first readings of the three observers. Sensitivities, specificities, positive predictive value, negative predictive value, and accuracy of two radiographic methods were compared using Chi-square test, with a significance level of 0.05. The *P* value and Chi-square value for the sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of conventional film and PSP were 1 and 0.00, 0.71 and 0.14, 0.74 and 0.11, 1.00 and 0.00, and 0.81 and 0.06, respectively. The results showed no statistical significance between the diagnostic ability of the two radiographic modalities ($P > 0.005$).

To evaluate diagnostic ability, the scores of conventional film and PSP were compared with histological gold standard using ROC curve. Considering the very high intra- and interobserver coefficients suggestive of strong intra- and interobserver agreement, ROC was plotted for the first reading of the first observer. The ROC was plotted with false-positive rate (1 – specificity) on the X-axis and its sensitivity on the Y-axis using the SPSS-10 software [Figure 1].

The areas under the ROC curves (Az) for each image type, observer, and reading were calculated [Table 4]. Considering the very high intra- and interobserver kappa coefficients, Az value calculations were based on the first readings of the first observer. The highest Az value for the first observer was obtained with PSP. Az values of the two radiographic modalities were compared by significance level of 0.05. However, there were no statistically significant results ($P > 0.05$) between any of the Az values for the two detection methods. The *P* value obtained for the first observer's area under the curve independently was < 0.001, which was statistically significant.

Table 1: Results in conventional film, storage phosphor plate, and stereomicroscope

Results	Number of surfaces (%)		
	Conventional film	PSP	Stereomicroscope
R_0	130 (65)	128 (64)	120 (60)
R_1	12 (17)	13 (18)	17 (21)
R_2	19 (27)	20 (27)	23 (28)
R_3	39 (55)	39 (54)	40 (50)

PSP: Storage phosphor plate

Discussion

Dental caries is one of the most prevalent chronic diseases of people worldwide. Carious lesions are the outcome of events that progress over time. Hence, early and accurate

Table 2: Measures of accuracy for conventional film

	Observer I	Observer II	Observer III
Sensitivity	77.5 (66.5-85.8)	78.8 (67.9-86.8)	73.8 (62.5-82.7)
Specificity	78.3 (69.7-85.1)	77.5 (68.8-84.4)	78.3 (69.7-85.1)
Positive predictive value	70.5 (59.6-79.5)	70.0 (69.3-79.0)	69.4 (58.3-78.7)
Negative predictive value	83.9 (75.5-89.9)	84.5 (76.1-90.5)	81.7 (73.2-88.1)
Accuracy (%)	78.0	78.0	76.5
Positive likelihood ratio	3.57	3.50	3.40
Negative likelihood ratio	0.28	0.27	0.33

Table 3: Measures of accuracy for storage phosphor plate

	Observer I	Observer II	Observer III
Sensitivity	77.5 (66.5-85.8)	77.5 (66.5-85.8)	76.3 (65.2-84.8)
Specificity	80.0 (71.5-86.5)	77.5 (68.8-84.4)	80 (71.5-86.5)
Positive predictive value	72.1 (61.2-81.0)	69.7 (58.9-78.7)	71.8 (60.8-80.7)
Negative predictive value	84.2 (75.9-90.1)	83.8 (75.3-89.9)	83.5 (75.1-89.5)
Accuracy (%)	79.0	77.5	78.5
Positive likelihood ratio	3.87	3.44	3.81
Negative likelihood ratio	0.28	0.29	0.29

Table 4: Area under the curve values, standard errors, and significance levels for the first observer obtained from the graph

	Observer I	
	AZ (SE)	*P*
Conventional film	0.818 (0.033)	<0.001
Storage phosphor plate	0.821 (0.033)	<0.001

AZ: Area under the curve, SE: Standard error

diagnosis of caries is essential.[3] Diagnosis of caries is mostly based on direct visual examination and intraoral radiography.[3,4,6] Intraoral radiography includes both conventional film and digital imaging systems. 25%–42% of the carious lesions remain undetected by clinical examination performed without the aid of a radiographic diagnosis.[11]

In this *in vitro* study, the diagnostic accuracy of conventional film and PSP in detecting proximal caries was compared with direct measurements using stereomicroscope as gold standard. The radiographic and histologic examinations were evaluated based on a four-point scale (R_0–R_3). Stereomicroscopy was considered as gold standard in this study.

The present study found that the diagnostic accuracy of conventional film and PSP independently was good when compared to gold standard stereomicroscope. However, there were no statistical differences in the diagnostic accuracy of both conventional film and PSP in detecting proximal caries compared to gold standard stereomicroscope.

In this study, histological examinations by stereomicroscope revealed 60% noncarious and 40% carious surfaces. Both radiographic modalities showed a higher percentage of caries extending into the inner surface of the dentin than caries confined to the enamel and the outer half of the dentin. Senel *et al*. 2010 in their comparative study using stereomicroscope as gold standard found that in conventional film, 89.2% of the surfaces were noncarious, 10.6% had enamel caries, 17.8% had dentine caries, and 40.2% had deep dentine caries, and in PSP, 91.3% of the surfaces were noncarious, 12.2% had enamel caries, 13.3% had dentine caries, and 47.9% had caries into the inner dentin. All the studied modalities were performed poorly in detecting incipient lesions. However, none of the modalities tested showed high sensitivity and specificity and significantly outperformed the others.[5] The authors suggested that minimum 40% demineralization of hard tissue is required before lesions are identified on radiographs and also concluded that deeper caries lesions were easier to detect by radiographic modalities rather than superficial ones. The results from our study also revealed that carious lesions extending into the inner half of the dentin can be easily detected using both conventional film and PSP than the superficial lesions.

Radiographic images in the current study were evaluated by three observers. Intraobserver kappa coefficients calculated for each observer for the two caries detection methods ranged from 0.914 to 0.956. Interobserver kappa coefficients for each image set ranged from 0.8788 to 0.9583. Senel *et al*. 2010 in their study comparing the diagnostic accuracy of visual inspection, film, CCD sensor, PSP sensor, and cone-beam computed tomography (CBCT) in detection of proximal caries obtained intraobserver kappa coefficients that ranged from 0.739 to 0.928 and interobserver kappa coefficients that ranged from 0.631 to 0.811. The authors were of opinion that the differences in intra- and interagreement kappa values among the different studies may be related to observer experience, radiographic quality, viewing conditions, study design, and study material, all of which are important factors in determining observer agreement.[5]

The diagnostic accuracies such as sensitivity, specificity, positive predictive value, negative predictive value, accuracy, positive likelihood ratio, and negative likelihood ratio were calculated. The present study showed higher sensitivity values above 70% for all the observers and all the two radiographic modalities. Pontual *et al*. in their comparative study using 88 sound surfaces and 64 surfaces with enamel caries found that both conventional film and PSP had low sensitivity (14%–16%) in detecting enamel approximal caries when compared to the stereomicroscope. The authors were of opinion that low sensitivity suggests failure of radiographic modalities to detect enamel approximal caries efficiently and concluded that the deeper carious lesions were easier to detect than relatively superficial ones. They also suggested that there is no increase in detection of caries with increased depth of enamel caries.[13]

A comparative study by Abesi *et al*. 2012 to determine the diagnostic accuracy of CCD, PSP, and film radiography with gold standard stereomicroscope in detection of proximal caries revealed a low range of sensitivity of 15%–38% for enamel caries and 55% sensitivity for dentinal carious lesions. They suggested that in noncavitated lesions, the diagnostic accuracy improved more with the depth of the lesions.[14] The above studies concluded that there was low sensitivity in detecting superficial lesions, but they also found that the sensitivity increased as the depth of lesion advanced. In our study, we observed a high sensitivity which could be probably due to higher sample size of deeper carious lesions.

The area under the ROC curves (Az) for each image type, observer, and reading in the present study ranged between 0.777 and 0.818, which was statistically significant. Zhang *et al*. 2011 found no statistically significant differences in their study using two CBCT systems, E-speed film and PSP digital imaging systems. The Az values for film, PSP, and the two CBCT systems were 0.567, 0.531, 0.513, and 0.486,

respectively.[9] Krzyzostaniak *et al*. 2015 found that the diagnostic accuracy of conventional film, PSP, and CBCT was low in detection of early caries detection. Az values for CBCT, Digora, and film were 0.629, 0.665, and 0.667, respectively. The study revealed low Az values, which was suggestive of the inefficiency of the studied radiographic modalities to detect superficial lesions.[15] The studies conducted by both Krzyzostaniak *et al*. and Zhang *et al*. in the detection of early carious lesions revealed low Az values, which was suggestive of the inefficiency of the studied radiographic modalities to detect superficial lesions. In contrast, our study showed high Az values which was probably due to the higher number of samples with deeper carious lesions.

Another study by Huda *et al*. 1997 comparing PSP with conventional film suggested that PSP was better than film in detecting proximal caries. In this study, they used much less radiation exposure for PSP than conventional film and observed that the images were of good density and image contrast. Thus, it was concluded that the advantage of PSP of having a wider dynamic range is the main contributing factor to low radiation exposure than conventional film.[16] Our study was in accordance with Huda *et al*. where we used low radiation exposure for PSP compared to conventional film and the results were comparable.

Our study evaluated the efficiency of E-speed film and PSP in detection of proximal caries which was compared with gold standard stereomicroscope. Histological examination revealed 60% noncarious and 40% carious surfaces. The area under the ROC curves (Az) for each image type, observer, and reading in the present study ranged between 0.777 and 0.818, which was statistically significant. This was in accordance with Alkurt *et al*. where the authors investigated the efficiency of different speeds of three conventional intraoral films and a direct digital system for proximal caries detection. True caries depth was determined by histological examination. Histological examination of the teeth confirmed that 63.54% of the proximal surfaces were caries free, whereas 36.46% of the proximal surfaces determined carious lesions of various depths. The Az values for the four radiographic modalities ranged between 0.843 and 0.793, which was statistically significant.[17]

Dehghani *et al*. 2017 comparing PSP with CCD and conventional film suggested that digital radiography using PSP receptor with 70 kVp is recommended to detect initial enamel caries and PSP with 60 kVp is more appropriate for detection of noncavitated and cavitated dentin caries. In this study, they used much less radiation exposure for PSP than conventional film and observed that the images were of good density and image contrast. Thus, it was concluded that change in voltage (kVp) did not affect the diagnostic accuracy for detection of caries, and the type of receptor was a more important factor in this regard.[18]

Taghiloo *et al*. 2019 comparing conventional film and digital radiography reported that there is no significant difference in the diagnosis of interproximal caries by different methods, and the only advantage of digital radiography, compared with the conventional one, is storing radiographs without losing important information and the lower dose of radiation for the patient.[19]

All the above studies concluded that both conventional film and PSP were inefficient in detecting incipient lesions compared to deeper carious lesions. However, the results also suggested that there was a strong relationship between diagnostic accuracy of conventional film and PSP with lesion depth. It was reported that there is an increase in the detection of carious lesion with increase in lesion depth. In studies measuring the function of radiation exposure of each imaging system, it was observed that PSP had a wider dynamic range compared to conventional film which resulted in low radiation exposure with minimal compromise in image quality.

Conclusion

The results of the study demonstrated that the diagnostic accuracy of conventional film and PSP was independently good in the detection of proximal caries when compared to direct observations with stereomicroscope as gold standard. However, when the diagnostic accuracy of two radiographic modalities was compared, there were no significant difference and none outperformed the other in detection of proximal caries. An excellent intra- and interobserver agreement in the study suggests the agreement in the diagnostic accuracies of the radiographic modalities among the observers. The sensitivity and specificity of both conventional film and PSP in detecting proximal caries were high, indicating that the two systems were effective in detecting proximal caries. In the present study, majority of the samples were having deeper lesions extending to the inner half of the dentin (nearer to pulp chamber) which is a limitation of the study. According to the principle of as low as reasonably achievable, radiographic examinations must be fully justified before they are performed and selection criteria should be evidence based. Considering the radiation dose required for imaging using PSP plate and conventional film in this study, it is recommended that digital radiographic system (PSP plate) should be preferred over conventional films in detecting cavitated proximal carious lesions. Further studies that include samples with more noncavitated proximal surfaces, especially initial superficial lesions, are required to conclusively establish the diagnostic ability of digital imaging system using PSP over conventional film in the detection of incipient enamel lesions.

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Conflicts of interest

There are no conflicts of interest.

References

1. Castro VM, Katz JO, Hardman PK, Glaros AG, Spencer P. *In vitro* comparison of conventional film and direct digital imaging in the detection of approximal caries. Dentomaxillofac Radiol 2007;36:138-42.
2. Kühnisch J, Ifland S, Tranaeus S, Hickel R, Stösser L, Heinrich-Weltzien R. *In vivo* detection of non-cavitated caries lesions on occlusal surfaces by visual inspection and quantitative light-induced fluorescence. Acta Odontol Scand 2007;65:183-8.
3. Stookey KG, Cabezas GC. Emerging methods of caries diagnosis. J Dent Educ 2001;65:1001-6.
4. Das D, Misra J, Mitra M, Bhattacharya B, Bagchi A. Prevalence of dental caries and treatment needs in children in coastal areas of West Bengal. Contemp Clin Dent 2013;4:482-7.
5. Senel B, Kamburoglu K, Ucok O, Yuksel SP, Ozen T, Avsever H. Diagnostic accuracy of different imaging modalities in detection of proximal caries. Dentomaxillofacial Radiol 2010;39:501-11.
6. Cortes DF, Ekstrand KR, Elias-Boneta AR, Ellwood RP. An *in vitro* comparison of the ability of fibre-optic transillumination, visual inspection and radiographs to detect occlusal caries and evaluate lesion depth. Caries Res 2000;34:443-7.
7. Price N, Ergul A. Comparison of a film-based and a direct digital dental radiographic system using a proximal caries model. Dentomaxillofac Radiol 1997;26:45-52.
8. Paurazas SB, Geist JR, Pink FE, Hoen MM, Steiman HR. Comparison of diagnostic accuracy of digital imaging by using CCD and CMOS-APS sensors with E-speed film in the detection of Periapical bony lesions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;89:356-62.
9. Zhang Z, Qu X, Li G, Zhang Z, Ma X. The detection accuracies for proximal caries by cone-beam computerized tomography, film and phosphor plates. Oral Surg Oral Med Oral Radiol Endod 2011;111:103-8.
10. Torres MG, Santos A, Neves FS, Arriaga ML, Campos P, Rebollo IC. Assessment of enamel-dentin caries lesions detection using bitewing PSP digital images. J Appl Oral Sci 2011;19:462-8.
11. Oancea R, Vasile L, Marchese C, Sava-Rosianu R. Stereomicroscopic Study of Human Tooth Caries: Clinical Morphological Correlation. Proceeding of SPIE; 2012. p. 842740.
12. Hintze H, Wenzel A, Larsen MJ. Stereomicroscopy, film radiography, microradiography and naked-eye inspection of tooth sections as validation for occlusal caries diagnosis. Caries Res 1995;29:359-63.
13. Pontual AA, de Melo DP, de Almeida SM, Boscolo FN, Neto FH. Comparison of digital systems and conventional dental film for the detection of approximal enamel caries. Dentomaxillofac Radiol 2010;39:431-6.
14. Abesi F, Mirshekar A, Moudi E, Sayedmajidi M, Haghanifar S, Haghighat N, *et al*. Diagnostic accuracy of digital and conventional radiography in the detection of non cavitated approximal dental caries. Iran J Radiol 2012;9:17-21.
15. Krzyzostaniak J, Kulczyk T, Czarnecka B, Surdacka A. Comparative study of the diagnostic accuracy of cone beam computed tomography and intraoral radiographic modalities for the detection of non cavitated caries. Clin Oral Invest 2015;19:667-72.
16. Huda W, Rill LN, Benn DK, Pettigrew JC. Comparison of a photostimulable phosphor system with film for dental radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;83:725-31.
17. Alkurt M, Peker I, Bala O, Altunkaynak B. *In vitro* comparison of four different dental X-ray films and direct digital radiography for proximal caries detection. Oper Dent 2007;32:504-9.
18. Dehghani M, Barzegari B, Tabatabai H, Ghanea S. Diagnostic value of conventional and digital radiography for detection of cavitated and non-cavitated proximal caries. J Dent 2017;14:21-30.
19. Hamid T, Sina T, Mahdi R, Deniz S. Comparison of the accuracy of digital radiography with conventional radiography and visual examination in the detection of permanent teeth proximal caries. Pesqui Bras Odontopediatr Clín Integr 2019;19:1-10.