



The Effect of Delayed Scanning of Photostimulable Phosphor Plates on Inter-proximal Caries Detection

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Objectives: The aim of this study was to determine the effect of different scan delays and different kV on the diagnostic accuracy of inter-proximal caries detection in photostimulable phosphor plates (PSPs).

Materials and Methods: 45 non-cavitated extracted human posterior teeth were radiographed using DIGORA® PSPs (Soredex Corporation, Helsinki, Finland). The plates were exposed at 60 kVp and 70 kVp and were scanned immediately, 10 min, 30 min, 1h, 6 h, 24 h and 48 h after exposure. In between the exposure and the scan period, the plates were stored in light-tight boxes. The true presence of caries was determined by sectioning the teeth mesiodistally. The accuracy was expressed as the area under the curve (A_Z). The A_Zs were compared using SPSS version 17 software and repeated measurements Kappa was used to measure inter and intra observer agreement.

Results: There was no significant difference between caries detection A_Zs of the images that were scanned immediately and within 30 min after exposure at 60 kVp and 70 kVp ($P > 0.05$). The immediate

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scanned A_z at 60 kVp was significantly higher than the A_z s with 6 h, 24 h and 48 h scan delays ($P < 0.05$). The immediately scanned A_z at 70Kvp was significantly higher than the A_z s of 1 h, 6 h, 24 h and 48 h ($P < 0.05$).
Conclusions: PSP scanning should not be delayed higher than 30 min in order to have an accurate proximal caries detection. Longer delays may cause loss of quality of images.

Keywords: Tooth; dental caries; radiography; dental; digital.

1. INTRODUCTION

The innovation of digital radiography led to a revolution in radiology and increased using of this modality, which has replaced the conventional methods in various cases and has eliminated chemical processing, hazardous remains, lead sheets and reduced patient exposure [1,2]. One type of the digital radiography is storage phosphor plates (PSPs) [3].

Regarding the size and flexibility; the PSP and conventional systems are almost alike; the PSPs have high diagnostic value and broad dynamic range [4,5]. PSPs are considered as an appropriate alternative for conventional films.

Due to increasing use of PSP system; the need to discuss the means to decrease technical errors if this system should be considered in all aspects.

Many studies have reported that the quality of the PSP images are equal to or even better than conventional and charge-coupled device (CCD) systems [6,7] and result in better endodontic diagnosis and treatments [2]. One disadvantage of this system is the need to scan the plates in order to achieve a radiographic image [3]. It's has been recommended that it would be better to scan the plates right after the exposure to prevent data loss caused by background light and to eliminate diminution of PSPs surface electrons [1,3]. This can't always be done and the delay in scanning the plates will lead to decreased quality and loss of data in the images. For instance, this error happens more in full mouth set of radiographs which have been taken in a crowded radiology center [2,4]. Several studies have stated that a delay in scanning the plates will cause effects that lower the quality of PSP images [8-11]. Although, the data regarding the effect of scanning delay time on quality of PSP images are varied [12-14], some studies (e.g. Sogur study) reported notable reduction in quality of the images made for diagnosis of caries of occlusal surfaces with a 30 min delay, and some other (e.g. Melo study) reported a

reduction in quality during radiographic evaluation of endodontic files after 6 h delay [12-14]. Bramante reported reduction in quality of images evaluation of different parts of the tooth structure after a 120 min delay [10].

The effect of different scanning times on inter-proximal caries detection with PSP plates has been investigated in recent studies [8-12] but the different scanning delay time is not evaluated [13]. No studies regarding the evaluation of different scanning delay time with different kVps of DIGORA® PSP for inter-proximal caries detection have been done yet subjectively. Thus, the aim of this study is to assess the effect of different scanning delay with 60 kVp and 70 kVp exposure on inter-proximal caries detection.

2. MATERIALS AND METHODS

In this analytical cross-sectional study, 45 non-cavitated human permanent premolar and molar teeth with or without proximal caries were selected. Before mounting, the teeth were cleaned with prophylactic disk and water. To disinfect, the teeth were stored in 5% cholaramin T for one week. Then the selected teeth were mounted in a block made of silicone putty. Each block contained 3 premolar and molar teeth mounted in an anatomical order just like the normal anatomy in the vinyl polysiloxan putty reaching their CEJ [3].

One silicone block containing the teeth and one PSP (Soredex Corporation, Helsinki, Finland) were put and pressed into the vinyl polysiloxane putty while it was soft; to ensure repetition of imaging geometry (Fig. 1 [15]).

Intraoral X-ray tube (Planmeca, ProX, Finland) was placed at 25 cm distance of constructed block. This distance was similar in all stages of radiographic procedure; then a rubber dam was placed close to the silicone blocks and facing the X-ray tube for soft tissue simulation.

Digital images were acquired with DIGORA® Optim (Sordex Corporation, Helsinki, Finland) system using number 2 film size blue PSPs. Images were acquired using bitewing projection

geometry [3,8]. The standard exposure condition 60 kVp and 0.12 s was regulated for all teeth [3]. Although for each dental block a exposure was made with 70 kVp and with the same exposure time. So the exposure was done twice; once at 60 kVp and then at 70 kVp. The Plates were scanned with Digora Optim scanner immediately after exposure and 10 min, 30 min, 60 min, 6 h, 24 h and 48 h after they were exposed. Before this stage all plates were cleared of any background effect by means of strong laser source. In the interval between exposure and scanning, the plates were stored in a dark and light-tight box . Scanned images were saved in the personal computer (Acer Aspire V17 Nitro).

In this study 420 (15 blocks × 7 scan time × 2 kVp × 2 light storage conditions). Radiographs were taken some images that scanned immediately, with 60 kVp exposure were assigned as the standard group and the result of consideration of other images were compared with this standard group.

2 oral and maxillofacial radiologists and 1 specialist in operative dentistry scored a total of 420 images for the presence or absence of caries using a 5-grade scale: 1) caries definitely present, 2) caries probably present, 3) unsure whether caries is absent or present, 4) caries probably absent, 5) caries definitely absent [3]. The images were displayed to observers at full size 1:1 on a 17 inch Liquid-crystal-display (LCD, Acer Apire V17 Nitro) with a resolution 1920×1080 pixel and 256 gray levels in a room where the light was reduced.

Observation conditions were similar for all images and observer. The viewing distance was kept at about 50 cm for all observers. Images were presented randomly.

The observers were not given permission to perform any image enhancement and changes in contrast and density. No time limit was set for the viewing procedure. The evaluation was repeated after one week to assess the intra observer agreement [16].

For the validation of the true presence of inter-proximal caries (gold standard) the teeth were sectioned in the mesiodistal direction of long axis of teeth with a 200 µm thickness diamond disk (Tizkavan, Iran Company). The presence of caries was considered visually by the general dentist and the result was reported using the following scale: 0) absence of caries, 1) presence of caries. The comparison of accuracy of caries detection by observers with true

presence of inter-proximal caries (gold standard) on images was expressed as the area under the receiver operating characteristic curve (ROC curve). The area under ROC curve was named A_z [3,9,16]. Primarily we consider the opinion of observers (dependent variable) that was in 5 grade classifications and then calculated A_z values using ROC curves. After that repeated measurement test was used to compare the A_z values of different scan delay times (independent variable) and different kVps (independent variable). Where as the A_z values follow a normal distribution we apply repeated measurement for this part of statistical analysis. Data were analyzed using SPSS version 17. The level of significance was considered as $p=0/05$. The level of agreement in and between observers was measured using kappa. The results were explained using the five-point scale as offered by Landis and Koch [17].

3. RESULTS

The mesiodistal section of teeth using 0.2 mm thickness disc, revealed that of 90 interdental surfaces, ie; 44% were without any caries and 56% showed true and identical caries visually and caries were considered if white spot demineralization or brown discoloration was observed by clinical observation.

In A_z value evaluation area under ROC curve in 60 kVp and after 1h scan delay and 70 kVp and after 30 min scan delay was significantly diminished, it means that the ability of caries detection by observers was reduced (Table 1).

Repeated measurements revealed that the A_z value obtained from immediately scanned images in 60 kVps was higher than the images scanned with different delays. Pair-wise comparison revealed significant difference in A_z s of immediately scanned plates in 60 kVp and after 6 h (p -value = 0.042), 24 h (p -value = 0.031), 48 h (p -value = 0.024) delays and A_z s of immediately scanned in 70 kVp after 1 h (p -value = 0.043), 6 h (p -value = 0.036), 24 h (p -value = 0.032) and 48h (p -value = 0.19). But there was no significant difference in 10 min (p -value = 0.061), 30 min (p -value = 0.067), 1 h (p -value=0.057) delays in 60 kVp and immediate scan and 10 min (p -value = 0.074) and 30 min (p -value = 0.061) in 70 kVp. Pair-wise comparison of A_z s of 10 min, 30 min and 1 h delayed images were higher than scan delays in 60 kVp and A_z s of 10 min and 30 min in 70 kVp (p -value < 0.05).

Table 1. Mean area under the ROC curves (A_z values) \pm SD, at immediate scans and different delays in scanning

Scan delays	Immediate	10 min	30 min	1 h	6 h	24 h	48 h	
Observers	MD $A_z \pm SD$	MD $A_z \pm SD$	MD $A_z \pm SD$	MD $A_z \pm SD$	MD $A_z \pm SD$	MD $A_z \pm SD$	MD $A_z \pm SD$	
60 kVp	1	0.62 \pm 0.19	0.55 \pm 0.2	0.47 \pm 0.2	0.45 \pm 0.2	0.35 \pm 0.19	0.35 \pm 0.19	0
	2	0.55 \pm 0.2	0.52 \pm 0.2	0.5 \pm 0.2	0.47 \pm 0.2	0.37 \pm 0.19	0.32 \pm 0.19	0.3 \pm 0.18
	3	0.2 \pm 0.6	0.55 \pm 0.2	0.52 \pm 0.2	0.5 \pm 0.2	0.37 \pm 0.19	0.32 \pm 0.19	0.25 \pm 0.17
70 kVp	1	0.6 \pm 0.2	0.57 \pm 0.2	0.55 \pm 0.2	0.4 \pm 0.2	0.37 \pm 0.19	0.32 \pm 0.19	0.3 \pm 0.18
	2	0.62 \pm 0.19	0.6 \pm 0.2	0.57 \pm 0.2	0.45 \pm 0.2	0.4 \pm 0.2	0.35 \pm 0.19	0.22 \pm 0.17
	3	0.57 \pm 0.2	0.52 \pm 0.2	0.52 \pm 0.2	0.4 \pm 0.2	0.35 \pm 0.19	0.3 \pm 0.18	0

Fig. 2 shows that with increasing scan delays, the accuracy of caries detection decreases, therefore the areas under ROC curves (A_z s) decrease Fig. 2 [15].

Kappa analysis showed that inter-observer agreement ranged between slight and moderate whereas intra-observer agreement ranged between fair and substantial (range=0.23 -0.7). Both intra- and inter-observer agreement decreased with an increase in scan delays.

4. DISCUSSION

Various studies have reported the quality of images made by PSP systems equal or even better than of those made by Conventional and CCD systems [6,7].

The effects of scan delay on primary versions of white phosphor plates, DIGORA PSP system have been inspected in past studies; kVp, mA and exposure time used in those studies differ from the parameters used in Ehsan Tavakoli the present study [9,11-13]. Based on previous studies, exposure is a major factor in designation of image quality [7,11]. The parameters used in this study were set as 0.12 s for exposure time, mA based on the configuration provided by the manufacturer and 60 and 70 kVp for determination of the effect of kVp on image quality [18-20]. The results of this study cannot be compared directly with results of past studies because the PSP system and exposure conditions were different. Although in all studies the scanning delay time has a major effect on decreasing the image and caries detection quality.

If the delay of scanning the PSPs increases, the images will get brighter due to electron loss. PSP are also sensitive to background light. Data on these plates will be lost over the time with

absorption of background light which results in releasing of inactive electrons from phosphor particles of PSPs. The loss of surface electrons will change the image of enamel and dentin compared to the real case [21,22]. Reduction in caries detection ability and agreement between intraobserver and interobserver are also related to this matter. Sogur and colleagues surveyed this agreement and concluded that with increasing the delay of scanning the agreement decreases, which in turn is consistent with our study [3]. In this study, detection of caries and main structure of teeth in the images provided by the plates which were stored in daylight was not feasible even after a 10 min delay in both exposures (60 and 70 kVp). In Bramante's study, the synchronous effect of scan delay and the condition of PSPs was inspected and the plates were exposed and then divided into 2 groups. One group was put in an impervious opaque coverage and the other in a coverage which could transit light. Images from the second group were poor and couldn't be used in studying mandible structures. This finding is consistent with the results of our study [10]. Sogur and colleagues studied the effect of different scan delay times on PSPs stored in a dark place on caries detection ability. They concluded the caries detection ability on occlusal surfaces decreases significantly with delays more than 30 minutes. This is consistent with the results of our study [3]. In this study, based on statistical results, images provided by exposing with 60 kVp and 70 kVp didn't have enough certainty regarding the inspection of inter-proximal caries respectively after 60 and 30 min.

In Ang and colleagues study, it was determined that even after 6 h images are reliable. It should be noted that in their study, the detectable length of endodontics file was studied in different scan delays and of course the accuracy needed for caries detection is more than that [11].



Fig. 1. Sample teeth in contact mounted in a silicone block with PSP [15]

Some recent studies [16,21,23] evaluated the effect of different times of erasing data from PSPs on the quality of inter-proximal caries detection; Melo reported no effect on caries detection ability [16]. Result comparison between Melo's study and our study regarding this matter is not feasible due to fundamental and structural differences.

As it was stated before, the scan delay will result in loss of electrons and brightening of images. This loss was reported more in dark areas of the image, which have less contrast, by Akdeniz and colleagues [9] and Danfrer RH and colleagues [24,25]; which in turn results in brightening of image background and discrepancy between density of the background and other areas. This will lead to aberration in viewer's eye. This phenomenon is termed "Background contrast effect" [9,26]. When scanning is delayed, This effect will be raised more in higher kVps because brightness of background image will increase and the light from background will lead to sensitivity diminution of viewer's eye to caries; radiolucent component of the image [27-29]. This occurrence will justify that why the reliable delay time in scanning the exposed plates with 70 kVp is less than those exposed with 60 kVp. For more accurate inspection of caries a high contrast is needed. Contrast has a reverse relationship with kVp; so, with increasing of kVp the contrast will decrease and therefor the caries detection ability will be reduced [30,31].

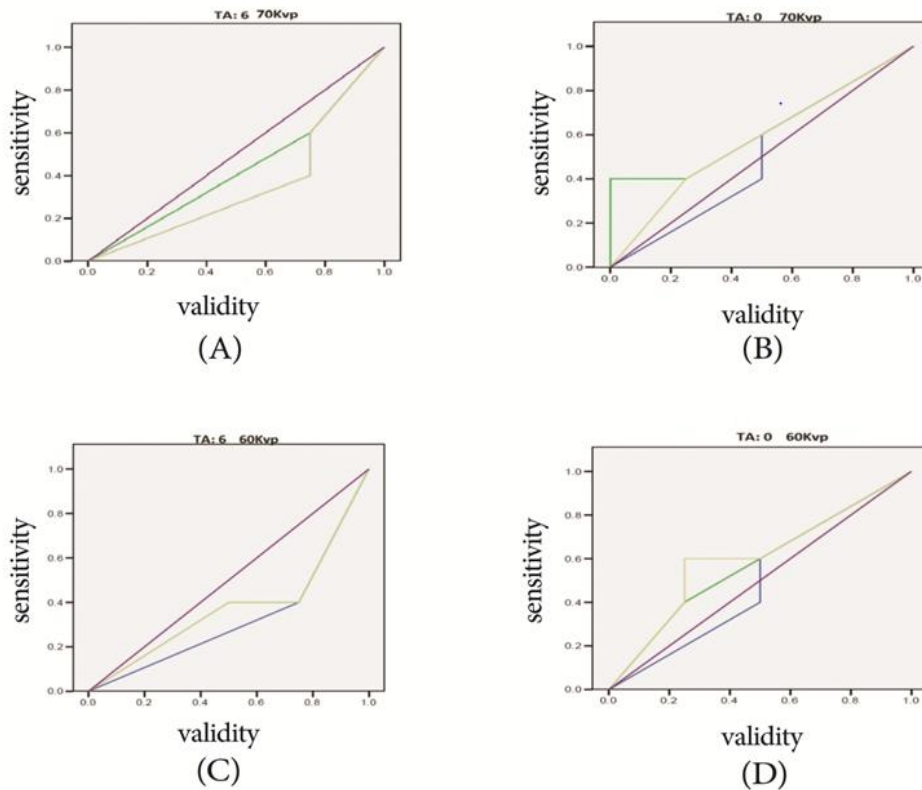


Fig. 2. ROC curves for inspection of inter-proximal caries detection accuracy; (A), (C) immediately scan (TA:0) (B), (C) 48h scan delay (TA: 6) [15]

5. CONCLUSION

According to the result of this study PSP scanning should not be delayed higher than 30 min in order to have accurate proximal caries detection. Longer delays may cause loss of quality of images.

It should be stated that this study was done subjectively and invitro; therefore for gaining more realistic results, invivo and objective studies are also recommended.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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