ORIGINAL ARTICLE

Assessment of intraoral image artifacts related to photostimulable phosphor plates in a dentomaxillofacial radiology department

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Abstract

Objective: The aim of the present study was to evaluate the presence, frequency, and causes of artifacts in intraoral images obtained using photostimulable phosphor (PSP) plates.

Materials and Methods: A total of 11,443 intraoral images, including 4291 periapical and 7152 bitewing images, acquired over a 6-month period as well as over a month 1-year after the initial imaging were evaluated by a single observer and image artifacts only related to the PSP system were recorded. Before the study, an experienced dentomaxillofacial radiologist and a research assistant assessed a set of image artifacts and agreed on the causes of these artifacts. All unidentified artifacts were reassessed by both researchers before the final decision. The data were analyzed using the statistical software SPSS 11.5.

Results: The total number of images with one or more artifacts was 2344 (20.4%). Of these, 2008 were of adult patients and 336 were of pediatric patients. While movement of the phosphor plate in the disposable pocket was the most common cause of the observed image artifacts in the children, non-uniform image brightness was the most frequently observed artifact in the case of the adults.

Conclusion: The percentage of images with artifacts in the 6th month was lower than that during the 1st month. More significantly, the lowest percentage was obtained 1-year after the initial imaging, owing to the increase in familiarity with the system. Understanding the reasons for the image artifacts and studying ways of preventing are of high clinical importance.

Key words: Image artifact, intraoral digital imaging, photostimulable phosphor

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Introduction

Digital receptors for intraoral radiography were developed in the late 1980s. All around the world, general dental practitioners are switching from conventional film radiography to digital imaging.[1] The main advantages of digital imaging over conventional radiography are that the former method is faster, allows for real-time imaging and communication, does not require darkroom procedures and chemicals, can avail of image improvement tools, and results in dose reduction.[2-9] Digital image receptors based on two distinct technologies are used most widely: (1) Solid-state technology (e.g., charge-coupled devices [CCD] or complementary metal oxide semiconductors [CMOS]) and (2) photostimulable phosphor (PSP) technology.[3,4] In CCD and CMOS systems, a cable usually connects the sensor to the computer, and the image is displayed almost immediately on the computer monitor after the exposure of the sensor.[4]

On the other hand, PSP systems employ phosphor plates that produce a latent image when exposed to radiation. The stored image is transferred to a computer for viewing

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using a laser scanner. The PSP plates are made of a plastic coated with a polymer base containing embedded phosphor particles. The indirect nature of the image acquisition process in the case of this system results in increased processing times. Further, it necessitates the use of additional equipment.[10] The scanning times range from a few seconds to several minutes, depending on the type of scanner used and the spatial and contrast resolutions of the image.[5] PSP plates are manufactured in a variety of sizes in a manner similar to dental films and are susceptible to bending and scratching during handling.[3-5,10,11] However, PSP plates are intended to be reusable and, therefore, must be handled with greater care than conventional films.[3] The main advantage of PSP systems is that they allow for easy sensor placement within the oral cavity with little discomfort. Therefore, these systems are preferred by dental patients.[10] Image artifacts have been reported in film-based radiography. Digital radiography produces new types of image artifacts, which remain an issue for clinicians.[12] A few examples of the commonly observed image artifacts are listed in Table 1. Although a number of studies have investigated the various features of PSP systems.[1,4-6,13-15] The effects of delayed scanning and visible light on PSP plates,[9,16-18] and the effects of damage of PSP plates on image quality,[10,19] few have assessed PSP image artifacts using representative figures in a clinical setting.[12] Therefore, the aim of the present study was to evaluate the presence, frequency, and causes of PSP artifacts in intraoral images.

Materials and Methods

A PSP digital intraoral imaging system (Digora® Optime, Soredex, Finland) has been used in our university's Department of Dentomaxillofacial Radiology since April 2013. While we had been using digital extraoral imaging since 2002, digital intraoral imaging was a new concept for our faculty. Initially, when using digital intraoral imaging, we adapted the interpacs picture archiving and communication system.

The radiographic and scanning conditions used were those recommended by the respective manufacturers. The PSP system was operated by two experienced radiology technicians and a rotation of students from the department. In the first 2 weeks of implementing PSP imaging, one plate (size 2) was lost, while two plates were damaged during the scanning procedure. Therefore, three new plates had to be used. For infection control, all the intraoral PSP plates were covered with disposable pockets. All the intraoral digital images were obtained using a Prostyle intra X-ray source (65 kVp, 8 mA; Planmeca, Helsinki, Finland). The exposure time was varied, depending on the patient (adult or child) and radiograph type (anterior/posterior or periapical/bitewing). This study was approved by Baskent University Institutional Review Board (Project number D-KA14/01) and supported by University Research Fund.

All the intraoral digital images acquired during a 6-month period (from April, 2013 to October, 2013), including the periapical and bitewing images, as well as those recorded over 1-month 1-year after the initial imaging (April 2014), were evaluated by a single observer (CKS), who is a research assistant in the dentomaxillofacial radiology department. Before the study, an experienced dentomaxillofacial radiologist (AG) and the research assistant assessed a set of image artifacts and agreed on the causes of the observed artifacts. When the cause could not be identified, the possible causes were investigated experimentally. At the end of the evaluation process, all the unidentified artifacts were reassessed by both researchers before the final decision. Only image artifacts related to the PSP system were included in this study.

The data were analyzed using the statistical package of the social sciences (SPSS) version 11.5 for windows (SPSS Inc., Chicago, IL, USA).

Results

A total of 11,443 intraoral images (4291 periapical images and 7152 bitewing images) were evaluated during the initial 6-month period and in the course of a single month 1-year after the initial imaging. Of these images, 9099 (79.6%) had no artifacts, while 2344 (20.4%) had one or more image artifacts. Of all the images evaluated, 10,750 (94%) were obtained from adult patients; of these, 2008 (19%) had one or more image artifacts. Further, 693 images (6%) were obtained from the pediatric patients; of these, 336 (48.4%) had one or more image artifacts. The percentage of image with artifacts was lower in the 6th month than in the 1st month, and it decreased significantly 1-year after the initial imaging (i.e. in April 2014) [Table 2]. During the initial 6-month period, we observed the lowest percentage of artifacts in July. On the other hand, the lowest overall percentage (5%) was observed in April 2014. All the images obtained in July were recorded by an experienced technician because the rotational students did not have classes in this month. The PSP system was completely adopted by April 2014.

The types of image artifacts most commonly observed and their number percentages are listed in Table 3. These were related to non-uniform image brightness [Figure 1], non-uniform image density [Figure 2], and the movement of the phosphor plates in the disposable packets [Figure 3]. A reduction in the image size displayed after scanning was seen in 0.7% of all the images [Figure 4]. Artifacts related to delayed phosphor plate scanning [Figure 5] and plate surface contamination [Figure 6] were 5th and 6th most frequently observed artifacts. A few artifacts occurred owing to the phosphor plates being exposed from the backside [Figure 7], because of noisy images [Figure 8], the presence of an

Figure 1: Non-uniform image brightness. A bitewing image whose right part is too bright

Figure 2: Non-uniform image density and an image with an additional horizontal black line

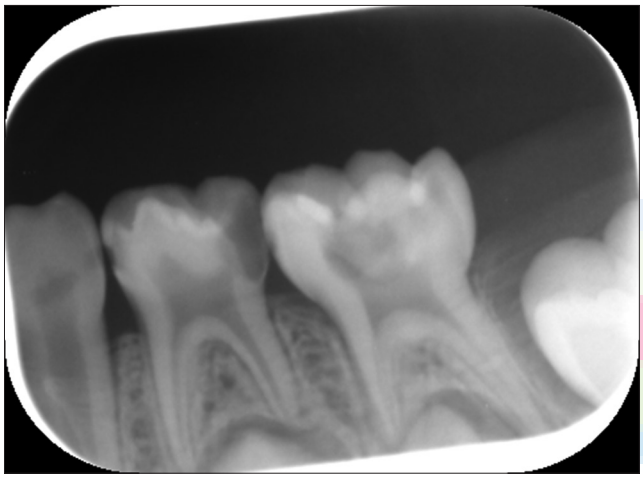

Figure 3: Movement of a phosphor plate in a disposable packet

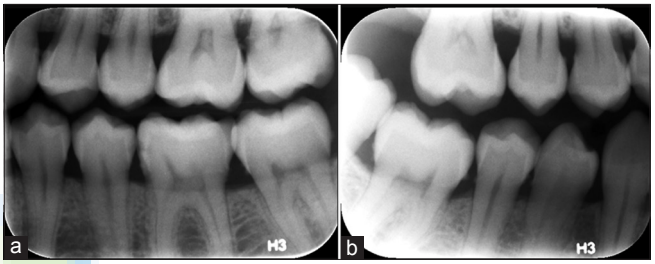

Figure 4: Reduction in the image size (4a). Right (4a) and left (4b) bitewing images of the same patient, respectively; the right one (4a) shows a reduction in size after scanning

Figure 5: Delayed phosphor plate scanning. An image is too bright resulting from a delay in phosphor plate scanning

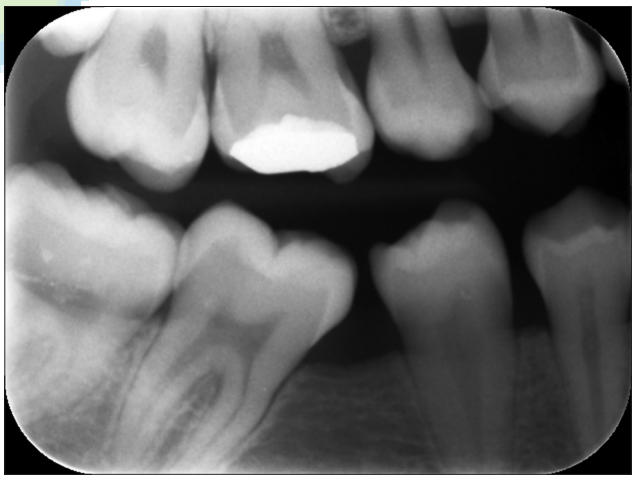

Figure 6: Plate surface contamination. A right bitewing image whose lower right part has radiopacities resulting from surface contamination with foreign particle

additional horizontal black line after scanning [Figure 2], and the use of damaged plates [Figure 9]; these were seen in only a few images and were detected only in the 1st month. The artifact caused by the movement of the phosphor plates in the disposable packets was the one observed most frequently in the pediatric age group while related to non-uniform image brightness was the most common one in the adults.

The regions in which the image artifacts were seen are listed in the Table 4. The regions in which the artifacts were observed most frequently were the primary maxillary

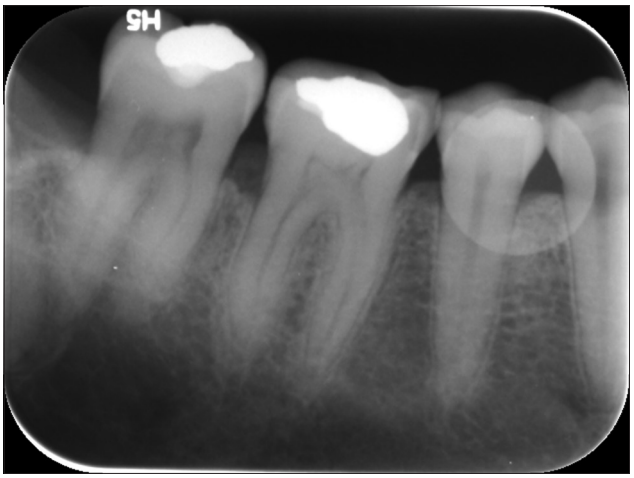

Figure 7: Imaging plate exposed backside. A round metal disk becomes visible on the image due to the backward exposure

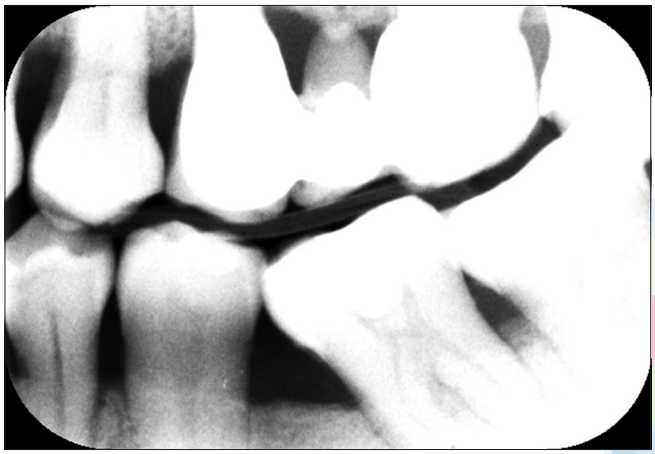

Figure 8: A noisy image. Excessive exposure to ambient light between image acquisition and scanning

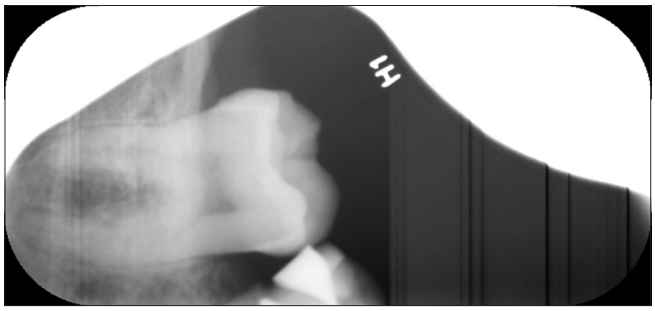

Figure 9: A physically damaged plate due to scratching

Table 1: The most frequent observed image artifact of Digora PSP plate

Artifact	Cause
Nonuniform image brightness	Some parts of the image are exposed to excessive ambient light
Nonuniform image density	Plates are overlapped while exposed to excessive ambient light
Movement of phosphor plate in disposable pocket	Movement of the phosphor plate in a disposable pocket
Reduction in the image size	Scanning procedures
Delayed phosphor plate scanning	Images that are too bright because of delayed sensor plate scanning
Plate surface contamination	This artifact may be caused by a foreign particle such as glove powder
Imaging plate exposed backside	Phosphor plate exposed backward. A round metal disk becomes visible on the image
Noisy image	Excessive exposure to ambient light between image acquisition and scanning
An additional horizontal black line after scanning	Scanning procedures
Damaged plate	Scratched phosphor surface or excessive bending of the PSP plate

Table 2: The percentage of image with or without artifacts according to the months

Months	Artifact (%)		Total
	Without artifact	At least one artifact	
April	825 (64.6)	453 (35.4)	1278
May	1050 (68)	494 (32)	1544
June	1085 (74.9)	363 (25.1)	1448
July	1818 (87.4)	261 (12.6)	2079
August	992 (75.5)	322 (24.5)	1314
September	1385 (80)	346 (20)	1731
April (one year after the initial)	1944 (95)	105 (5)	2049
Total	9099 (79.6)	2344 (20.4)	11443

Table 3: The most commonly observed image artifacts and their percentages

Image artifacts	*n* (%)
Nonuniform image brightness	1442 (12.6)
Nonuniform image density	437 (3.8)
Movement of phosphor plate in disposable pocket	425 (3.7)
Reduction in the image size	84 (0.7)
Delayed phosphor plate scanning	55 (0.4)
Phosphor plate surface contamination	9 (0.07)
Imaging plate exposed backside	6 (0.05)
Noisy images	4 (0.0)
An additional horizontal black line after scanning	3 (0.0)
Damaged plate	2 (0.0)

molar, the primary mandibular molar, and the primary maxillary anterior regions. While the artifact related to non-uniform image brightness was seen most commonly in the images of the primary maxillary molars and the primary maxillary anterior regions, that related to the movement of the phosphor plate was seen most frequently in the images of the primary mandibular molar region. Interestingly, the maxillary premolar and mandibular anterior regions were the other regions in which image artifacts were seen frequently, with the artifact related to non-uniform image brightness being the most common in these images.

Table 4: The presence and frequency of the image artifacts according to the region

Region	Artifact	
	Without artifact	At least one artifact (%)
Primary maxillary molar	176	174 (49.7)
Primary mandibular molar	156	136 (46.5)
Primary maxillary anterior	25	26 (50.9)
Maxillary premolar	285	119 (29.4)
Mandibular anterior	122	28 (18.6)
Mandibular premolar	199	42 (17.4)
Maxillary anterior	475	100 (17.3)
Maxillary molar	769	159 (17.1)
Maxillary canine	149	29 (16.2)
Mandibular canine	92	15 (14.0)
Mandibular molar	999	125 (11.1)

Discussion

The advent of digital imaging has revolutionized radiology. This revolution is the result of both technologic innovations in the image acquisition processes and the development of networked computing systems for image retrieval and transmission.[3] Despite the development of new advanced methods, intraoral radiography is still the most commonly used the radiographic technique in dental practice.[5] At present, two types of receptors are used for digital intraoral radiography: Solid-state sensors (i.e. CCD or CMOS sensors) that can be used with or without a cord and PSP plates. While sensors based on solid-state technology have been used for more than two decades, systems that use PSP plates have begun to be used in clinical practice only recently. Therefore, the disadvantages associated with PSP plates and the artifacts that occur in the images obtained using them have not been well documented in the literature.

In this study, 2344 (20.4%) of all the 11,443 intraoral images had one or more image artifacts. At the end of the study, it was concluded that the number percentage of the image artifacts was lower in the 6th month than in the 1st month. In addition the percentage decreased significantly 1-year after the initial imaging. In the initial 6-month period, we observed the lowest number of image artifacts in July, because all the images were recorded by an experienced technician in this month. However, the lowest percentage of image artifacts was recorded 1-year later, owing to an increase in familiarity with the system by this time.

While pediatric patients constituted only 6% of the study population, the percentage of images of pediatric patients that exhibited artifacts (48.4%) was higher than the percentage of images of adults that did so (19%). This is probably because of the difficulty in obtaining radiographic images of pediatric patients. However, in digital imaging, it is not essential to retake the radiographs; this protects against excessive exposure to radiation.

While 12.6% of the 11,443 intraoral images recorded in the present study exhibited non-uniform brightness, in another study, 0.37% of the 15,912 scanned PSP images had exhibited errors due to defective plates, and 0.18% had shown scanning-related errors.[12] It is possible that non-uniform image brightness results when some parts of the image are exposed to excessive ambient light as one waits for the other plates to be scanned. Interestingly, all the artifacts were seen on the distal surfaces of the plates, which might have been exposed to ambient light between the cardboard sheaths. Our results showed that non-uniform image density was the second most observed image artifact in the initial 6-month period. This artifact was caused by the partial exposure of the PSP plates to excessive ambient light prior to scanning.[3] Therefore, the plates should not be made to overlap after being exposed. As we were able to determine the case of this artifact, we could prevent it from occurring 1-year after the initial imaging.

While the artifact related to the movement of the phosphor plates in the disposable packets was observed frequently in the present study, other studies have not discussed this type of artifact. It is likely that this artifact is seen only in the images recorded using the Digora® PSP system because this system requires the use of both cardboard sheaths and disposable plastic envelopes. Although the cardboard sheaths protect the PSP plates, they can cause the movement of the plates, resulting in artifacts. As mentioned previously, this artifact was seen mostly in the images of pediatric patients. This may be because of the difficulty in getting pediatric patients to cooperate fully during radiographic procedures. A decrease in the displayed image size after scanning was also seen in the present study. This was probably because of scanning-related errors, as all the plates were scanned under the same conditions.

Chiu *et al.*[12] have classified the artifacts observed in intraoral and extraoral images as follows: Those related to operator errors, those related to scanning machine errors, and those related to PSP plate defects. They concluded that artifacts resulting from operator errors were the ones observed most frequently in extraoral images, while those caused by uneven image brightness because of delayed sensor plate scanning were seen most frequently in intraoral images. However, the latter type of artifact was seen in only 0.4% of all the images in the present study. As the PSP plates can tolerate light while being inserted into the scanner, the scanner can be placed in a room exposed to normal daylight or having regular lighting. However, several studies have shown that the higher the light intensity and the longer the exposure, the greater is the loss of information in the plate.[5,9,16] It is recommended

that PSP plates be scanned no later than 10 min after exposure. If this is not possible, they should be kept in a light-tight environment until scanning.[16] One study showed that plates placed in complete darkness before scanning exhibited no change in image quality, even after several days of storage.[18]

Artifacts caused by factors such as plate surface contamination, backwards phosphor plate exposure, noisy images, the presence of an additional horizontal black line after scanning, and the use of damaged plates were detected in only a few images in the present study. These artifacts occurred owing to the image recorder's lack of familiarity with the PSP system. Indeed, all of these image artifacts could have been eliminated through sufficient training in PSP techniques. In the Digora® PSP system, phosphor plates exposed backward can be recognized easily because a metal dot is seen in such cases. In contrast to the case with conventional radiography, the resultant image can be corrected by using the mirror function of the image acquisition software that accompanies the PSP system.[3,12] Further, the sensors can be physically damaged if they are dropped on the floor or if a patient bites hard into their surface.[5] Disposable packets are used for infection control; however, they also act as a barrier against ambient light, and do not provide adequate protection against damage to the plates from bending, pressure from the positioning device, or tooth marks.[10,12] In this study, only a few PSP plates were damaged and replaced, mostly in the initial stage of using the PSP system. However, a previous study showed that a large number of PSP plates are usually damaged during imaging.[12] Another study concluded that the main reason for the replacement of plates was damage to the phosphor layer.[10]

Conclusion

The change from conventional to digital radiography has been a revolution, and the use of digital imaging systems has increased significantly over the past decades. According to the results of this study, 20.4% of all intraoral images had one or more image artifacts, and the lowest percentage (5%) was obtained 1-year after the initial imaging period. The most frequently observed artifacts were non-uniform image brightness, non-uniform image density, and those caused by movement of the phosphor plates in disposable packets. Understanding the causes of image artifacts and studying methods of preventing these artifacts are of great clinical importance.

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Authors declare that there are no conflicts of interest in the study.

This article does not contain any studies with animal subjects performed by the any of the authors.

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