Integrating Photo-Stimulable Phosphor Plates into Dental and Dental Hygiene Radiography Curricula

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Abstract: It is not known whether the integration of photo-stimulable phosphor (PSP) plates into dental and dental hygiene curricula creates unique learning challenges for students. The purpose of this two-year study was to determine if dental hygiene students had more and/or different types of errors when using PSP plates compared to film and whether the PSP imaging plates had any particular characteristics that needed to be addressed in the learning process. Fifty-nine first-year dental hygiene students at one Canadian dental school were randomly assigned to two groups (PSP or film) before exposing their initial full mouth series on a teaching manikin using the parallel technique. The principal investigator determined the number and types of errors based on a specific set of performance criteria. The two groups (PSP vs. film) were compared for total number and type of errors made. Results of the study indicated the difference in the total number of errors made using PSP or film was not statistically significant; however, there was a difference in the types of errors made, with the PSP group having more horizontal errors than the film group. In addition, the study identified a number of unique characteristics of the PSP plates that required special consideration for teaching this technology.

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Keywords: radiography, digital radiography, radiographs, digital imaging, dental hygiene education, phosphor storage plates, photo-stimulable phosphor imaging plates

Submitted for publication 10/18/12; accepted 12/20/12

It has been predicted that digital imaging will eventually replace conventional film radiography as an adjunct means of diagnosing dental diseases.[1,2] In an effort to keep up with this changing technology, dental and dental hygiene programs are incorporating digital radiography into their curricula. Since all ionizing radiation is harmful, it is imperative that students learn to expose patients to "as low as reasonably achievable" (ALARA) amounts of radiation.[3-6] Ludlow et al.[7] conducted a study using the 2007 International Commission on Radiological Protection (ICRP) guidelines to assess the risk associated with dental radiographic procedures. They found an increase in effective doses of common dental radiographic exposures, and they emphasized the strong need to consider all means of reducing patient exposure to radiation. One way to reduce radiation exposure is to eliminate the need for retakes due to poor radiographic techniques. Therefore, it is imperative that students in dental and dental hygiene programs become highly proficient in dental radiography.

We found little information in the literature related to implementing digital radiography in dental and dental hygiene programs. Therefore, even the initial decision of whether to implement the direct or indirect imaging system into the curriculum can be difficult since both direct and indirect digital systems have advantages and disadvantages. Direct digital has the advantage of almost instantaneously transferring an image to a computer monitor, while the reusable photo-stimulable phosphor (PSP) imaging plates used in the indirect digital system require scanning for image display.[3-5] The literature indicates that the bulkiness and rigidity of the direct digital sensors could lead to problems in patient compliance, difficulties in correct positioning, and more repeats of images.[8-12] Conversely, the entire PSP plate is capable of image capture, and the size and thinness of the plates are much more like film than the thicker, more rigid sensors.[1] The low cost of the PSP receptor replacement in comparison to the expensive sensors in direct digital is also a consideration for a large teaching institution where quality control of the receptors could be an issue.

We also found little information in the literature related to teaching digital radiography. A systematic review on digital radiography[9] found no studies that indicated whether any special training phase was required to work with digital compared to film radiography. Sommers et al.[8] compared dental hygiene student performance using film and charge-coupled device (CCD) systems; however, there were no comparable studies that looked at the student learning experience using PSP imaging plates.

After much consideration, the Faculty of Dentistry at Dalhousie University decided to integrate the PSP imaging system into its dental and dental hygiene programs. This decision stemmed, in part, from the belief that the utilization of PSPs for taking a full mouth series (FMS) of radiographs was more similar to film[1,10] than the direct digital sensors and would therefore be an easier transition into the curriculum. With this in mind, faculty members in the dental hygiene program at Dalhousie University decided to begin a two-year study with first-year dental hygiene students for the purpose of determining if students had more and/or different types of errors when using PSP plates compared to film and whether the PSP imaging plates had any unique characteristics that needed to be addressed in the learning process. This information was deemed necessary to assess if there was a need for any special considerations in teaching PSP imaging plate technology and to help integrate the technology into the curriculum. The study focused on the practical utilization of the PSP plates and not on software and computer applications.

Materials and Methods

The project received research ethics approval from the Health Sciences Research Ethics Board of Dalhousie University. To ensure the anonymity of the participants, the administrative assistant at the School of Dental Hygiene explained the study to the dental hygiene students and then distributed and collected the consent forms.

During the academic years of 2010-11 and 2011-12, a total of sixty-four first-year dental hygiene students consented to participate in the study. To assess the need for any special considerations in teaching digital technology, the study focused on the results of the students' first experiences using the paralleling technique to complete an initial FMS using PSPs or film. Therefore, students who had previous experience taking intra-oral radiographs were ineligible to participate. Five students were certified to take radiographs as dental assistants, so they were not included in the study. Therefore, the results are based on the performance of fifty-nine students (twenty-six from 2010-11 and thirty-three from 2011-12). Each student was given a number, and a random number generator assigned each student to one of two groups: the film group or the PSP group.

The students completed the FMS using parallel technique on a Dental Education X-Radiation Teaching Resource manikin (DEXTR). The Extension Cone Paralleling (XCP) holder (Rinn Corp., Elgin, IL, USA) was used to position both the film and PSPs in the mouth. Paralleling technique was the preferred method for completing the FMS. This technique produces the most accurate images of teeth and their surrounding structures with the least amount of distortion.[3-5] Paralleling technique is based on two principles: the film/PSP plate is placed as parallel to the long axis of the tooth as possible; and the central ray is directed at right angles to the film/PSP plate.

For this study, a standard FMS of twenty views comprised of eight anterior and twelve posterior placements was required. Size one and two Kodak Insight F-speed films (Carestream Dental, Rochester, NY, USA) and size one and two Air Techniques ScanX PSP plates were used. All images were exposed using the Belmont PHOT-X II intra-oral x-ray operating unit. Students developed and processed the film using DentX automatic processor (Kodak Readymatic chemical solutions) with a processing cycle of 4.5 minutes at a temperature of 83°F. Students scanned the PSPs using the ScanX digital imaging system (Air Techniques, Hicksville, NY, USA).

It was determined that it would take approximately three laboratory sessions of three hours each to complete an acceptable FMS. The study was incorporated into regular laboratory sessions. Students were allotted one laboratory session to complete the anterior views of the FMS and one laboratory session to complete the posterior views of the FMS. There was also one session allotted to complete retakes. Any extra time to complete the initial FMS acceptably was given without penalty during regular radiology laboratory sessions.

The principal investigator (PI) of this study (author CLT) was the course director for radiology and had the most experience using the PSP imaging system. Therefore, for reliability and to eliminate interrater inconsistencies, it was the responsibility of the PI to assess the images and radiographs for each student according to the prescribed criteria. To

address potential examiner drift over the two-year period, the PI reviewed the first-year radiographic evaluations prior to the beginning of the second-year study and then reviewed all of the images and radiographs together after completion of the second-year study.

The teaching format was the same for each laboratory session. First, students had a demonstration by the radiology instructor (the PI) on parallel technique and then worked on their own to complete the assigned FMS requirement. They completed the anterior or posterior views, and then the radiology instructor reviewed them against a specific set of performance criteria. Errors were classified as one of the following types: horizontal, vertical, placement, or bending (Table 1). All errors had to be retaken. The student and radiology instructor discussed how to correct the errors, and then the student retook just the views that had errors. If the second attempt resulted in another error, the instructor asked the student to place the film or PSP into position, and the instructor looked at the placement. At that point, the instructor had an opportunity to analyze the problem further, so that alterations in technique could be made. Again, the instructor evaluated the retaken image for acceptability. It was possible that a student could perform multiple retakes on the same views before successfully meeting the specified criteria.

The number and types of errors were recorded on an assessment form. Once all of the views in the FMS were correct, the total number and types of errors were calculated for each student. All radiographic images were evaluated in a controlled dim setting with digital images viewed on a 19.5 inch IMAC computer monitor with a resolution of 1680 X 1050, and all films were viewed on a backlit view box. No enhancement features were utilized when evaluating the digital images.

All students submitted their assessment forms for the initial FMS to the administrative assistant at the School of Dental Hygiene. The administrative assistant compiled the assessment form data from eligible students who had consented to participate in the study. The assessment forms were returned to all students after the data had been entered. The investigators received the final tabulations from the administrative assistant without any knowledge of who had participated.

Data were tested for normality using the Shapiro-Wilk test ($p=0.01$) and for homogeneity of variance using Levene's test of equality of error variances. The two groups (PSP vs. film) were compared for total number of errors per student (of all types) using an independent samples t-test. A one-way MANOVA followed by a series of one-way ANOVAs (using a Bonferroni corrected p-value of 0.02 for multiple tests) was used to test for differences between the two groups in the type of errors made.

Results

Fifty-nine subjects were included in the data analysis. Of these, thirty had completed the initial FMS using film, and twenty-nine had completed the initial FMS using PSPs. There was no difference between the two groups on their final grades in the radiology course ($t=0.55$, $df=57$, $p=0.59$), indicating successful randomization into groups. The mean

Table 1. Description of errors

Error Type	Description
Horizontal	Overlapped contacts prevent the examination of interproximal areas, resulting in a non-diagnostic image.
Vertical	The radiographic image is not the same length as the tooth. It is either elongated or foreshortened, resulting in a non-diagnostic image.
Placement	
• Premolar	The crown and root of the first and second premolar and first molar, including the apices, alveolar crests, contact areas, and surrounding bone, are not visible on the radiograph and/or the distal contact of the maxillary canine is not visible.
• Molar	The crown and root of the first, second, and third molar, including the apices, alveolar crests, contact areas, and the surrounding bone, are not visible on the radiograph.
Bending	The radiographic image is distorted in either shape or length of crown or root, resulting in a non-diagnostic image.

Source: Adapted from Iannucci JM, Howerton LJ. Dental radiography: principles and techniques. 4th ed. St. Louis: Elsevier Saunders, 2012.

number of errors of all types for the PSP group was 10.7±0.6 (mean±SE) and 8.7±0.8 (mean±SE) for the film group. The difference between the two was not statistically significant (t=-1.93, df=57, p=0.06). See Figure 1 for a box plot showing median, mean, and spread of errors.

A one-way MANOVA revealed a significant multivariate effect of method on the types of errors made (Wilk's λ=0.683, F(2, 55)=8.51, p<0.001, partial eta squared=0.32). Given the significance of the overall test, the differences between the two groups were examined for each type of error using one-way ANOVA with a Bonferroni corrected p-value of 0.02. Significant univariate effects of method were obtained for total horizontal errors (F(1, 57)=15.4; p<0.001; partial eta squared=0.21), with the PSP group having more horizontal errors than the film group. There was no statistically significant effect of method on the number of placement errors (p=0.582) or bending errors (p=0.045) (Table 2). No vertical errors occurred with either film or PSPs, so this type of error was not included in tables or figures. There were significantly more horizontal errors made by the PSP group than by the film group. Closer analysis of the data indicated that, for both the PSP and film groups, a majority (59 percent PSP; 60 percent film) of the horizontal errors were made in the premolar region (Table 3).

A sizeable percentage (39.5 percent PSP; 48.5 percent film) of the placement errors for each group also occurred in the premolar region. The majority of the premolar placement errors (84.9 percent) using film occurred because the film was too far posterior and did not capture the distal of the canine. This was a particular problem on the bitewing radiographs where students had difficulty getting both the distal of the maxillary and mandibular canines. Conversely, the majority of the PSP premolar placement errors (53.2 percent) were the result of the plates being placed too far anterior to the midline of the canine (Table 3). This error was distributed equally between the maxillary and mandibular periapical images.

A larger percentage of total PSP placement errors occurred in the anterior region compared to the film placement errors (42 percent PSP; 24.9 percent film). Importantly, 36.4 percent of the PSP anterior placement errors were caused by shifting of the imaging plate in the bite block of the Rinn holder (Table 3). Bending accounted for 4.2 percent of the total PSP errors and 0.8 percent of the total film errors. Most of the bending errors for the PSP group were in the posterior rather than the anterior (Table 3). Unique

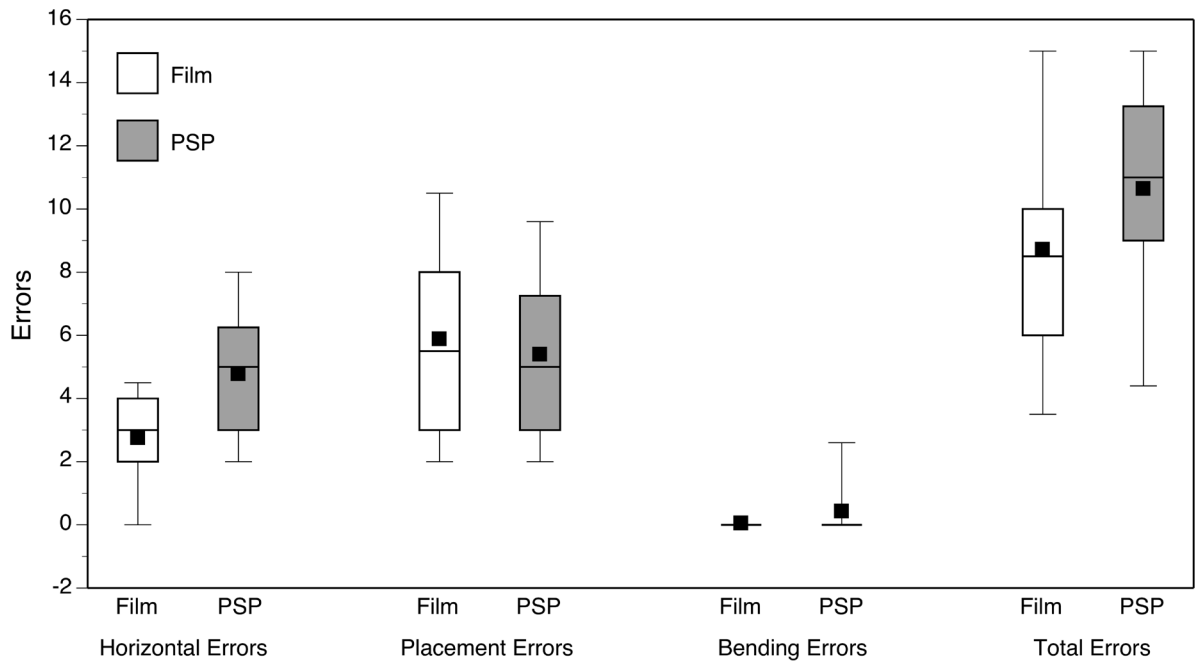

Figure 1. Median, mean, and spread of errors for film and PSP groups

Table 2. Number and types of errors (mean±SE) made by students using PSPs versus film

Type of Error	Film (N=30)	PSP (N=29)	p-value*
Horizontal errors	2.77±0.31	4.79±0.42	<0.001
Placement errors	5.90±0.66	5.41±0.57	0.582
Bending errors	0.07±0.05	0.45±0.18	0.045

*One-way ANOVA (with a Bonferroni-corrected p-value=0.02)

occurrences for PSP digital imaging included the following: subtle variations of density and contrast among images within the same FMS; mirrored imaging when PSP plates are exposed to x-radiation on the non-sensitive side; and evidence of improper handling of PSP plates.

Discussion

The total number of errors per student was greater for students who learned the paralleling technique using the PSP imaging plate versus those who learned the technique using film; however, statistically this difference was insignificant. These results supported the decision to implement the PSP imaging system based on the similarity of the PSPs to film. A closer analysis was needed to identify differences in the types of errors made using each method and to identify characteristics of the PSPs that could lead to unique errors. This was necessary in order to provide an overview of any special considerations when teaching paralleling technique using the PSP imaging system. This analysis also helped to develop recommendations for integrating PSPs into the curriculum.

Errors Common to Film and PSP Plates

Placement errors and horizontal errors. Placement errors and horizontal errors are not always mutually exclusive, particularly in the posterior, so the discussion will address both in relation to each other. The results suggested that both groups had difficulty learning to place the film/plates correctly in the premolar region. A majority of the film premolar placement errors occurred as a result of not meeting the criteria of the distal of the canine in the anterior portion of the film. Students had a particular problem capturing both the distal of the mandibular and maxillary canines in the premolar bitewing radiograph. It

Table 3. Details of types of errors made by students using PSPs versus film

Type of Error	Film n (%)	PSP n (%)
Horizontal errors		
Premolar	50 (60.2%)	82 (59.0%)
Molar	33 (39.8%)	57 (41.0%)
Total	83	139
Placement errors		
Premolar	86 (48.5%)	62 (39.5%)
Too far anterior†	13 (15.1%)	33 (53.2%)
Too far posterior†	73 (84.9%)	29 (46.8%)
Molar	47 (26.6%)	29 (18.5%)
Anterior	44 (24.9%)	66 (42.0%)
Plate/film shifting†	0	24 (36.4%)
No plate/film shifting†	44 (100%)	42 (63.6%)
Total	177	157
Bending errors		
Premolar	1 (50.0%)	10 (76.9%)
Anterior	1 (50.0%)	3 (23.1%)
Total	2	13

†Percent errors within each subcategory

appears that the rigidity of the film made it difficult to place the film far enough anterior in order to capture the distal of the canines. Conversely, a large percentage of the premolar placement errors using PSPs occurred when the plate was pulled too far forward. In some cases, the anterior border included central or lateral incisors and was clearly too far anterior. In other cases, the anterior edge of the plate remained on the canine but was located near the mesial of the tooth. This placement often resulted in changes in the horizontal alignment of the PSP plate.

To achieve correct horizontal alignment, the receptor must be positioned parallel to the horizontal plane of the teeth being radiographed. The correct horizontal position of the receptor in relation to the teeth differs throughout the mouth because the teeth

form a curved arch. Therefore, all teeth will not have the same horizontal position or mean tangent defined as the "plane joining the most exterior points of the curved facial surfaces in a particular region of the oral cavity."[4]

Increased horizontal errors using PSPs compared to film are of statistical significance, and it is important to recognize that a large percentage of the horizontal errors using PSPs occurred in the premolar region. When the PSP plates are pulled too far forward, the mean tangent begins to reflect the anterior curvature of the arch. This horizontal position is different from the horizontal plane of the premolars[4] and can result in overlapping contacts of the premolars. In this study, there were cases of severe misplacement of the PSP plate where the central or lateral incisor was captured in the view. This resulted in a horizontal position parallel to the mean tangent of the more anterior teeth and caused extreme overlap of the premolar contacts. In other cases, slight overlap occurred even when the PSP plate remained on the canine, but the edge of the plate was positioned closer to the mesial of the canine.

There was evidence in this study to suggest that the flexible nature of the PSP plates allows them to be pulled more easily forward; depending on the degree of curvature of the arch, this characteristic can contribute to horizontal errors. Students need to be taught to examine the arches so that they can assess if the curvature will place the horizontal alignment at risk. Strict adherence to keeping the anterior edge of the plate close to the distal half of the canine as well as positioning the receptor away from the teeth will reduce the risk of improper parallel alignment of the receptor to the horizontal plane of the premolars.

We also considered that the type of disposable barrier envelopes placed over the PSPs for infection control may have contributed to placement and horizontal errors because they are black and not easily seen in the mouth. In addition, the flaps on the protective barriers that extend several millimeters beyond the periphery of the PSP plates made the edges of the plates difficult to determine and therefore more difficult to place.[13] Students were instructed to fold these pieces back and secure them in the bite blocks of the Rinn holders; however, this was not always done correctly.

Disposable barrier envelopes are now available that have minimal edge design and offer a more precise fit (Figure 2). If possible, these types of barriers should be used to help reduce placement errors. Product accessories for PSP imaging plates are improving, so educators should be checking with manufacturers to see if barriers that are more easily seen in the oral cavity are available.

In addition, the study identified the problem of PSP plate shifting particularly in the anterior region. The shifting of the PSPs led to placement errors in which the teeth of interest were not centered in the image. These errors were recognized as being different from regular off-centered placement errors because, in the case of shifting, the tooth being centered in the view was clearly biting on the center of the bite-block, but the plate had shifted sideways in the bite-block causing the tooth to be off center in the image. This problem stemmed less from op-

Figure 2. Comparison of disposable barrier to new barrier with minimal edge design

erator error than from ill-fitting PSP plate holders. Unfortunately, at the time of the study, the products used to support the use of the plates did not meet the needs of the new technology. The same Rinn holders were used for both film and PSPs; however, the thinner PSP plates had a tendency to shift in the bite block.[13] New bite blocks with tighter slots were used to address this issue. In addition, students thickened the plates by placing cardboard tabs around the barriers of the imaging plates. These initiatives helped, but the results of the study indicated that it was still a problem. Rinn holders that have been specifically designed to offer better PSP grip are now available and should be considered for use.

Bending. While many errors were the result of the receptors being positioned too far forward, there was evidence of bending in only a small number of views. There had to be distortion of roots, crowns, or bone to qualify as a bending error. Results indicated that all of the PSP bending errors occurred in the maxilla, and most of those bending errors were in the premolar region. It appeared that the flexibility of the plates contributed to the bending problems since the PSP plates curved along the palate more easily than film. Chiu et al.[10] indicated that bending due to operator error and inexperience with correct technique was a more frequent problem with PSPs than film. Our study also found more bending errors using PSPs; however, due to the low number of bending errors overall, this difference was not statistically significant.

Educators need to be aware of the increased flexibility of the PSPs and how this can contribute to bending errors. In particular, in the premolar view, the PSP plate has to be placed away from the teeth and more towards the center of the palate where the palate is deeper. This will keep the PSP from flexing or bending against the palate and will also align the plate in a parallel position to the teeth.

Unique Occurrences Using PSP Imaging

The identification of different types of occurrences unique to the PSP group is of great interest and importance to this study. Although the incidence of these occurrences is low, their presence is significant for the purpose of the study and helps to develop recommendations for integrating PSP plates into the curriculum.

Subtle variations of density and contrast among images in the same FMS. Variations of density and contrast were found among images within the same full mouth series. The clinical relevance of these occurrences is unknown since adjustments to the images can be made with the digital software. While these occurrences were not expected and therefore not quantified, they were still of interest to the study. We considered a number of possible reasons for this occurrence. Possibilities ranged from operator error to more complex explanations that are currently being studied by other researchers. A simple operator error such as using incorrect exposure times could cause variations in density.

When the kVp and mA are fixed, the exposure time is the most important factor in controlling density, so strict adherence to appropriate placement exposure times must occur.[3-5] In addition, the curriculum should emphasize the importance of assessing patient variations in body mass to help ensure that correct settings such as child, average adult, or large adult are used.

We identified possible explanations for the variations in contrast. The literature indicated that delayed scanning of exposed PSPs causes fading of the latent image and leads to a loss in image quality.[10,14-16] Akdeniz and Grondahl[14,15] concluded that more information is lost in darker image areas resulting in lower contrast when scanning is delayed. This has an implication for teaching institutions where the time for novice students to complete and scan an FMS may be significant. It is possible that the time between exposing the first few images and the actual scanning of those same images could exceed scanning time delay parameters and result in loss of image quality.

There is no consensus in the literature regarding a threshold value for scanning delay,[14-16] and research indicates that some PSP imaging systems may be more sensitive to delayed scanning than others.[16] The lack of consensus is problematic; however, it is generally recommended that, in order to obtain the best quality images, PSPs should be scanned shortly after exposure. Two studies suggested that the lapse time between exposure and scanning should not exceed half an hour.[14,15] If the imaging plates cannot be scanned shortly after exposure, then they must be stored in a light-tight environment until scanning can be done. More research needs to be conducted using various system plates so that more definitive recommendations for scanning time delays can be identified. Since knowledge in this technology is evolving through research, it is the responsibility of the institution to keep abreast of this research.

In addition to the effects of scanning delay, the evidence in the literature indicated that phosphor

plates exposed to ambient light prior to scanning will result in excessive fading of the latent image and loss of information.[14,17,18] In our study, the edge of a PSP plate was exposed to ambient light while the rest of the plate remained protected in an envelope (Figure 3). This figure shows the excessive fading of the image where light exposure occurred.

The curriculum should include current research on the effects of ambient light and delayed scanning on image quality. During preclinical radiology laboratories, students need to practice scanning PSPs under optimal conditions. Therefore, exposed PSPs should be stored in containers without light leakage,[9,14,15] and the plates should be scanned in a subdued light environment.[9,17,18] Student self-evaluation of image quality should be emphasized during preclinical radiology, and this should be considered part of the evaluation process.

Mirrored imaging of PSPs exposed to radiographs on non-sensitive side. In our study, there was only one occurrence of backward placement of the PSP in the bite block of the Rinn holder and, therefore, exposure to the non-sensitive side of the receptor. While this number appeared insignificant, the consequence of such an error is significant because it could lead to incorrect mounting of a digital image and the risk of treatment planning the wrong teeth. Exposure to radiographs on the non-sensitive side of a film is easily detectable because of the "herringbone effect" and the lightness of the film.[3-5] This situation is not as evident for some PSP imaging systems, and the error can easily be overlooked.[5,10] The image of a PSP that has been exposed by x-radiation on the non-sensitive side will appear to belong in the opposite quadrant. The radiographer must pay close attention to the "a" printed on the PSP, which is used as a reference, similar to the "dot" on a film. The "a" should appear consistently positioned on the mesial or distal of all images depending on the quadrant that is being viewed. For example, when looking at an FMS, all of the "a"s in quadrant 2 will appear towards the distal of the image, and all the "a"s in quadrant 1 will appear towards the mesial of the image. If a quadrant 2 view was exposed with the PSP plate reversed in the biteblock or the plate was placed in the barrier envelope backwards, the image would appear to be in the opposite quadrant (quadrant 1), and the "a" would be oriented on the mesial of the image (Figure 4). Closer look at the image would also show that the teeth did not correspond with the other teeth in quadrant 1. If the reversed image error is detected, it can be corrected by using the "mirror" function in the software that accompanies the system.[10]

In general, mounting of digital images on a computer screen is difficult for the inexperienced student, so extra time should be incorporated into the preclinic sessions for image mounting practice. The radiology curriculum should include lectures on normal anatomical landmarks, and students should learn how this knowledge is applied to image mounting.

Evidence of improper handling of PSP plates. PSP plates can be scratched if they are not handled correctly. Scratches were found in the images of three separate PSPs. Studies have indicated

Figure 3. Fading of image where light exposure occurred

Figure 4. Image A is a mirrored image of B due to exposure of non-sensitive side of PSP

that mechanical degradation such as scratching of the phosphor layer is a problem that can affect the diagnostic quality of the image as well as the durability and longevity of the reusable plates.[9,18,19] In order to prevent scratching, the PSP plates should not have contact with hard and rough surfaces. In addition, studies have indicated that PSPs are vulnerable to scratching during the scanning process.[13,19] Bedard et al.[19] suggested that plates could scratch as they are removed from scanning drums. According to Ramamurthy et al.,[13] scanners that use a plate guide system instead of a drum carousel can also cause scratches. The scanned PSPs can be damaged when falling onto the hard collecting area or when falling out of the periphery of the collecting area.

Rubber mats for the collecting area are available for many of the plate guide systems, and these should be used to prevent scratching. In addition, the preclinical radiology laboratory should have a designated preparation area where plates can be placed into barrier envelopes without rubbing hard surfaces. When exposed PSP plates are removed from the barrier envelopes, they should be dropped carefully onto sponge pads and stored in black boxes until scanning. Dental and dental hygiene students at Dalhousie University are issued their own PSP plates for use in preclinical radiology laboratories and are accountable for returning undamaged plates at the end of the academic year.

This study did have some limitations. The results are based on the student experience using skull manikins. The results regarding placement of the PSP plates are not affected by other variables such as patient compliance and comfort; therefore, the results of this study may not be generalized to patient applications. The PI made every attempt to reduce inter- and intrarater inconsistencies to the extent that was reasonably possible. In addition, there are different PSP imaging systems available in the marketplace, and the results of this study may or may not apply to every PSP imaging system.

Conclusion

Any new technology brings different challenges and can create a complex learning curve. The results of our study reinforced the idea that there were significant similarities between using PSP plates and using film; however, closer analysis of the data identified characteristics of the PSPs that required special considerations for teaching this technology. The investigators concluded that the flexibility of the PSP plates contributed to horizontal, placement, and bending errors. In addition, the inherent thinness of the plates and the use of inadequate equipment such as ill-fitting disposable barrier envelopes and Rinn holders could lead to errors.

The study also identified a number of unique characteristics of the PSP imaging system that needed to be addressed. Exposure of the plates to ambient light, delayed scanning of the plates, and physical mishandling of the plates were identified as affecting the image quality, and we recommended that these topics should be included in the curriculum. In addition, the error of exposing a reversed PSP plate and causing mirrored images needed to be addressed in the preclinical radiology laboratories. This study identified a number of specific recommendations for teaching parallel technique using PSPs as well as recommendations for preventing errors that could occur due to some of the unique characteristics of the PSP plates. These recommendations should be considered for dental and dental hygiene preclinical radiology curricula.

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