Analysis of photostimulable phosphor plate image artifacts in an oral and maxillofacial radiology department

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Objective. To analyze image artifact types and occurrence frequency when using a phosphor storage plate (PSP) digital radiographic system.
Study design. A total of 15,912 scanned digital images were evaluated by 3 observers, and image artifacts were classified into: 1) operator errors; 2) scanning errors; 3) PSP plate defects. To avoid damage to the sensor plate, a modification technique innovated by Roberts and Mol was used where needed and 2 double-sided pieces of tape were placed around the sensor plate covering.
Results. A total of 643 image artifacts were identified. The main image artifact cause was operator error (n = 554), followed by defects of plate (n = 60) and scanning (n = 29). Scanning errors could generally be corrected by rescanning, but most other artifacts required image retaking. The use of a modified clinical technique greatly reduced artifacts caused by wearing of the sensor plate (20%).
Conclusions. Modified methods to decrease the occurrence of image artifacts using PSP digital radiographic system are encouraged. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:749-56)**

Conventional silver halide emulsion film has long been used to record, display, and store radiographic images. Digital radiography, using the same projection technology as film-based radiography, has recently been implemented in dental practice as an alternative to film-based radiography. Digital radiographic images are captured by a digital sensor and directly [charge-coupled device (CCD) or complementary metal oxide semiconductor (CMOS)] or indirectly [photostimulable phosphor storage plate (PSP)] displayed on a monitor. The direct technique transfers the signal of the exposed sensor directly through a wire with an almost instant image on the monitor.[1,2] However, this technique has predominant drawbacks of the stiffness of the sensor plate and the presence of a cord linking the plate and computer, which causes discomfort to the patients and difficulty in placing the sensor within the oral cavity, although an almost instant image is available to the practitioner after exposure of the sensor plate in this system. On the other hand, PSP systems are cordless and share similarities with conventional film. The PSP sensor plates are composed of a polyester base coated with a crystalline halide emulsion that transforms x-ray photons to stored energy, which is then released as blue fluorescent light when scanned with a helium-neon laser beam.[3,4] Although a short scanning of the plate is needed before image display, this system has the main advantage of easy and comfortable sensor placement within the oral cavity ease and is therefore favorable to the patient.[5] Furthermore, this system is more compatible with existing intraoral positioning devices. Therefore, to ensure a smooth transition from film-based radiography to digital radiography, PSP digital radiography was chosen as the new system for use in our institution.

Image artifacts have already been reported in film-based radiography.[6,7] Digital radiography, like any emerging technology, produces new and different challenges, such as new aspects of image artifacts, which practitioners need to overcome. To our knowledge, a

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comprehensive systematic analysis of artifacts in dental digital radiography in clinical usage has not yet been reported. The aim of the present investigation therefore was to evaluate the occurrence and frequency of artifact images when using a PSP digital radiographic system in our institution and to present the possible methods of handling these image artifacts from PSPs.

MATERIALS AND METHODS

Starting from September of 2006, film-based radiography in the Oral and Maxillofacial Radiology Department of our institution has gradually been replaced by dental digital radiography using a PSP system (Air Techniques, Melville, NY). The entire digital image system in our institution consists of the following: 2 classic A/T ScanX laser scanners, which can accommodate all sizes of reusable PSP sensor plates (both intraoral and extraoral); 2 PCs (Windows XP Professional with service pack 2; IBM, Armonk, NY), installed with the image acquisition software (CaptureLink Version 10.8.5, Adstra Systems, Toronto, Canada); a 17” LCD monitor of resolution 1600 × 1200 dpi; and a server computer (Microsoft Windows server 2003R2; IBM) with a 200-gigabyte hard disk.

For infection control purposes, all intraoral sensor plates were covered with disposable barrier envelopes (size 0, PN 73248-0; size 2, PN 73248-2; size 4, PN 73248-4). The A/T manufacturer claims that ordinary room lighting (up to 400 lux) was acceptable during the handling of exposed PSP sensor plates, and the necessity for subdued lighting was not emphasized[8]; we nevertheless loaded the exposed PSP sensor plates into the scanner under reduced ambient light conditions in a dim room.[9] Although ScanX has an inline erase function, following image acquisition we erase the sensor plates by exposure to white light before reuse using the A/T ScanX eraser (PN 73800) which has a light output of 25,000 lux.

The operators of the PSP digital radiographic image system, including both intraoral and extraoral radiography, comprised 3 experienced radiologic technicians and a rotation of dental or oral hygiene students with different levels of experience. All the intraoral digital images were obtained using a Siemens 7-mA 60-kVP x-ray source (Munich, Germany), and all of the extraoral digital images were acquired by a Siemens Orthophos-3 10-mA 60–80-kVP source. The radiographic and scanning conditions used were according to the operator manuals of the manufacturers. The images were ordered by the clinicians from other departments in our institution and with the consents of the patients as well as approval of our institution. All scanned digital images were checked by 3 experienced oral and maxillofacial radiologists, and image artifacts were identified and stored in a separate file for subsequent analysis. The 3 observers independently evaluated the image artifacts which were then agreed on by all 3 observers. When disagreement existed among the 3 observers, consensus was reached by discussion. Interobserver agreement was evaluated using kappa statistics.[10] The kappa values were calculated to assess interobserver agreement. A kappa value of less than 0.40 was considered to show poor agreement, 0.40-0.59 fair agreement, 0.60-0.74 good agreement, and 0.75-1.00 excellent agreement. Artifacts due to incorrect horizontal or vertical projections when taking the intraoral digital radiography images were excluded for the present analysis, because they usually did not compromise the diagnostic quality of the image.

In the first 4 weeks of PSP digital radiography implementation, 1 intraoral PSP was accidentally lost; moreover, 12 out of the 50 new intraoral PSP needed replacing, owing to various damage sustained to the plates, such as scratches, pressure from the teeth of Snap-A-Ray intraoral positioning devices (Dentsply Rinn, Elgin, IL), or tooth marks, which would result in permanent degradation of all subsequent images. The XCP ring positioning device (Dentsply Rinn) used for intraoral paralleling of the radiographic projection did not cause damage to the sensor plates. To reduce the damage to the intraoral sensor plates, especially from the teeth of the jaws of Snap-A-Ray film holders, we searched the literature to find a potential method of overcoming this problem. Consequently, a modified clinical technique innovated by Roberts and Mol[11] (2004) was adopted. Briefly, the teeth from both sides of the jaws were removed with an acrylic bur and polished. An autoclavable 3/8-inch inside dimension vinyl tubing was cut to length and inserted over the smaller jaw (Fig. 1). Furthermore, to avoid the risk of tooth marks indenting the PSPs in occlusal image taking, we placed 2 double-sided pieces of tape (2-3-mm in thickness, 5-6 cm in length; 3M Co., St. Paul, MN) on the disposable covering of a size 4 sensor plate (one on each side).

RESULTS

Interobserver agreement among the 3 observers was excellent for the assessment of image artifacts, showing a kappa value of 0.92. By September 2007 a total of 15,912 dental digital images had been recorded; the majority were intraoral digital images (n = 10,652), and the remaining were extraoral digital images. Of these digital images (n = 15,912), 643 were found to have image artifacts, of which the potential causes were classified into 3 categories: 1) operator errors (n = 554; 86.2%); 2) scanning machine errors (n = 29; 4.5%);

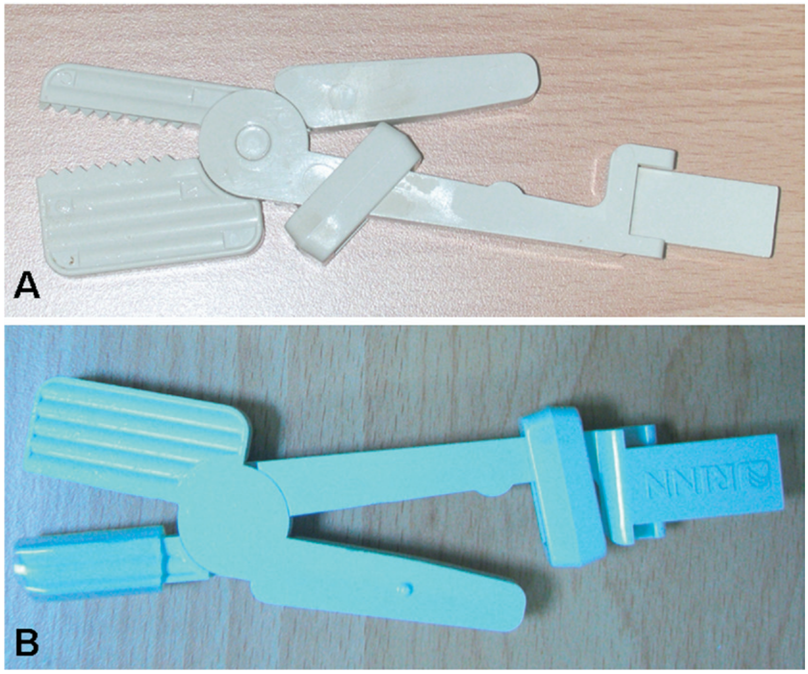

Fig. 1. **A,** The original Snap-A-Ray holding device. **B,** The modified Snap-A-Ray holding device, in which the teeth of both jaws were ground down until smooth and a plastic tube was inserted into the smaller jaw.

and 3) PSP defects (n = 60; 9.3%). The further classifications, frequency, and percentage of occurrence for each category are summarized in Tables I-III. Most artifacts that occurred owing to operator errors (such as items 1-3, 5, 7, 8, and 10 in Table I) were similar to those seen in conventional film-based radiography, whereas error items 4, 6, and 9 in Table I (Figs. 2 and 3) were unique to PSP digital radiography. Furthermore, items 1, 2, and 8-10 of the operator errors were limited to intraoral radiography, whereas items 3-7 were confined to extraoral radiography (Table I).

Representative image artifacts are shown in Figs. 2-4. The operator errors generated by the inexperienced dental or oral hygienic students were significantly higher than those by the experienced technicians (Table IV; $P < .0001$ [chi-squared test]); on the other hand, after implementing the aforementioned modified clinical technique, the number of image artifacts caused by damage to the intraoral sensor plate was significantly reduced (Table V; $P < .0001$ [chi-squared test]). After using the modified techniques, 8 sensor plates subsequently required replacement owing to severe tooth mark indentations and 4 needed replacing owing to partial peeling of the PSP halide emulsion coating from the periphery. No extraoral sensor plates (panorex/cephalometric; 5 of each) were so damaged as to require replacement.

Table I. Frequency of image artifacts due to operator errors

Item no.	*Operator error*	*n (%)*
1	Cone cut image	153 (27.62)
2	Bending of the intraoral sensor plate within the mouth	141 (25.45)
3	Opposite side of the cassette wrongly placed facing the x-ray tube	70 (12.64)
4*	Sensor plate incorrectly placed upside down within the cassette (Fig. 2, *A* and *B*)	63 (11.37)
5	Cassette incorrectly placed upside down within the cassette holder of the x-ray machine	54 (9.75)
6*	Surface of the sensor plate exposed to x-ray incorrectly inclined during the scanning process (Fig. 2, *C*)	46 (8.31)
7	Miscellanous (retained denture or earring artifact, leaded apron artifact, and so on)	12 (2.17)
8	Repeated x-ray exposure of the same intraoral sensor plate	11 (1.99)
9*	Image obtained was too bright owing to delayed sensor plate scanning (Fig. 3)	2 (0.36)
10	Intraoral sensor plate placed upside down for periapical projection	2 (0.36)
	Total	554 (100)

*Unique occurrences for PSP digital radiography

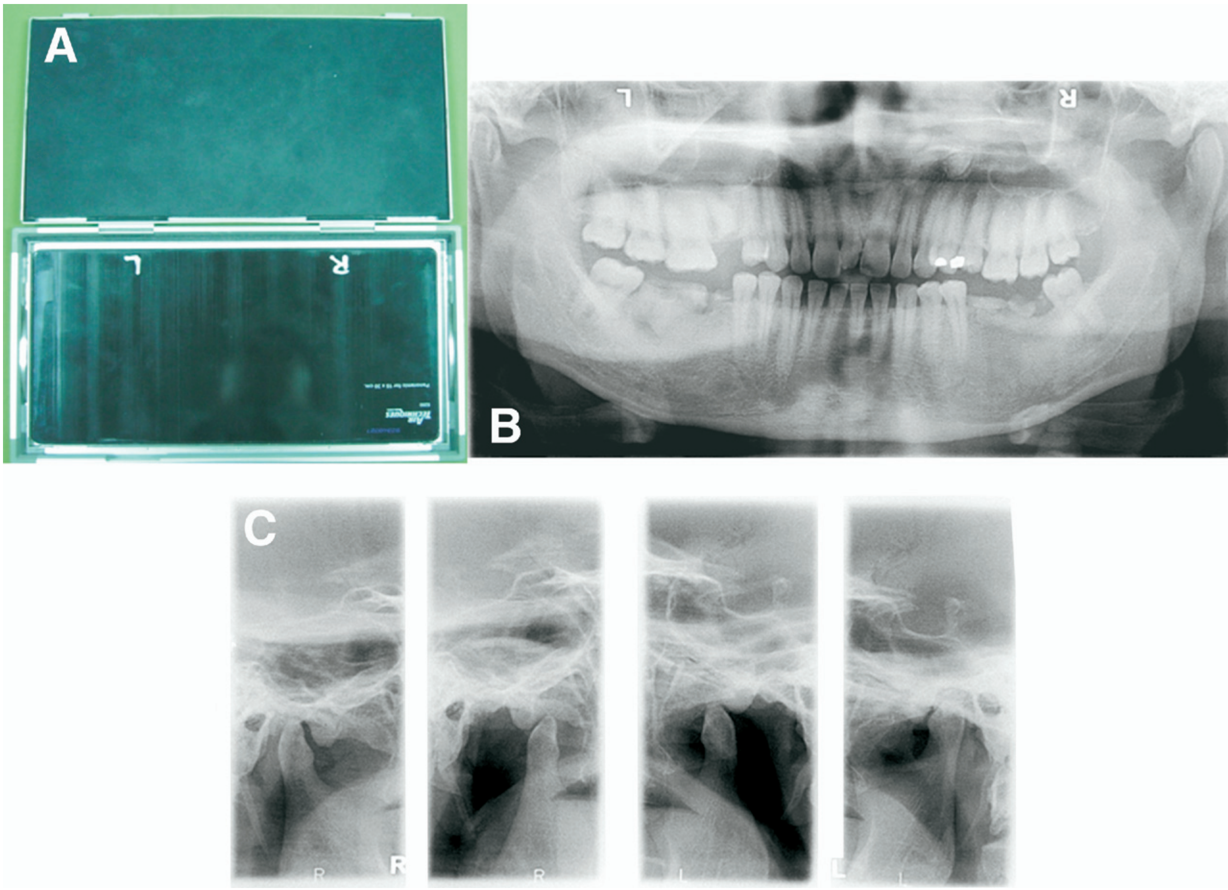

Fig. 2. **A,** The sensor plate incorrectly placed upside down within the panorex cassette, with a resultant image (**B**) in which it is difficult to determine the actual "right" or "left" side. **C,** An inclined image resulting from an incorrect inclination of the extraoral sensor plate during the scanning process.

DISCUSSION

One of the important ways of decreasing the radiation dose is to make sure that each exposure is taken under adequate conditions, thereby avoiding the formation of image artifacts and minimizing the necessity for repeated exposures. Therefore, understanding the reasons for the formation of image artifacts, particularly for the newly emerging dental digital radiography techniques, is of high clinical importance.

In our institution, when using a PSP digital radiographic system 3 types of image artifacts were identified, with the majority of artifacts occurring owing to operator errors (86.2%). Those artifacts produced by the operator that would impair diagnostic quality of the image were categorized as operator errors. In the category of operator errors, the most frequently occurring artifact was the cone cut image, followed by bending of the intraoral sensor plates (Table I). This might be due to the fact that our department of oral and maxillofacial radiology is an educational institution, and therefore some operators were inexperienced dental or oral hygienic students. As a result, many artifacts occurred owing to a lack of complete familiarity with dental radiographic techniques.

Some image artifacts such as error item 6 of the operator errors were unique to the A/T ScanX system (Table I; Fig. 2, *C*), because the x-ray–exposed surface of the sensor plates in this system needed to be pressed horizontally with both hands against the wall of the scanner to induce the scanning motion. Therefore, there was a possibility that inexperienced operators pressed the sensor plate incorrectly, causing it to incline to one side. Fortunately, such artifacts did not affect the quality of the image in terms of clinical evaluation. Also, as the markers "R (right)" and "L (left)" on the extraoral sensor plate were manufacturer made, error item 4 (Table I; Fig. 2, *A* and *B*) might be unique to the A/T ScanX system and there would be some confusion in determining the actual "right (R)" and "left (L)" side of the resulting images. In the 2 occasions of error item 9,

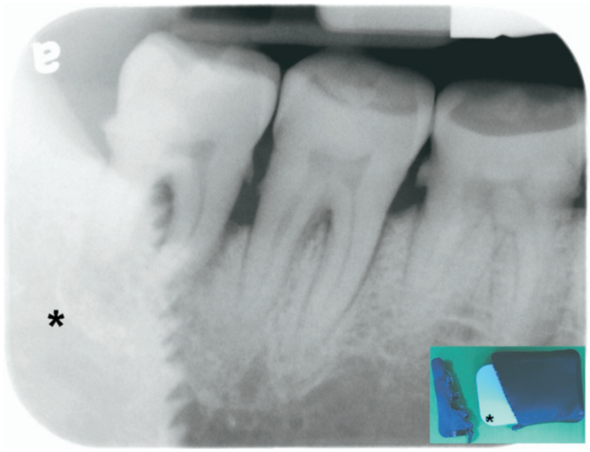

Fig. 3. Image is too bright where indicated by the asterisk; this resulted from delayed scanning of an intraoral sensor plate. **Inset,** the original situation in which the barrier envelope was torn off but the partially exposed area (indicated by the asterisk) of the intraoral sensor plate was exposed to room light for more than 10 min.

image scanning of the intraoral sensor plates was delayed by careless operators who had already torn off the barrier envelopes but left the partially exposed sensor plates on the shelf for more than 10 min while the imaging of other patients was completed (Table I; Fig. 3). Indeed, all of these operator errors could have been minimized to almost zero through sufficient radiographic technique training.

One point should be restated: that the backward exposure by the A/T ScanX system does not have a too-"bright" image with "railway-like" marks as noted for a conventional intraoral radiographic film if the "reversed" side is incorrectly exposed to the x-ray tube. Thus, this situation may easily be overlooked unless, at all times, the operator checks the rightness of tooth position of the resultant image after scanning or has a close alert to the orientation letter "a," printed on the PSP plate, which is used for reference as we would use the "dot" on a conventional intraoral x-ray film. A backwards "a,", appearing in an image, is an indication that the image has been reversed. In the present study, we noted that backward exposure of the A/T ScanX system seldom occurred. This might be due to the fact that there was a distinct color difference between the side of an intraoral sensor plate to be orientated toward the x-ray tube (which is whitish in color) and the rear side (black in color). Moreover, there was a very clear written explanation indicating the side that should face away from the x-ray tube on the rear side of the intraoral sensor plate, which isn't conspicuous on conventional intraoral radiographic film. A useful image could not be rescued when this kind of artifact occurred in film-based radiography, and the image had to be retaken. However, should this event happen in PSP digital radiography, the resultant image can easily be remedied by using the "mirror" function in the image acquisition software that accompanies the system.

In the PSP digital radiographic system, the image has to be acquired via a laser scanner, which then introduces new types of artifacts due to accidental errors of the scanning machine itself (Table II). Although the frequency of occurrence of machine error artifacts was not found to be very high (Table II), this type of artifact nevertheless deserves recognition. Such types of error ranged from mild situations, e.g., items 1 and 6 in Table II, to more severe errors, such as item 4; these 3 situations did not usually warrant retaking the images, because the images were still valuable in terms of use in clinical evaluation. In the other 3 more serious situations, i.e., items 2, 3, and 5, the resulting images were not valuable to practitioners. The exact reasons for errors of this kind are difficult to fathom but might be related to faults of the laser scanning machine. Such kinds of machine artifacts in digital radiographs acquired with PSP systems causing impaired image quality have also been reported by Oestmann et al.[12] (1991), indicating that these types of artifacts need to be identified to guarantee adequate system handling.

Scanner artifacts can possibly be corrected by rescanning the sensor plate (using another ScanX scanner) without the need to retake the image. The PSPs can be scanned within 10 min of exposure without obvious loss of quality[13]; therefore, there would be enough time to perform a rescan using another scanning machine that is functioning normally. It should be noted that the A/T ScanX system has an inline erase function, whereby the image can be read and then automatically erased in 1 continuous cycle. This inline erase tool has the advantages of saving time and simplifying the imaging process, with the additional merit that the need for a separate plate eraser is eliminated. Nevertheless, if we opted to use this function, there would be no second chance to rescan the image, and the image would have to be retaken. In our institution, we have withdrawn the inline erase function, because the opportunity to rescan the image is considered to be more important.

It is worth noting that the image artifacts that occurred owing to sensor errors were irreversible and the need to retake the image unavoidable, because the quality of the generated images usually affected clinical evaluation (Table III; Fig. 4). Also, significantly, such kinds of image artifacts could be critical, as demonstrated in Fig. 4, *B*, in which the image artifacts of 2 radiopaque shadows could have been misdiagnosed as

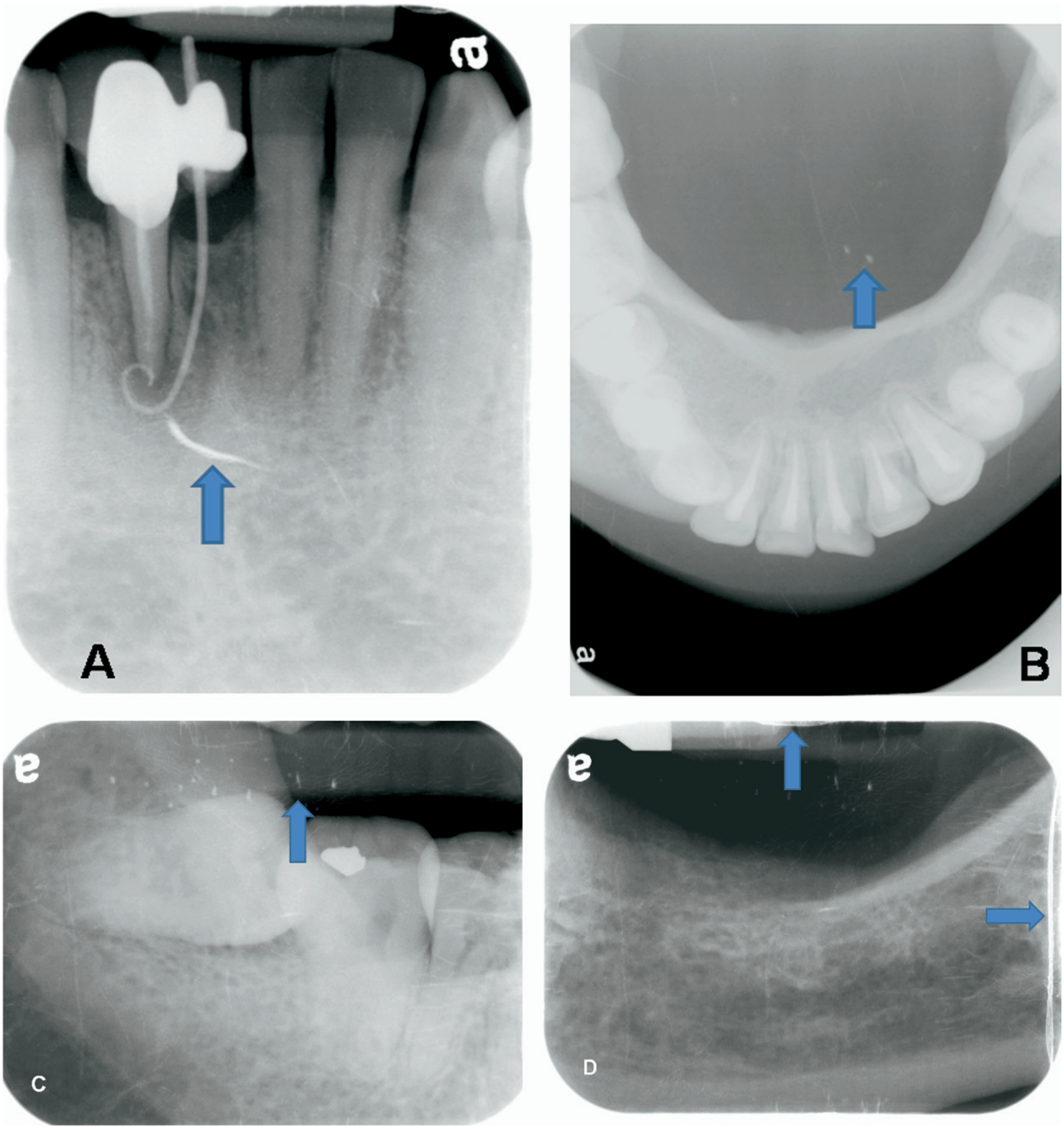

Fig. 4. **A,** A periapical image resulting from a scratched sensor plate, as indicated by the arrow. **B,** A defective occlusal image due to a tooth mark, as shown by the arrow. **C,** A defective image resulting from a sensor plate damaged by the teeth of the jaws of a Snap-A-Ray holder, as indicated by the arrow. **D,** A defective image resulting from the partial peeling of the coating of an intraoral sensor plate, indicated by the arrows.

salivary calculi of the mouth floor by inexperienced practitioners. This situation could cause a legal issue to arise, as most recently described by MacDonald-Jankowski.[14]

Although the reusable PSPs were placed within sealed plastic barrier envelopes, primarily for infection control purposes but which also provided a barrier against ambient light, we found that these barrier envelopes did not provide enough protection against mechanical wear from bending, Snap-A-Ray holding device pressure, or tooth marks. Bedard et al.[15] reported that PSPs were so damaged after 50 uses that they

Table II. Frequency of image artifacts due to scanning machine errors

Item no.	*Scanning machine error*	*n (%)*
1	An additional horizontal white line was noted after scanning	13 (44.83)
2	Image obtained was too bright despite scanning with optimal conditions and procedures	8 (27.59)
3	Only half of the intraoral image was displayed after scanning	5 (17.24)
4	Reduction in image size of an intraoral image was displayed after scanning	1 (3.45)
5	After scanning of two different intraoral sensor plates in two different slots, the two resulting images overlapped	1 (3.45)
6	Uneven brightness of an extraoral image after scanning	1 (3.45)
	Total	29 (100)

Table III. Frequency of image artifacts due to sensor defects

Item no.	*Sensor defect*	*n (%)*
1	Defective image resulting from sensor plate damaged by scratches or bite mark (Fig. 4, *A* and *B*)	32 (53.34)
2	Defective image resulting from sensor plate damaged by teeth of the jaws of a Snap-A-Ray (Fig. 4, *C*)	20 (33.33)
3	Defective image resulting from partial peeling of the coating of the intraoral sensor plate (Fig. 4, *D*)	8 (13.33)
	Total	60 (100)

Table IV. Statistical analysis of the frequency of operator errors between experienced technicians and inexperienced students

	No. of images without artifacts	*No. of images with artifacts due to operator errors*
Experienced technicians	8,769	44
Inexperienced students	6,500	510*
Total	15,369	554

*Number of image artifacts produced by the inexperienced students is significantly higher than that by the experienced technicians ($P <$ .0001 [chi-squared test]).

Table V. Statistical analysis of the frequency of sensor defects before and after implementing the modification techniques

	No. of images without defects	*No. of image artifacts due to sensor defects*
Before	724	48*
After	9,396	12
Total	10,120	60

*Number of image artifacts before is significantly higher than that after implementing the modification techniques ($P <$ .0001 [chi-squared test]).

needed to be replaced. Although the PSP digital radiographic system used in our institution was different from that used by Bedard et al.,[15] we experienced similar consequences, i.e., that quite a number of PSPs were damaged and needed replacing, especially in the initial period of use of the PSP digital radiographic system. However, after adopting the modified clinical technique introduced by Roberts and Mol[11] (2004), as well as our own technique, the longevity of the intraoral sensor plates were dramatically lengthened.

Significantly, the coating of 4 intraoral PSPs suffered from a partial peeling off from the periphery (Fig. 4, *D*), which might be due to the plastic barrier envelopes possibly not providing perfect protection of the PSP plates from the potentially harmful effects of contamination with saliva during multiple placements of the plates within the oral cavity. Further studies concerning this issue are needed.

In conclusion, various image artifacts were encountered in our institution after the adoption of PSP digital radiography, and some possible methods of avoiding the occurrence of these kinds of image artifacts have been described here.

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