Image quality in partially erased DenOptix® storage phosphor plates

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Abstract: This study aimed at investigating the effect of the partial erasing of DenOptix® system storage phosphor plates on the image quality of digital radiographs. Standardized digital radiographs were acquired of a phantom mandible, using size 2 intraoral DenOptix® storage phosphor plates (n = 10). Subsequently, the active areas of the plates were placed in a viewing box with a constant light intensity of 1,700 lux for 130 seconds to achieve complete erasing (control plate), as well as for 0, 5, 10, 15, 20, 25, 34, 66, and 98 seconds, to compose the experimental group of partially erased plates. The same exposure settings were repeated using the control and experimental plates, which were scanned at a resolution of 300 dpi. Five radiologists independently examined the pairs of digital radiographs obtained with the control and partially erased plates, in random order, and indicated the best image for oral diagnosis. Cochran-Mantel-Haenszel's chi-square test, at a significance level of 5%, was used to compare the percentages of superior quality images in each combination of control and partially erased plates, subjectively assessed. No significant differences were found between radiographic images acquired with control and partially erased plates, except for the combination of 0 second (30%) *versus* 130 seconds (70%), $p = 0.0047$. It can be concluded that, under adequate light intensity conditions, erasing intraoral DenOptix® storage phosphor plates may require time intervals of as little as 5 seconds.

Descriptors: Diagnosis; Radiography, dental, digital; Quality control.

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Introduction

At present, there are a number of digital radiography systems commercially available for dental use. In this context, studies comparing the performance of storage phosphor systems to that of conventional film and charge-coupled device (CCD) systems reported similar or better image quality with the former.[1-5] Furthermore, the storage phosphor systems have a wider dynamic range and better low-contrast detectability in relation to the CCD systems.[1,5,6] However, despite their relevant contributions in the technological advancement of the field of oral and maxillofacial diagnosis, it should be emphasized that digital systems have their inherent practical limitations.[4,7]

There are storage phosphor plates (SPPs) having, approximately, the same size and flexibility as that of conventional film. This kind of sensor consists of a polyester base coated with a crystalline halide composed of europium-activated barium fluorohalide compounds. When an image plate is irradiated, the absorbed X-ray energy is temporarily stored within the phosphor crystals. To read the stored information, a thin collimated helium-neon laser beam scans the plate surface and the energy is thereby released as fluorescent blue light, which is detected by a photomultiplier and converted to electrical signals. An amount of the stored energy remains in the image plate even after scanning, but it is eliminated when the plate is exposed to strong light.[8,9]

With regard to DenOptix®, the SPPs might be erased just before use. To completely erase the plates, it is recommended that they be exposed to direct and intense light.[10,11] In the user manual and installation guide of the DenOptix® system, the manufacturer gives some instructions on how to erase the plates under special conditions of light intensity.[10] Nevertheless, sometimes these recommendations cannot be correctly followed, because of operational restrictions, such as the impossibility of measuring light intensity from a viewing box or incandescent lighting. Thus, the purpose of this study was to investigate the effect of incomplete erasing of the DenOptix® SPPs on the image quality of digital radiographs.

Material and Methods

Experimental design

In this experimental model, a phantom mandible was used to produce the radiographic images, in agreement with the current ethical principles (Resolution 196/96 of the National Health Committee/ Health Department, Brazil). The phantom presented sufficient anatomical and pathological characteristics to simulate oral tissue images obtained in clinical settings (enamel, dentine, pulp cavity, periodontal ligament space, lamina dura, trabecular pattern, caries-like lesions, and radiolucencies in the periapical region).

Standardized radiographs of different regions of the phantom were taken with DenOptix® system (Denstply International/Gendex® Dental X-ray Division, Des Plaines, IL, USA) size 2 intraoral SPPs completely erased (n = 10), using a GE 1000® X-ray unit (General Electric Co., Milwaukee, WI, USA). The X-ray unit operated at 60 kVp, 10 mA, 2.5 mm total aluminum filtration, and a 40 cm focus–receptor distance. The exposure time was set at 0.3 seconds, and the dose defined was 840 σGy. An acrylic device was manufactured to hold the phantom, X-ray beam indicator device and image plate in a reproducible relationship. After the radiographic exposures, the SPPs were not scanned, but remained sealed in their protective light-tight polymer envelopes until the erasing, which was the subsequent step.

An EMB® (Electro Médica Brasileira, São Paulo, SP, Brazil) viewing box measuring 38 x 48.5 cm, which gives off 1,700 lux of fluorescent light, was used to erase the SPPs in a secluded room where light intensity was 20 lux. Light intensity (from the viewing box and procedure room) was measured by a Photometer® 07-621 (Fluke Biomedical, Cleveland, OH, USA). In order to completely erase one of the SPPs (control plate), the plate active side was positioned facing down and in contact with the front surface of the viewing box for 130 seconds. The experimental group consisted of the SPPs submitted to erasing procedures which lasted 0, 5, 10, 15, 20, 25, 34, 66, and 98 seconds. Immediately following the erasing procedures, the plates were stored in the protective light-tight envelopes and then re-exposed.

The same exposure settings were repeated using the control and experimental plates. Next, the SPPs were scanned at a standard resolution of 300 dpi and the digital radiographs were stored in compact disc-recordable media as 8-bit TIFF (tagged image file format) images. The DenOptix® SPP size 2 has an active area of 41 x 31 mm², and at the resolution selected for scanning, pixel size is estimated at 85 x 85 σm², resulting in a matrix of 485 x 367 pixels with 8-bit quantifying gray levels, determining a spatial resolution of around 6 lp/mm.[10]

No time intervals were systematically allowed to elapse throughout the experiment with the DenOptix® SPPs (first exposure – erasing; erasing – second exposure; second exposure – scanning) to avoid any possible effects of time delay or storage conditions on image quality.

Image assessment

A panel of five experienced oral and maxillofacial radiologists independently examined the resultant ten pairs of digital radiographs (obtained with the control and experimental plates) imported into VixWin® (Gendex Division, Des Plaines, IL, USA), the software that manages capture, display, treatment, analysis, and archiving of images acquired with the DenOptix® system.[10] Digital radiographs were presented in random order on an SVGA 17-inch monitor screen. Observers were blind to the experimental procedures used; therefore, the files were named *A* or *B* plus an identification number unrelated to the erasing times, and the identification numbers were not consecutive.

Only one pair of radiographs was displayed at a time and all viewing was performed under uniform subdued lighting in a quiet, secluded room. The analog brightness and contrast controls on the monitor were kept constant during the assessments. Following a calibration session, the observers were instructed to use the software brightness and contrast commands to manipulate image characteristics intuitively and better extract the diagnostic signals by reference to the abovementioned anatomical and pathological features. The observers were asked to compare the two radiographs (*A* and *B*) and indicate the image that provided superior quality for oral diagnosis.

Data analysis

Two-dimensional cross-tabulation was performed on the radiographic interpretation data, using the SAS® 8.02 package (SAS Institute Inc., Cary, NC, USA). Differences between the percentages of superior quality images in each combination of control and partially erased plates, subjectively assessed by the five observers, were analyzed using the Cochran-Mantel-Haenszel's chi-square test. The level of significance was set at $p = 0.05$.

Results

Table 1 shows the results of pair-wise comparisons between images acquired with control and partially erased SPPs. Chi-square statistics demonstrated a significant difference only between completely and not erased plates, i.e. between SPPs that were positioned in the viewing box for 130 seconds and 0 second, respectively ($p = 0.0047$). There were subtle contrast differences between images acquired with the control and experimental plates. However, in most cases, the decreased image contrast in partially

Table 1 - Comparison of the diagnostic quality, expressed as percentages of selected digital radiographs by five observers, between images acquired with completely and partially erased DenOptix® SPPs.

Erasing time combinations	Erasing pattern*		(θ^2)**	p value
	Partially	Completely		
0 x 130	15 (30)	35 (70)	8.00	0.0047***
5 x 130	22 (44)	28 (56)	0.72	0.3961
10 x 130	20 (40)	30 (60)	2.00	0.1573
15 x 130	22 (44)	28 (56)	0.72	0.3961
20 x 130	19 (38)	31 (62)	2.88	0.0897
25 x 130	20 (40)	30 (60)	2.00	0.1573
34 x 130	26 (52)	24 (48)	0.08	0.7773
66 x 130	23 (46)	27 (54)	0.32	0.5716
98 x 130	22 (44)	28 (56)	0.72	0.3961
130 x 130	0 (0)	50 (100)	0.00	1.000

*Data are presented as n (% of total sample, considering five observers). **(θ^2) indicates chi-square values. ***Highly significant difference, $p < 0.01$.

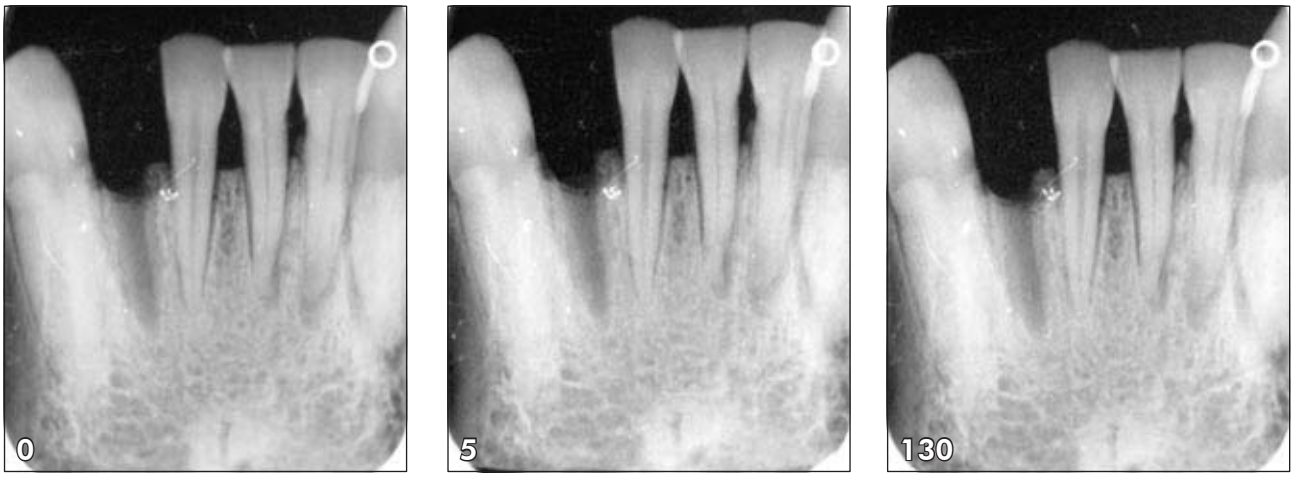

Figure 1 - Radiographic images acquired with the DenOptix™ storage phosphor plates. 0, not erased. 5, erasing time set at five seconds. 130, erasing time set at 130 seconds.

erased SPPs did not impair radiographic diagnosis (Figure 1).

Discussion

Storage phosphor systems may be considered the most suitable commercially available substitutes for conventional radiography, since they provide all the image processing facilities of digital radiographs as well as high diagnostic accuracy[1-5] and wide dynamic range[3,6,11,12] at the expense of low radiation doses. However, there are some operational drawbacks that must be overcome in order to establish their use in clinical practice, despite the relatively higher cost in comparison with conventional radiography.

After exposure, it is recommended that the SPPs be scanned within a short period of time to prevent information loss that may occur due to degradation from surrounding light and freeing of some of the trapped electrons produced by the absorbed X-ray photons.[2] Hildebolt *et al.*[13] (2000) reported that 25-50% of the latent image stored in SPPs is lost within the first hour after exposure, even though the rest of the radiographic information can persist for many days.

One of the main causes of the latent image fading in SPPs is the time interval between exposure of the plate and its scanning. Because it may not always be possible to perform the scanning procedure in clinical settings, previous studies were carried out to assess the effects of different storage and scan delay conditions on image quality.[1,2,9,14] According to Akdeniz *et al.*[1] (2005) and Martins *et al.*[14] (2006), it is reasonable to assume that after exposure, SPPs should be stored in a light-tight environment, under ambient or low humidity (60% and 26%, respectively) conditions at approximately 25∀C, and scanned no longer than 3 hours later.

Although the two well-known worldwide marketed storage phosphor systems, DIGORA⊇ and DenOptix⊇, apply the same basic technology for capture and digitization of the radiographic information, they differ in the scanning procedure. Once the DIGORA⊇ SPPs are scanned, they are flooded with light to erase any remaining image and to prepare them for the next exposure, whereas the DenOptix⊇ SPPs must be erased just before they are used. Scanning the DenOptix⊇ SPPs does not erase all the radiographic information.[10] The need for an outside erasing procedure may be considered an impractical time-consuming task.[13] In addition, the lack of adequately controlled light intensity and exposure time parameters during the erasing procedure may compromise image quality, which in turn, might lead to under-diagnosing in a clinical situation.

Based on the manufacturer's instructions, viewing boxes typically give off between 1,000 and 5,000 lux. With the use of a viewing box that gives off 1,000 lux of fluorescent light, the DenOptix⊇

SPPs will be erased in one minute. At 2,000 lux or more, 30 seconds are sufficient.[10] Conversely, Menig[11] (1999) suggested that using a viewing box, a two-minute time interval was necessary for completely erasing the DenOptix® SPPs. In fact, there is controversy about the extent to which reduced erasing times will affect the diagnostic information obtained with DenOptix® radiographs. When assessing subjective image quality evaluated in digital radiographs acquired with partially erased DenOptix® SPPs, it has been observed that exposure times as low as five seconds may be sufficient to yield an acceptable diagnostic signal, under controlled viewing box luminosity of 1,700 lux. On the other hand, it should be emphasized that the DenOptix® SPPs must definitely be erased, even if only for a few seconds, in order to avoid significant information loss (Table 1).

Considering the time spent on scanning the DenOptix® SPPs, a reduction in erasing time would optimize the radiographic settings. For example, scanning the top row of the DenOptix® carousel takes less than one and a half minute at 300 dpi.[10] According to the findings of this study, irrespective of the time spent on radiographic exposure of the patient, if an erasing time interval of five seconds is achieved, the total operational setting may be accomplished in about two minutes. The proposed time interval is shorter than those previously suggested.[10,11]

Another issue that should be taken into account is the radiation dose.[7] The higher the selected radiation dose, the more stored X-ray energy has to be eliminated by exposing the SPPs to light. In the present study, exposure time was intentionally higher than that recommended by the manufacturer when anatomical regions of the mandible are supposed to be imaged, with the purpose of ensuring that the DenOptix® SPPs were irradiated with a considerable X-ray dose.

This experimental investigation was conducted under controlled radiation exposure parameters, as well as lighting conditions for handling and erasing the DenOptix® SPPs, and thus provided a real scientific contribution to the amount of time that may be spent during the erasing procedure. Nevertheless, subjective assessment of image quality probably fails to detect small signs of image degradation due to an incomplete DenOptix® SPPs erasing procedure, as the human eye is unable to discern more than 32 gray levels.[14] Although subjectively assessed image quality may be an important aspect for clinical comparisons, it does not correspond most appropriately to diagnostic accuracy.[15] Therefore, future studies should address the objective characteristics of DenOptix® radiographs acquired with partially erased plates.

Conclusion

This study demonstrated that under adequate and controlled viewing box luminosity, the DenOptix® SPPs can be erased using time intervals of as little as five seconds, since incomplete erasing did not cause significant loss of diagnostic image quality in simulated clinical settings.

References

1. Akdeniz BG, Gröndahl HG, Kose T. Effect of delayed scanning of storage phosphor plates. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005;99(5):603-7.
2. Akdeniz BG, Gröndahl HG. Degradation of storage phosphor images due to scanning delay. Dentomaxillofac Radiol. 2006;35(2):74-7.
3. Almeida SM, Oliveira AEF, Ferreira RI, Bóscolo FN. Image quality in digital radiographic systems. Braz Dent J. 2003;14(2):136-41.
4. Borg E, Attaelmanan A, Gröndahl HG. Subjective image quality of solid-state and photostimulable phosphor systems for digital intra-oral radiography. Dentomaxillofac Radiol. 2000;29(2):70-5.
5. Ferreira RI, Haiter-Neto F, Tabchoury CPM, Paiva GAN, Bóscolo FN. Assessment of enamel demineralization using conventional, digital, and digitized radiography. Braz Oral Res. 2006;20(2):114-9.
6. Wenzel A, Gröndahl HG. Direct digital radiography in the dental office. Int Dent J. 1995;45(1):27-34.
7. Oliveira AE, Almeida SM, Paganini GA, Haiter Neto F, Bóscolo FN. Comparative study of two digital radiographic storage phosphor systems. Braz Dent J. 2000;11(2):111-6.

8. Borg E, Attaelmanan A, Gröndahl HG. Image plate systems differ in physical performance. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000;89(1):118-24.
9. Martins MGBQ, Haiter Neto F, Whaites EJ. Analysis of digital images acquired using different phosphor storage plates (PSPs) subjected to varying reading times and storage conditions. Dentomaxillofac Radiol. 2003;32(3):186-90.
10. Gendex Dental X-Ray Division. DenOptix digital imaging system – user manual and installation guide. Des Plaines: The Division; 1998.
11. Menig JJ. The DenOptix digital radiographic system. J Clin Orthod. 1999;33(7):407-10.
12. Berkhout WE, Beuger DA, Sanderink GC, van der Stelt PF. The dynamic range of digital radiographic systems: dose reduction or risk of overexposure? Dentomaxillofac Radiol. 2004;33(1):1-5.
13. Hildebolt CF, Couture RA, Whiting BR. Dental photostimulable phosphor radiography. Dent Clin North Am. 2000;44(2):273-97.
14. Martins MGBQ, Whaites EJ, Ambrosano GMB, Haiter Neto F. What happens if you delay scanning Digora phosphor storage plates (PSPs) for up to 4 hours? Dentomaxillofac Radiol. 2006;35(3):143-6.
15. Gröndahl HG, Wenzel A, Borg E, Tammisalo E. An image plate system for digital intra-oral radiography. Dent Update. 1996;23(8):334-7.