RESEARCH

Effect of alternative photostimulable phosphor plates erasing times on subjective digital image quality

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Objective: To evaluate the influence of alternative erasing times of DenOptix® (Dentsply/Gendex, Chicargo, IL) digital plates on subjective image quality and the probability of double exposure image not occurring.

Methods: Human teeth were X-rayed with phosphor plates using ten different erasing times. Two observers evaluated the images for subjective image quality (sharpness, brightness, contrast, enamel definition, dentin definition and dentin-enamel junction definition) and for the presence or absence of double exposure image. Spearman's correlation analysis and ANOVA was performed to verify the existence of a linear association between the subjective image quality parameters and the alternative erasing times. A contingency table was constructed to evaluate the agreement among the observers, and a binominal logistic regression was performed to verify the correlation between the erasing time and the probability of double exposure image not occurring.

Results: All 6 parameters of image quality were rated high by the examiners for the erasing times between 25 s and 130 s. The same erasing time range, from 25 to 130 s, was considered a safe erasing time interval, with no probability of a double exposure image occurring.

Conclusions: The alternative erasing times from 25 s to 130 s showed high image quality and no probability of double image occurrence. Thus, it is possible to reduce the operating time of the DenOptix® digital system without jeopardizing the diagnostic task.

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Introduction

Technical aspects, physical performance, and exposure range of the DenOptix® (Dentsply/Gendex, Chicargo, IL) digital system have all been reported in the literature,^{1–14} but there remains a lack of information on the effects of alternative erasing times on the final image quality. This may be important, as a decrease in the erasing time of the plates could lead to a reduction in the operating time.

In 1997, Gendex released the DenOptix® radiographic digital system, which uses photostimulable phosphor plate (PSP) technology. When the DenOptix® plate is exposed to X-rays, the absorbed energy is stored within

the phosphor crystals, forming latent images. The information contained in the plate is released by scanning it with a thin collimated laser beam and the data are captured into the DenOptix® system. After the plate is scanned, there is some energy still left on the plate that needs to be erased before it can be reused. In order to clear off the entire residual image signal, the DenOptix® PSP has to be exposed to a bright light source for a period of time. The erasing time for the imaging plate depends on the intensity of the light source and can range between 30 s and 2 min.¹⁴ The erasing procedure is time-consuming, and reducing the time taken, without jeopardizing the quality of the next digital image, would be advantageous during clinical procedures in dental practice.

The radiographic image must reproduce the X-rayed object with high fidelity, demonstrating visual quality

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and the structural details. As well as maximum detail, radiographic digital images of high diagnostic quality must have optimum brightness and contrast. Brightness is very important for the diagnostic quality of the image since it is not possible to visualize details without adequate brightness. Contrast is determined by the difference between the darkest area and the lightest area of the image. The contrast may vary depending on the structure that is being analysed; optimum contrast depends on the diagnostic task. For instance, an image with high contrast is better for the diagnosis of proximal caries.^{15,16} A recent study¹⁷ evaluated the effects of different erasing times of DenOptix® PSPs on the diagnosis of caries and its variation on mean pixel intensity values, and determined that the reduction of the erasing time to 20 s did not interfere with caries diagnosis however, the study did not evaluate the effect of erasing time on subjective image overall quality.

Time reduction is essential, since during clinical practice a few minutes for each radiographic procedure represents a significant loss of working time, particularly in radiology clinical practice, where a great number of dental radiographs are made each day.

High-quality images are very important for any diagnostic task, and a reduction in the operating time, while maintaining the same subjective image quality, would be helpful in clinical practice. Until now, there has been no study on the influence of reduced erasing times on the image quality of DenOptix® PSP digital images. The aim of this study was to verify the subjective image quality of DenOptix® PSP images submitted to alternative erasing times.

Materials and methods

This study was approved by the Piracicaba Dental School Ethics Committee. 50 extracted human teeth (10 canines, 20 premolars and 20 molars) were mounted in 10 blocks of silicone, each with 4 test teeth (2 premolars and 2 molars) and 1 non-test tooth (canine). The canine was used in order to ensure proximal contact with the first premolar. The premolars and molars were either intact or had small demineralization on their proximal surfaces.

The digital images were acquired using bitewing projection geometry. A GE 1000 (General Electric Company, Milwaukee, WI) unit was used for all exposures, operating at 60 kVp and 3 mAs. A 1.2 cm thick acrylic plate was placed adjacent to the models as soft tissue-equivalent material (Figure 1). To ensure reproducible imaging geometry, the blocks of silicone were stabilized on a customized acrylic device that was used to provide a focus-to-PSP distance of 34 cm, a central X-ray beam orientation and a teeth-receptor distance of 2 cm. Eight storage phosphor plates (Gendex® DenOptix® Imaging System), size 2, were X-rayed and subsequently scanned in the DenOptix® scanner with the following parameters: 8 bit depth and resolution of 300 dpi. All images were saved and stored in

Figure 1 Acrylic device used to ensure reproducible geometry during X-ray exposure

tagged image file format (tiff). Ten erasing times (130, 98, 66, 34, 25, 20, 15, 10, 5 and 0 s) were used, based on previous studies.^{17–19} Albuquerque *et al*¹⁸ determined that 130 s was sufficient to remove all image signals that had been left after scanning the plate; a light box with fluorescent light intensity of 1700 lux was used. The phosphor plates were exposed to X-rays, scanned and subsequently exposed to fluorescent light from a light box of 1700 lux for 130 s, then exposed to X-rays again, scanned and erased for 98 s. That procedure was repeated for each of the erasing times to be tested. After each exposure, the teeth block was moved from side to side so that a possible residual image would not be superimposed, jeopardizing the identification of a double-exposed image. All manipulation of the plates (releasing from protective envelopes, mounting on drums, mounting on protective envelopes) was done in dimmed light conditions. Between each erasing time, the phosphor plates were exposed to fluorescent light of 1700 lux for 130 s in order to avoid any accumulation of residual image. All the images obtained at each erasing time from each block were stored for further evaluation.

Viewing sessions

Prior to the examination sessions, verbal and practical instructions and calibration tests were provided. The images were coded and displayed to the observers in random order at full size, 1:1 on a 17 inch monitor, and placed in a quiet room with dimmed lighting that could not be enhanced. The images were not magnified nor were enhancement tools used for the displacement of the images. Two independent observers, both oral radiologists with at least seven years' experience in evaluating digital images, assessed a total of 200 images (20 images of each erasing time) for subjective image quality, using PowerPoint software (Microsoft®, Redmond, WA), based on the following image quality parameters: 1, sharpness; 2, contrast; 3, brightness; 4, enamel definition; 5, dentine definition; and 6, dentinoenamel junction

definition. Pairs of images with the same dimensions were presented to the observers in groups of 20 images; each pair had an image from a plate erased for 130 s and another one for the erasing time under study. For each image quality item the following scores were used: 0, poor-quality image; 1, fair-quality image; 2, good-quality image; or 3, excellent-quality image. The observers also scored the image for the presence or absence of double exposure images by scoring yes or no. The observers were not allowed to enhance or modify in any way the images evaluated.

Data analysis

Spearman's correlation analysis was performed to verify the existence of a linear association among the subjective image quality parameters and the alternative erasing times. After linear correlation was confirmed ($P < 0.0001$), ANOVA was conducted to test differences between alternative erasing times and image quality parameters.

On the assessment for the presence of double exposure images, a contingency table was constructed to evaluate the agreement between observers, and then a binomial logistic regression was performed to verify the correlation between the erasing time and the probability of a double exposure image not occurring.

Results

Figures 2–7 show that all six parameters of image quality were rated higher, between fair and good with scores between 1 and 2, for the erasing times between 25 s and 130 s. The only exception was for enamel definition, which showed higher rates between 34 and 130 s (Figure 5), although the 25 s time is in the same confidence interval. The percentage of agreement between the observers in all six parameters of image quality was 90%.

Double exposure

Table 1 demonstrates a high percentage of agreement between the observers (96.5%), indicating that the

Figure 2 Mean values and confidence intervals (CI) of sharpness quality for each alternative erasing time

Figure 3 Mean values and confidence intervals (CI) of contrast quality for each alternative erasing time

assessed images were efficient as a model to predict the occurrence of double exposure when using different erasing times.

Figure 8 shows that erasing times ranging from 25 s to 130 s can be considered a safe time interval, with no probability of double exposure images occurring.

Discussion

The optimum level of brightness and contrast is a subjective criterion that depends on the observer's preference when analysing the radiographic image. A digital image is a dynamic image; its contrast and brightness can be changed according to one's needs. Radiographs need to be quite dark with good contrast to provide an optimal basis for caries diagnosis.¹⁸

Borg and Gröndahl¹⁷ reported that even though subjective image quality analysis does not completely reflect clinical diagnostic needs, it can be used as a comparative parameter for radiographic systems.¹⁶ This is mostly true when the observers are instructed to evaluate the quality of the images and not the appearance. In this study the observers assessed the information shown by the image using pre-established criteria. In addition, the appearance of the images was

Figure 4 Mean values and confidence intervals (CI) of brightness quality for each alternative erasing time

Figure 5 Mean values and confidence intervals (CI) of enamel definition for each alternative erasing time

standardized by the acrylic apparatus, allowing the same geometric pattern in all images.

The observers were not permitted to enhance the images assessed in this study, as the aim was to evaluate the influence of the erasing time on the subjective digital image quality. The presence of image noise on partially erased phosphor plates should be considered when enhancement of the image is needed. Versteeg *et al*²¹ noted that digital image density can be increased until it is adequate for diagnosis, but the enhanced digital image will show an increase in noise. Therefore, a higher amount of noise may be generated during digital enhancement if the digital image already has increased noise due to a suboptimal erasing time which will interfere with the final image quality.

According to Lopes *et al*,²¹ under adequate and controlled viewing box luminosity, the DenOptix® PSPs can be erased in 5 s, since incomplete erasing did not cause significant loss of diagnostic image quality in simulated clinical settings. The results in this study differ from Lopes *et al*,²¹ probably because in their study the observers were told to choose one of the paired images based on no specific criteria. Also, the object was an acrylic phantom fixed on the positioning apparatus to acquire a geometric pattern. The present study's object was moved from side to side on the apparatus so that the

Figure 6 Mean values and confidence intervals (CI) of dentine definition for each alternative erasing time

Enamel–dentine junction definition

Figure 7 Mean values and confidence intervals (CI) of dentinoenamel junction definition for each alternative erasing time

object's image was not superimposed, which could incorrectly lead to an image with higher density instead of a double image. Although there have been studies based on subjective image quality for alternative erasing times, an evaluation to determine whether these times interfere with the diagnostic quality of the image is mandatory.

Melo *et al*¹⁷ reported that erasing DenOptix® PSPs, using a 1700 lux light box for 20 s, did not influence the image quality for diagnosis of incipient proximal caries and pixel intensity values. The current study's results differ from Melo *et al*'s¹⁷ findings only for the erasing time of 20 s, which was not considered acceptable, especially for enamel definition, when subjective image quality was evaluated.

According to Albuquerque *et al*,¹⁸ alternative erasing times can be established based on light intensity, thereby reducing the erasing time by up to 74%. The results from the current study showed statistically significant differences between 130–25 s and 20–0 s for almost all the criteria studied. The results from this study demonstrate that reducing the erasing time to 25 s did not cause any deterioration of the overall image quality and did not result in the presence of double images. These findings suggest that the residual image on the PSP after alternative erasing times might be clinically acceptable, in agreement with Albuquerque *et al*'s findings.

This study showed that reducing the erasing time of the DenOptix® PSP to 25 s, using fluorescent light intensity of 1700 lux, does not cause any visual effects on the imaging quality parameters studied. This supports the hypothesis that any residual information on the phosphor plates, after using an erasing time of at

Table 1 Association of predicted probabilities and observer responses to double exposure

Per cent concordant	96.5	Somer's <i>D</i>	0.954
Per cent discordant	1.1	Gamma	0.978
Per cent tied	2.4	Tau-a	0.456
Pairs	95.16	C	0.977

Figure 8 Binomial logistic regression model to predict the occurrence of a double exposure image when using alternative erasing times

least 25 s, does not interfere with the image quality of the DenOptix® system. Further studies are needed to

verify the influence of this erasing time on noise and diagnostic quality of the image.

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