RANGE OF EXPOSURE TIME AND IMAGE QUALITY IN CONVENTIONAL AND DIGITAL RADIOGRAPHS: AN *IN VITRO* STUDY

Maria Ivete Rockenbach[1]
Karen Cherubini[2]
Elaine Bauer Veeck[1]
Nilza Pereira Costa[1]

[1]Department of Oral Surgery, Dental School, Pontifical Catholic University of Rio Grande do Sul, Porto Alegre, Brazil.

[2]Department of Dental Clinics/Oral Medicine, Dental School, Pontifical Catholic University of Rio Grande do Sul, Porto Alegre, Brazil.

ABSTRACT

The purpose of this study was to determine the range of exposure time to obtain acceptable bitewing radiographic images using conventional (InSight, Kodak) and digital (DenOptix™, Gendex) systems. Thirty sound molars were radiographed by bitewing technique at exposure times ranging from 0.06s to 2.50s. Five dental radiologists evaluated the resulting 340 radiographs, classifying them as (1) unacceptable, (2) acceptable and (3) of good quality. Frequencies were analyzed by Kruskal-Wallis and Wilcoxon tests, and inter-examiner agreement was determined by Cohen's kappa statistics. Radiographs of good diagnostic quality in conventional system were obtained with exposure times ranging from 0.10s to 1.00s while in digital system the time ranged from 0.06s to 1.60s ($P<0.05$). It was also observed that 75.3% of the digital images and 47.1% of the conventional images were considered of good quality. The digital system with phosphor plates (DenOptix™) produces acceptable interproximal radiographic images in a wider range of exposure time than the conventional system (InSight film).

Keywords: Bitewing radiography. Radiography. Dental. Digital. Exposure time. Radiation exposure. Laboratory research.

RESUMO

O objetivo deste estudo foi determinar o intervalo de tempo de exposição aceitável para obter imagens radiográficas interproximais utilizando sistemas convencionais (Insight, Kodak) e digital (DenOptixTM, Gendex). Trinta molares foram radiografados pela técnica interproximal em tempos de exposição variando de 0.06s de 2.50s. Cinco radiologistas odontólogos avaliaram 340 radiografias classificando-as como (1) inaceitáveis, (2) aceitável e (3) de boa qualidade. As freqüências foram analisadas pelo teste de Kruskal-Wallis e Wilcoxon, e concordância entre os examinadores foi determinada pela estatística kappa de Cohen. As radiografias de boa qualidade diagnóstica em sistema convencional foram obtidos com tempos de exposição variando de 0,10s a 1.00s, enquanto no sistema digital, o tempo variou de 0.06s a 1.60s para (P <0,05). Também foi observado que 75,3% das imagens digitais e 47,1% das imagens convencionais foram considerados de boa qualidade. O sistema digital, com placas de fósforo (DenOptixTM) produz imagens radiográficas interproximal aceitável em uma maior faixa de tempo de exposição do que o sistema convencional (filme InSight).

Palavras-chave: *Radiografia Bitewing. Radiografia dental digital. Tempo de exposição. Exposição à radiação. Pesquisa laboratorial.*

INTRODUCTION

Intraoral bitewing radiographs are widely used for complementary diagnosis of proximal caries since clinical examination may overlook early or secondary lesions. Digital systems provide several tools to manipulate the radiographic image and aid caries detection, such as changes of brightness and contrast, use of colors, determination of optical density of selected areas, examination in 3-dimension, correction of over- or underexposure, and linear and angular measurements. The main advantage of digital systems, however, is the possibility to use radiation doses lower than those of conventional radiographs. In addition, the images are displayed rapidly on a computer monitor, making the use of equipment and chemical solutions for film processing unnecessary (PFEIFFER et al., 2000).

Dental digital systems employ a charge-coupled device (CCD) or a phosphor plate to acquire the image instead of traditional radiographic films. The phosphor storage systems use an optical

plate of phosphor salts, similar in size and thickness to standard periapical films, and require a specific scanner to obtain images after exposure to X-rays (OLIVEIRA et al., 2000). Previous studies on systems with charge-couple device (FARMAN et al., 1995; WHITE; YOON, 1997) and with photostimulable phosphor plates (CONOVER et al., 1996; SVANAES et al., 1996) showed that the quality of digital images is similar to that obtained with conventional radiographic films.

Although digital image systems are becoming more popular, standards of use still are lacking. Therefore, it is necessary to establish guidelines for procedures of image acquisition and patient safety, which should include exposure time. A shorter exposure time is desirable to reduce the radiation delivered to the patient but should not compromise the radiographic image quality. The aim of this study was to determine the range of exposure time to obtain acceptable bitewing radiographs using the conventional system (InSight film, F-speed) and a digital system with photostimulable phosphor plates (DenOptix).

MATERIALS AND METHODS

The sample consisted of 30 sound human molars, extracted because of surgical indication. The teeth were washed in running water, scraped to remove organic residues, disinfected by immersion in 2% glutaraldehyde for 24h, and stored in saline until use. Ten groups of three teeth each were randomly formed. The three molars per group were positioned vertically, with the crowns maintaining proximal contact, and the roots were embedded in a 1-cm thick silicon block (Express STD™, 3M ESPE, St. Paul, MN, USA). The study protocol was approved by the Scientific and Ethics Committee of Dental School of Pontifical Catholic University of Rio Grande do Sul, Brazil (approval no. 0061/04).

Bitewings radiographs were taken from the ten groups using the conventional method and the digital system DenOptix™ (Gendex Digital Image System, Des Plaines, IL, USA). The tested exposure times were 0.06s, 0.08s, 0.10s, 0.12s, 0.16s, 0.20s, 0.25s, 0.32s, 0.40s, 0.50s, 0.64s, 0.80s, 1.00s, 1.25s, 1.60s, 2.00s, and 2.50s (Figure 1). The central ray was directed at the tooth crowns, in the buccolingual direction, with centric horizontal angulation and 0° vertical angulation. The conventional radiographs used periapical film InSight n.2 (Eastman Kodak Company, Rochester, NY, USA) and a standard dental X-ray equipment (Timex-70X DRS, Gnatus, Ribeirão Preto,

SP, Brazil. 70kVp, 7mA). Radiographic development was carried out in an automated machine (A/T 2000; Air Techniques Co, Hicksville, NY, USA) with developing time of 4.5min at 28ºC (Figure 2). Exposure of the 10 groups using the 17 different exposure times resulted in a total of 170 conventional radiographs. A total of 170 digital radiographs were also obtained using the optical plates (size 2: 31x41mm) of the digital image system DenOptix™.

Figure 1 - Example of a series of radiographs in the DenOptix digital system with different exposure times. The radiographs were shown as they were captured.

Five certified dental radiologists scored each radiograph as (1) unacceptable, (2) acceptable, or (3) of good quality, considering the adequate visualization and image clarity of the enamel, dentine, pulp, and root canals. The image evaluations were conducted under reduced illumination. The conventional radiographs were observed in an X-ray film viewer with a black mask with a central opening of 3x4cm. In the digital system, the images were examined in a 1024x768 pixels monitor (Dell, Round Rock, TX, USA), allowing the use of brightness and contrast tools (Figure 3). The radiographs were randomly distributed in both systems.
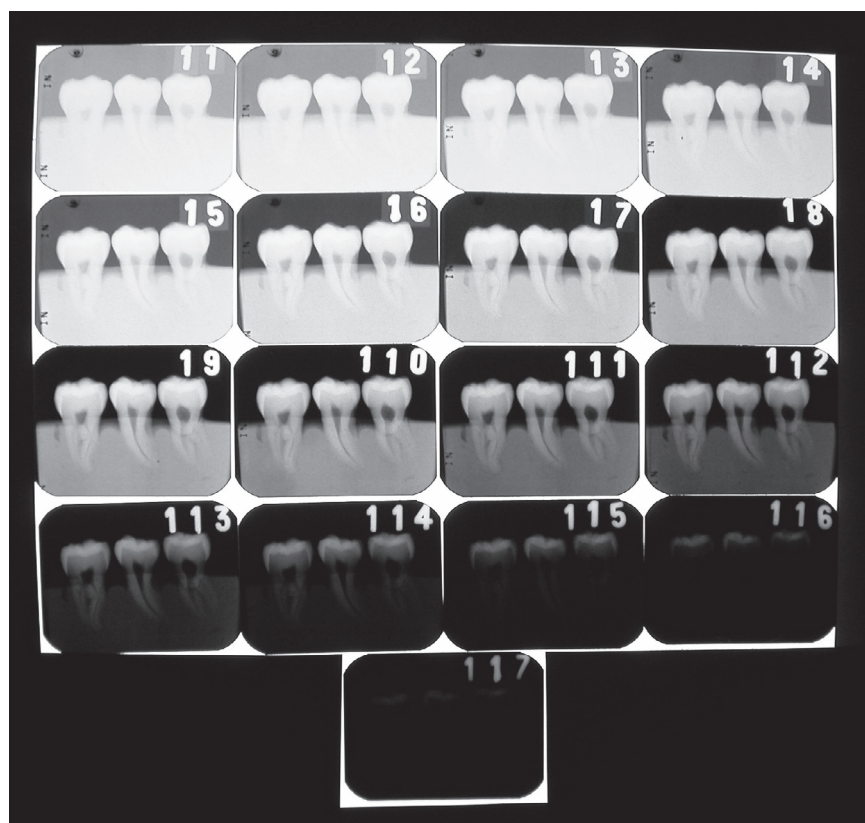
Figure 2 - Radiographs images produced with InSight with different exposure times.

Inter-examiner agreement was determined by Cohen's kappa statistics. Image quality data (modal score for each group of teeth and exposure time) were analyzed by Kruskal-Wallis and Wilcoxon tests.
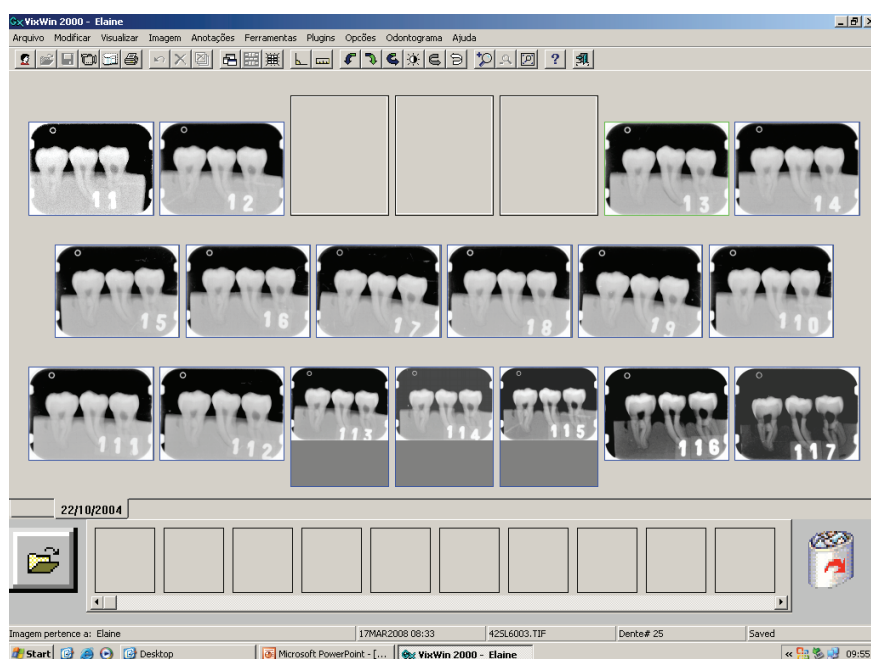
Figure 3 - Example of a series of radiographs in the DenOptix digital system with adjustments to enhance image quality.

RESULTS

The kappa values for inter-observer agreement ranged from 0.28 to 1.00 from conventional system and from 0.14 to 1.00 for digital system.

For the conventional radiographs, a significant difference was found among the exposure times (Kruskal-Wallis, P<0.05, Figure 1). Exposures of 0.06s, 0.08s, 1.25s, 1.60s, 2.00s and 2.50s produced images with high frequency of score 1 (unacceptable image) and low frequency of score 2 (acceptable image). Images from exposures of 0.16s, 0.20s, 0.25s, 0.32s, 0.40s, 0.50s, 0.64s and 0.80s showed high frequency of score 3 (good quality) and low frequency of scores 1 and 2 (Figure 4).

For the digital system, a significant difference was also demonstrated among the exposure times studied (Kruskal-Wallis, P≤0.05, Figure 2). The exposure time of 1.60s produced an image with uniform distribution among the three scores, whereas none of the images obtained with exposure times of 0.06s, 0.08s, 0.10s and 0.12s was classified as unacceptable, being distributed between scores 2 (acceptable) and 3 (good quality). For times of 0.16s, 0.20s, 0.25s, 0.32s, 0.40s, 0.50s, 0.64s, 0.80s, 1.00s and 1.25s, all images were

scored 3 by all examiners; for times of 2.00s and 2.50s all images were considered unacceptable (Figure 5).

Good quality images comprised 75.3 per cent of the digital images and 47.1 per cent of the conventional radiograph images. A comparison of the two systems showed that exposure times of 0.06s, 0.08s, 0.10s, 0.12s, 1.00s, 1.25s and 1.60s resulted in high frequency of scores 2 and 3 for the digital system (Wilcoxon, P=0.01). For the other exposure times no significant difference was found between the two systems (Wilcoxon, P=1.00).
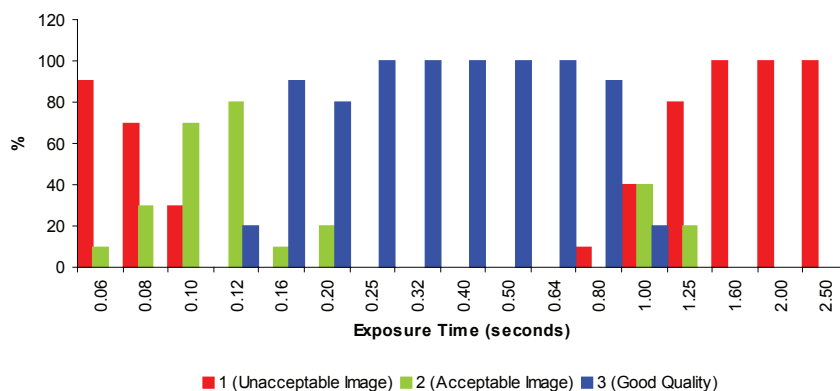

Figure 4 - Distribution of different exposure times according to image quality in the conventional system.
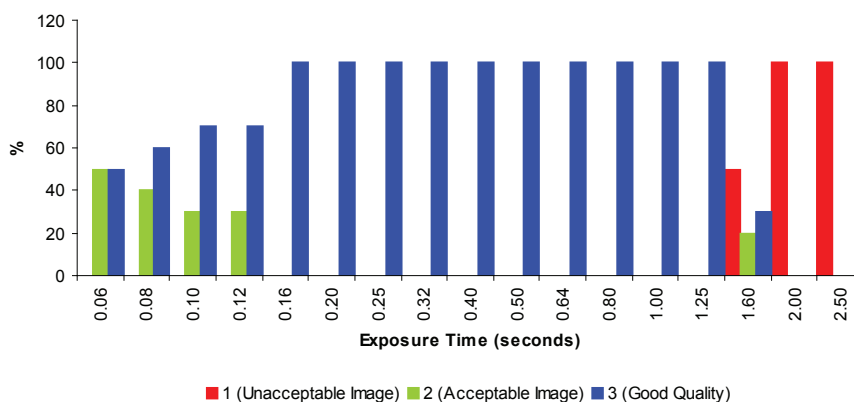

Figure 5 - Distribution of different exposure times according to image quality in the digital system.

DISCUSSION

Conventional radiographic films have an emulsion composed of silver bromide or iodide crystals, which when sensitized by X-

rays form a latent image visible after radiographic processing with chemical developers. The final image shows several shades of gray, which vary from absolute white to absolute black. A pixel is the digital equivalent of a silver crystal and has its location and gray level represented by a number in the computer. The number of shades of gray usually found in digital systems is 256; the darkest gray or black is given a value of zero, and the lightest or white, the value of 255. The diagnostic quality of a digitized image depends on the range of gray levels that it displays. It is improbable that a digital system captures all the gray levels of a radiographic image (KHADEMI, 1996). Conventional radiographs have a wider spectrum of gray levels than digitized images. Therefore, the subjective analysis of conventional radiographs limits the distinction of these shades of gray. Digitized images, on the other hand, can be analyzed mathematically, which makes its interpretation more efficient than for conventional radiographs, which is based on visual acuity (SARMENTO et al., 2000).

The principle of the computerized radiographic image is the mechanism of photostimulated luminescence. The imaging plate is covered with phosphors on a polyester base. When radiation falls on the plate, electrons are excited to a higher energy state and are trapped among phosphors crystals. After exposure, the latent energy is released from the plate upon scanning and converted to analogical and electric signals, digitized and stored in the computer. The residual energy on the plate is eliminated with exposure to halogen light, and the imaging plate can then be reutilized (KASHIMA, 1995; LIM et al., 1996).

The exposure time to radiation and radiographic processing are important factors for the image quality, but most dentists select exposure times that produce poor image quality and high radiation doses to speed up the radiographic processing (ARNOLD, 1987; YAKOUMAKIS et al., 2001). Previous studies showed that the radiation dose per exposure is lower in digital intraoral radiography than in conventional radiography (VELDERS et al., 1996; BORG et al., 1996; HUYSMANS et al., 1997; HINTZE et al., 2002). Moreover, there is no radiographic processing with chemical substances in digital systems. Thus, the shorter operational time and lower error rate in the processing of images are substantial advantages of the digital systems (HAAK et al., 2001). However, radiation dose also depends on the number of exposures, and professionals may take more digital radiographs than necessary because of the simple procedure and the short time to display the image on the screen (BERKHOUT et al., 2004).

This study showed that conventional radiograph images were scored acceptable with exposure times ranging from 0.10s to 1.00s, while in the digital system, the exposures ranged from 0.06s to 1.60s. In a similar study, Lim et al. (1996) reported acceptable images produced by computed radiography (Digora) for all tested exposure times (0.02s to 2.32s), but for conventional films (E-speed) only exposures from 0.38s to 1.8s provided acceptable images. Berkhout et al. (2004) investigated the quality of digital and conventional periapical radiographs for caries diagnosis, periapical lesions and periodontal changes. For the conventional system, the exposure time for the preferred radiograph was 0.52s, with a range from 0.23s to 1.02s for acceptable radiographs. The digital systems required less exposure than the conventional systems to obtain acceptable radiographs for diagnosis.

In the present study, the phosphor plate digital system provided radiographs of good quality with a range of exposure time wider than that of the conventional system. According to Berkhout et al. (2004), this fact can result in the use of high and unnecessary radiation doses for the patient. In digital radiography, the principle of radiation safety should be maintained, that is, the desired information should be obtained with the smallest possible amount of radiation. Due to the wide dynamic exposure range of the imaging plate, there is a minimal probability to occur under- or overexposure using different exposure times (LIM et al., 1996). Besides, phosphor plate systems do not indicate when an excessive exposure time is used (BERKHOUT et al., 2004). These systems also allowed to reduce the radiation dose to levels lower than those used in systems with sensors, however the limiting factor is the increase of the relative noise level (HUYSMANS et al., 1997). Noise increases at a very low dose, and the diagnostic accuracy is reduced.

The advantage of reducing the radiation dose by using shorter exposure time must not compromise the image quality. Svenson et al. (1994) recommended to increase the exposure time of radiographs for caries diagnosis because contrast and density increases proportionally with exposure. Although it is not possible to determine the independent effect of exposure time on density and contrast, the increase of these two factors provides greater accuracy in the detection of small lesions. On the other hand, Hildebolt et al. (1997) showed that small variations in exposure time alter the grayscale values of images obtained with phosphor plates. This, however, does not occur with digitized conventional radiographs, indicating that the phosphor plates are preferable when minimal differences in contrast need to be detected, such as in subtraction radiography.

The results of this study showed that three quarters of the digital images were considered of good quality, while only half of the conventional images reached such a score. The digital images were adjusted for brightness and contrast significantly improving the original images (LIM et al., 1996; PFEIFFER et al., 2000). Proper use of digital images can exceed conventional radiographic images in the detection of small alterations of mineralized tissues (YOSHIURA et al., 1999). With improvement of contrast, digital radiographs provide better visualization of structures than do conventional ones.

The safe and precise execution of the radiographic technique is essential since technology advances cannot compensate for techniques inadequately performed (ABBOTT, 2000). Acquiring diagnostic information without unnecessary exposure of patients and operators to the deleterious effects of radiation also depends on how rigorously the chosen technique is performed.

CONCLUSION

The digital system with photostimulable phosphor plate (DenOptix™) provides acceptable radiographs in a wider range of exposure time than the conventional system (InSight).

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