MAURO GUILHERME DE B. QUIRINO MARTINS

# INFLUÊNCIA DO TEMPO DE ESPERA, DE EXPOSIÇÃO E CONDIÇÕES DE LUZ EM IMAGENS OBTIDAS POR PLACAS DE ARMAZENAMENTO DE FÓSFORO

Tese apresentada à Faculdade de Odontologia de Piracicaba, da Universidade Estadual de Campinas, para obtenção do grau de Doutor em Radiologia Odontológica.

PIRACICABA

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Orientador: Prof. Dr. Francisco Haiter Neto

Banca Examinadora:

Prof[a]. Dr[a]. Luciane Farias de Araújo

Prof. Dr. Guilherme Monteiro Tosoni

Prof. Dr. Flávio Ricardo Manzi

Prof[a]. Dr[a] Gláucia Maria Bovi Ambrosano

Prof. Dr. Francisco Haiter Neto

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A Comissão Julgadora dos trabalhos de Defesa de Tese de DOUTORADO, em sessão pública realizada em 02 de Dezembro de 2005, considerou o candidato MAURO GUILHERME DE B. QUIRINO MARTINS aprovado.

PROF. DR. FRANCISCO HAITER NETO

PROFa. DRa. LUCIANE FARIAS DE ARAÚJO

PROF. DR. GUILHERME MONTEIRO TOSONI

PROF. DR. FLÁVIO RICARDO MANZI

PROFa. DRa. GLAUCIA MARIA BOVI AMBROSANO

Dedico este trabalho às pessoas mais importantes da minha vida: meus pais, meus irmãos, pelos sinceros momentos de confiança e amor.

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“Nenhuma grande vitória é possível sem que tenha sido precedida de pequenas vitórias sobre nós mesmos”.

L.M. Leonov

# SUMÁRIO

# RESUMO

O objetivo deste estudo foi verificar a influência do tempo de espera, tempo de exposição e condição de luz na qualidade final de imagens obtidas por placas de fósforo dos sistemas digitais DenOptix®, Digora® e Vistascan®. As placas foram sensibilizadas com uma escala de densidade, com a finalidade de realizar as análises objetivas, com um "*phantom*", constituído a partir de uma mandíbula macerada, para análise subjetiva e com dentes pré-molares, para o diagnóstico de cáries. As análises objetivas foram realizadas pelo valor do pixel dos *softwares* correspondentes aos sistemas digitais e estes dados, analisados estatisticamente pelos testes de Tukey e Dunnet. A análise subjetiva foi realizada por 3 radiologistas e os dados submetidos ao teste de Mann Whitney. Para o diagnóstico de cáries, foram utilizados oito avaliadores e os dados submetidos aos testes de Wilcoxom e Friedman. Como conclusões: 1. As imagens obtidas pelo sistema Digora® sofreram perda de qualidade de imagem a partir de 4 horas, após a exposição aos raios X; 2. O sistema DenOptix® apresentou-se estável quando submetido a diferentes tempos de exposição adequados e tempos de espera; 3. A qualidade da imagem das placas de armazenamento de fósforo é afetada pela qualidade dos invólucros plásticos disponíveis em cada sistema. Os invólucros do sistema Vistascan® foram capazes de proteger entrada de luz nas condições utilizadas por este estudo.

**Palavras-chaves**: Radiografia dentária, sistemas digitais, placas de armazenamento de fósforo, condições de armazenamento.

## ABSTRACT

The aim of this study was to verify the influence of the delay in scanning, exposure time and light condition in the final quality of images obtained using phosphor storage plates of DenOptix®, Digora® and Vistascan® digital systems. The plates were radiographed with an aluminium step wedge for the objective analysis, with a dry mandible for the subjective analysis and with premolars teeth for caries diagnosis. The objective analysis were carried through by the pixel value obtained from the corresponding softwares of each digital systems and these data analyzed statistically by Tukey and Dunnet tests. The subjective analysis were carried through by 3 radiologists and the data submitted to Mann Whitney U test. For caries diagnosis, eight observers were used and the data submitted to Wilcoxom and Friedman tests. As conclusions: 1. The images obtained using the Digora® system showed loss of quality of image at 4 hours after exposure; 2. The DenOptix® system presented a certain stability when subjected to different delays in scanning and exposure times; 3. The quality of the image of the phosphor storage plates is affected by the quality of the available plastic hygienic bags of each system. The bags of the Vistascan® system were able to protect under all the conditions used in this study.


**Key words:** radiography, dental; digital images; phosphor storage plates; storage conditions

# 1. INTRODUÇÃO GERAL

Com o rápido desenvolvimento da tecnologia, a informática passou a ser utilizada como auxílio a novos métodos de diagnóstico por imagem. Na década de 80, surge a radiografia digital representando um campo de constantes avanços e pesquisas na Odontologia, indo de encontro à redução da dose de radiação ao paciente (WENZEL & GRÖNDAHL, 1995).

Para a obtenção da imagem digital, podem ser utilizados os métodos indireto, semi-direto e direto. O método indireto utiliza o filme convencional como receptor da radiação que atravessa o paciente. A imagem analógica, contida na radiografia é registrada por meio de câmeras de vídeo ou *scanners*, transformada em números binários, tornando-se uma imagem digitalizada. Já no método semi-direto, a imagem é obtida por meio da exposição de placas de armazenamento de fósforo (PSP – *phosphor storage plates*), sendo posteriormente processadas por *scanner* apropriado. O método direto utiliza um dispositivo de carga acoplada (CCD – *charge-coupled device*) ou CMOS (*complementary metal oxide semiconductor*), que quando expostos aos raios X, geram uma imagem que é visualizada quase que instantaneamente na tela do computador.

O sistema de armazenamento de fósforo foi lançado pela Fuji em 1981 e os seus princípios descritos na literatura radiológica, em 1983. Mas, só em 1994, foi introduzido na Odontologia. Os principais representantes dos sistemas semi-indiretos de armazenamento de fósforo são: Digora (Soredex Finndent, 1994), DenOptix (Gendex Dental System, 1997) e em 2004 foi lançado pela Durr Dental o sistema Vistascan. Nestes sistemas, a imagem é obtida por meio da exposição de uma placa de armazenamento de fósforo (PSP) aos raios X que atravessam o paciente. O sensor se traduz numa placa óptica de sais de fósforo, que se caracteriza por não possuir fio acoplado e apresentar dimensões similares às do filme. Quando exposto à radiação, uma certa quantidade de energia é armazenada na sua superfície, criando uma imagem latente nos cristais da sua face ativa. O processamento da imagem é realizado posteriormente em um *scanner* apropriado que leva de 25 segundos(s) a 2 minutos(min) e 30s, dependendo do tamanho da placa escaneada, da resolução utilizada e do tipo do sistema. A imagem é então calibrada para uma produção de ótima qualidade e por meio de uma varredura à laser, a energia latente é liberada da placa, convertida numa série de sinais digitais-análogos, que são digitalizados e enviados ao computador, para exibição e armazenamento da imagem. Em alguns sistemas, após a leitura, se existir ainda alguma energia residual na placa, esta é descarregada por meio do brilho intenso de uma luz halógena, podendo-se, então, reutilizá-la inúmeras vezes. As placas do sistema semi-direto apresentam ainda como características, ampla escala dinâmica, face ativa de tamanho semelhante aos filmes convencionais e possuirem certa flexibilidade (BORG *et al.,* 2000; HILDEBOLT *et al.*, 2000; OLIVEIRA *et al.,* 2000b).

Além da boa qualidade de imagem da radiografia digital, diversas outras vantagens podem ser citadas, ressaltando-se: maior sensibilidade das placas, com redução do tempo de exposição de aproximadamente 50 a 80 % em relação ao filme convencional; aquisição rápida da imagem, com conseqüente redução do tempo de trabalho; ampliação com que a imagem é fornecida na tela do computador; eliminação do processamento químico, dispensando câmara escura, processadoras automáticas e ainda, o uso de soluções reveladoras e fixadoras, reduzindo assim as repetições das radiografias, pelo grande número de erros que ocorrem nesta fase; possibilidade de manipular a imagem por meio de recursos digitais ajustando-a a uma tarefa específica de diagnóstico; rápida aquisição de uma ficha clínica do paciente com suas respectivas imagens; facilidade de consulta instantânea com especialistas pela possibilidade de envio da imagem via *internet*; importante no trabalho educativo do paciente, facilitando o seu entendimento pela exibição das imagens na tela do monitor; maior escala dinâmica oferecida pelos sistemas de armazenamento de fósforo, com menor risco de sub ou superexposições; possibilidade de rapidamente ser feita cópia das imagens sem a necessidade de realizar uma nova exposição do paciente (HAITER NETO *et al*. 2000; WENZEL, 2000)

Já como desvantagens dos sistemas digitais, os mesmos autores citaram: o alto custo dos equipamentos e de sua manutenção quando necessária; o reduzido tamanho da face ativa dos sensores CCD/CMOS; o volume externo acentuado dos sensores CCD/CMOS; a rigidez dos sensores CCD/CMOS em comparação ao filme convencional; o fator legal das imagens digitais, e por último, a dificuldade de se conseguir na impressão a mesma qualidade daquela exibida na tela do monitor.

Ainda em 2000a, OLIVEIRA *et al.,* considerando os *softwares* dos sistemas digitais em seu estudo, referindo-se aos aspectos de relevante importância na seleção de um sistema radiográfico digital, elucidaram que, de maneira geral, todos os *softwares* dos sistemas digitais apresentam ferramentas básicas como manipulação do brilho e contraste, réguas digitais, pseudocolorização, inversão, relevo (3D) e *zoom*. Além de todas essas, alguns *softwares* apresentam ferramentas de mensurações angulares e verificação dos valores de densidade da imagem (valor do *pixel*).

Devido o alto custo dos equipamentos digitais e a possibilidade de aquisição das placas de armazenamento de fósforo separadamente ao *scanner*, em algumas condições, faz-se necessário armazená-las por um determinado período de tempo para posterior leitura. Tal situação é bastante comum nos trabalhos de pesquisa desenvolvidos nas universidades, onde muitas vezes a amostra radiográfica é coletada em lugares diferentes, como também, em uma situação clínica, com possibilidade de um único *scanner* ser utilizado por vários dentistas em momentos diferentes. O mesmo pode vir acontecer quando um exame periapical completo for realizado por um estudante principiante, uma vez que a primeira placa exposta pode ser escaneada com um certo tempo de espera, em relação à última placa exposta (FRIEDLAND, 1999; HAITER NETO *et al.*, 2000; AKDENIZ *et al.* 2005).

Sabe-se que o incorreto armazenamento dos filmes radiográficos convencionais, no que diz respeito às condições de temperatura ambiente, umidade e refrigeração, apresenta-se diretamente relacionado com a qualidade final da imagem. Estas condições também estão presentes na rotina dos usuários dos sistemas de armazenamento de fósforo. Ainda, o tempo de espera desde a exposição até o momento de escaneamento, como também as condições de luz ambiente, são informações importantes.

Os diferentes tempos e condições de armazenamento das placas de fósforo foram primeiramente estudados em 2003 por MARTINS *et al.* Foram realizados estudos objetivo e subjetivo de imagens obtidas pelos sistemas Digora (placa branca) e DenOptix, radiografando-se uma escala de densidade e uma mandíbula macerada, respectivamente. Imediatamente após as exposições, 12 placas foram escaneadas, caracterizando assim o grupo zero hora. As placas dos demais grupos foram escaneadas após 6, 12, 18, 24, 48 e 72 horas de armazenamento, em três diferentes condições: temperatura ambiente, refrigeração e isolamento da umidade. A análise objetiva foi realizada pelo valor do pixel e a análise subjetiva foi realizada por 3 radiologistas. Concluiu-se que não houve influência do tempo e da condição de armazenamento nas imagens radiográficas digitais obtidas pelo sistema DenOptix, havendo concordância entre as análises objetiva e subjetiva. No entanto, as imagens obtidas na análise objetiva do sistema Digora, apresentaram perdas de densidade a partir de 6 horas, em todas as condições estudadas. Ainda para este sistema, na análise subjetiva, a perda na qualidade da imagem foi observada a partir de 6 horas de armazenamento na condição refrigeração e 24 horas, para as demais condições estudadas.

Em maio de 2005 foi publicado por AKDENIZ *et al*, um estudo que verificou a resposta das placas de armazenamento de fósforo quando submetidas a diferentes tempos de exposição, condições de armazenamento e diferentes tempos de espera para o escaneamento. Quinze placas do sistema Digora (placas azuis) foram expostas entre 0.08 a 0.20 segundos e escaneadas imdediatamente, 10, 30 e 60 minutos e 24 horas após a exposição aos raios X. Foram também levadas em consideração as condições de armazenamento, luz do dia e caixa escura. Os autores recomendaram que as placas do sistema Digora sejam escaneadas no máximo, dez minutos após a exposição aos raios X, pois, períodos mais longos podem causar perda de qualidade da imagem.

Existem vários trabalhos na literatura que utilizam os sistemas digitais no diagnóstico de cárie (SYRIOPOULOS, *et al.*, 2000; GANZERLI, 2001). Entretanto, por terem sido lançadas no mercado recentemente, poucos trabalhos mostram a eficácia das novas placas azuis do sistema Digora. HINTZE *et al* (2002) compararam a precisão do diagnóstico de cáries proximais e oclusais de quatro sistemas de armazenamento de fósforo e de um filme radiográfico. Os autores utilizaram os sistemas digitais Digora, com a placa branca e a azul, o DenOptix, o Cd-Dent e o filme radiográfico Ektaspeed Plus na obtenção das radiografias, sob condições padronizadas, de 190 dentes extraídos. As placas de armazenamento de fósforo foram submetidas a dois tempos de exposição com respectivamente, 10% e 25% do tempo de exposição necessário à obtenção de radiografia com filmes convencionais. Quatro observadores avaliaram as imagens usando um *score* de 5 pontos. O exame histológico foi o método de validação empregado. Os resultados demonstraram que não houve diferença significativa na precisão do diagnóstico de cáries proximais entre os sistemas digitais Digora, DenOptix e o filme Ektaspeed Plus. Estes, por sua vez, foram mais precisos que o sistema Cd-Dent. Para cáries oclusais, o sistema Digora com a placa de fósforo azul foi o mais preciso dos sistemas digitais. O tempo de exposição influenciou na precisão do diagnóstico de cáries nas imagens obtidas com os sistemas digitais DenOptix e Digora (placa azul).

Desta forma, objetivamos neste trabalho, verificar a influência do tempo de espera de escaneamento, tempo de exposição e condições de luz em imagens obtidas por placas de armazenamento de fósforo.

# 2. PROPOSIÇÃO

De maneira geral, objetivou-se avaliar a influencia do tempo de espera, tempo de exposição e condições de luz em imagens obtidas por placas de armazenamento de fósforo.

Como objetivos específicos, foi proposto, dividido em três artigos:

1 - Verificar, objetiva e subjetivamente, o efeito de diferentes combinações de armazenamento e do tempo de espera no escanemento, nas primeiras quatro horas, após a exposição aos raios X, nas imagens obtidas pelo sistema Digora®.

2 - Avaliar objetivamente a resposta das placas de armazenamento de fósforo do sistema DenOptix®, quando submetidas a diferentes tempos de espera no escaneamento e diferentes tempos de exposição.

3 - Investigar a influência do tempo de espera no escaneamento das placas de armazenamento de fósforo, quando submetidas a diferentes condições de luz, no diagnóstico de cárie, utilizando os sistemas DenOptix®, Digora® e Vistascan®.

# 3. CAPÍTULOS

## 3.1 Capítulo 1

Artigo enviado e aceito para publicação no periódico Dentomaxillofacial Radiology.

**WHAT HAPPENS IF YOU DELAY SCANNING DIGORA PHOSPHOR STORAGE PLATES (PSP) FOR UP TO FOUR HOURS?**

MGBQ Martins[1], EJ Whaites[2], Ambrosano GMB[1], F Haiter Neto*[1]

*[1]Department of Dental Radiology, Piracicaba Dentistry School, University of Campinas, Brazil; [2]Guy`s, King`s and St Thomas` (GKT) Dental Institute, King`s College, University of London, London, UK*

***Correspondence to:**

**F Haiter Neto**
**Faculdade de Odontologia de Piracicaba – FOP/UNICAMP**
**Disciplina de Radiologia Odontológica**
**Av. Limeira, 901**
**Areião**
**Piracicaba – SP Brazil**
**CEP 13414-903**
**Tel: (19) 3412 5327**
**Fax: (19) 34125218**
**haiter@fop.unicamp.br**

## ABSTRACT

**Objectives:** To assess, both objectively and subjectively, the effects of different combinations of storage conditions and delaying scanning for up to four hours on digital images captured using Digora® phosphor storage plates.

**Method:** Standardised images were obtained of an aluminium step wedge and dry mandible in acrylic using GE 1000 and phosphor storage plates (PSP) from the Digora® (Soredex) digital system. 12 plates were exposed and immediately scanned to produce the baseline gold standard. The plates were re-exposed and stored using three different storage combinations – (A) ambient temperature, (R) refrigeration, and (S) low humidity and then scanned after 10 min, 30 min, 1 h, 2 h, 3 h and 4 h. The objective analysis was carried out by pixel density measurements and the data analysed statistically using analysis of variance. Subjective analysis was carried by 3 oral radiologists and the results analyzed using Mann Whitney U test.

**Results:** Objective analysis showed loss of pixel density after 4 hours using all storage combinations. Subjectively this loss of density was not evident.

**Conclusion:** There is a loss of image density at 4 hours when using Digora® PSPs which can not be detected clinically but could compromise multi-site research.

**Key words:** radiography, dental; digital images, phosphor storage plates, storage conditions

# WHAT HAPPENS IF YOU DELAY SCANNING DIGORA PHOSPHOR STORAGE PLATES (PSP) FOR UP TO FOUR HOURS?

## INTRODUCTION

Direct digital intraoral radiography systems are firmly established in clinical practice, and there is a steady increase in the number of general dental practitioners (GPDs) who wish to use digital radiography, although cost is still the main obstacle to going digital.[1,2,3]

Technical aspects, physical performance, image quality and exposure range of the digital systems have all been reported in the literature but there is still a lack of information on the effects of storage conditions and delaying reading on digital images captured using phosphor storage plates (PSPs). This may be important as it is often not possible to scan PSPs immediately after exposure and it may be possible to reduce costs by sharing a scanner between operatories.[4,5]

In previous research, published in 2003, we assessed, both objectively and subjectively, the effects of different combinations of storage conditions and varying delays in reading of up to 72 hours on digital images captured using two phosphor plate systems – DenOptix® (Gendex) and Digora® (Soredex).[6] The Digora® system showed statistically significant differences at the first reading following a delay of six hours. But the question remains - how quickly after exposing the plates did these detectable differences in image density become apparent? Therefore, the aim of this study was to repeat the previous research and to again assess, both objectively and subjectively, the effects of different combinations of storage conditions while delaying reading for different time intervals for up to four hours, on digital images captured using Digora® PSPs. In addition, to further test subjective assessments, we asked different oral radiologists to those involved in our previous research to view the images.

## MATERIAL AND METHODS

The methodology was identical to that used in our previous research - two different test objects were used for the different parts of the study. For the objective analysis, an aluminium step wedge of 2-16 mm thickness was used, with increments of 2 mm. For the subjective analysis, following ethical committee approval, a dry mandible was used covered with acrylic resin to simulate the soft tissues. This section of jaw presented sufficient anatomical and pathological characteristics for the subsequent radiographic images to simulate images obtained clinically. The plates were all exposed using a GE 1000 (General Electric Company, Millwaukee, WI, USA) intraoral X-ray unit.

Digital images were acquired using Digora® (Soredex, Helsinki, Finland) equipment and twelve standard size number 2 PSPs storage plates. Each Digora® plate has an active detection area of 40.0 x 30.0 $mm^2$. The plates were scanned at 360 dpi resolution. At this resolution the pixel size is estimated at 70 x 70 $\mu m^2$, resulting in a matrix of 416 x 560 pixels with 8-bit quantifying gray levels. This resulted in a spatial resolution around 6 pl/ $mm^{-1}$.

***Objective study:***

For the objective part of the study, separate exposures were made of the aluminium step wedge using three Digora® plates. The exposure factors were adjusted to 70 kVp, 10 mA and exposure time of 0.4 s using a focus-detector distance of 40cm. Each plate was scanned, following the manufacturer's instructions, immediately following the exposure (to avoid any possible effects of time delay or storage conditions) to provide the gold standard images. Each set of three plates were then cleared and reused. Identical exposures of the aluminium step wedge were repeated. However, scanning was delayed for 10 minutes after the exposures during which time the plates were stored in *Storage Condition (A) Ambient temperature (25$^0$C and 60% humidity)* by placing them in a drawer simulating conditions in a dental surgery. The temperature and humidity were measured using a digital thermometer and hydrometer (TFA Dostmann, Wertheim-Reicholzheim, Germany). The procedure was repeated; the plates were cleared, re-exposed and stored under the same conditions but each time scanning was delayed for 30 minutes, 1h, 2h, 3h and 4 h.

The entire procedure was repeated using the same exposure factors and using the same time delays in scanning, but with the plates stored in *Storage condition (R) Refrigeration (7.4$^0$C and 48% humidity)* achieved by placing the plates in the lower part of a refrigerator; it was then repeated again using *Storage*

*Condition (S) Low humidity (25.3$^0$C and 26% humidity)* achieved by placing the plates in a closed plastic box containing silex. Temperature and humidity was measured continuously in the three different storage conditions.

In total 57 exposures of the step wedge were carried out (3 gold standard plus 18 in each of the three different storage conditions covering the six different storage times).

The images were evaluated by the Digora software (Digora for Windows 1.51). Density (pixel value) measurements were made using the appropriate tool from the software, from which the average image density was obtained for each set of three plates. The results were then statistically analysed for any differences as a result of the different storage conditions or as a result of the different time delays in scanning using analysis of variance followed by the Tukey and Dunnet statistical tests.

***Subjective study:***

For the subjective part of the study, separate exposures were made of the dry mandible using nine Digora® plates using exposure factors of 60 kVp, 10 mA, 0.2s using a focus-detector distance of 32cm. Once again, each plate was scanned immediately following the exposure (to avoid any possible effects of time delay or storage conditions) to provide the gold standard images. Each set of nine plates were then cleared and re-used. Scanning was again delayed for 10min, 30min, 1h, 2h, 3h or 4 h with the plates stored in the same three storage conditions A, R and S used in the objective study.

171 exposures of the dry mandible were carried out (9 gold standard plus 54 in each of the three different storage conditions covering the six different storage times).

All captured images from the different times and storage conditions were randomly distributed and evaluated by three experienced oral radiologists, but different from those involved in the previous study. Before the analysis of these images, the evaluators were instructed in the digital system being used and how they should evaluate the images. They were asked to assess image quality by reference to the main anatomical tissues (enamel, dentine, pulp, periodontal ligament space, lamina dura and trabecular pattern) and score the images as: 0 = poor quality image; 1 = reasonable quality image; 2 = good quality image and 3 = excellent quality image. After the clinical evaluation, the values were tabled and submitted to statistical analysis using the Mann Whitney U test.

## RESULTS

The results for each part are presented separately:

- Objective study
- Subjective study

***Objective study***

The gold standard plates produced a mean density (pixel value) of 170.98. The mean densities obtained from the sets of plates stored in the three different storage conditions for the six different time periods are shown in Table 1.

**TABLE 1**

**Mean density (pixel value) in the objective analysis of the Digora® system**

| Time | Method | | | |
|---|---|---|---|---|
| | (A) Ambient | (R) Refrigeration | (S) Low Humidity | Tukey** |
| | Mean Density | Mean Density | Mean Density | |
| 10 min | 168.94 | 169.78 | 170.19 | A |
| 30 min | 168.89 | 171.15 | 168.71 | A |
| 1 h | 169.72 | 170.63 | 168.77 | A |
| 2 h | 169.53 | 172.08 | 170.15 | A |
| 3 h | 169.68 | 170.47 | 169.23 | A |
| 4 h | 160.68* | 160.49* | 160.85* | B |
| Tukey** | B | A | B | |

Gold standard group mean density = 170.98, coefficient of variation = 0.68%
* Differ from the gold standard group by the Dunnet test (p<0,05).
**Similar letters in the horizontal and in the vertical (capital and lower case) do not differ among themselves, but different letters in the horizontal and in the vertical (capital and lower case), do differ among themselves by the Tukey test (p<0,05).

The differences in mean density, from the gold standard, for each set of plates was not statistically significant until after 3 hours delay in scanning, as shown in Table 1. However, the mean density values obtained after 4 hours delay in scanning, for all three different storage conditions, were statistically significant.

Comparison of the means of the experimental groups indicated that the mean density between the storage conditions was statistically different; with storage conditions A and S different from storage condition R. Also, there was statistical significant difference at 4 hour storage time, as shown in Table 1.

The actual percentage differences between the gold standard image density and the image densities obtained after the varying time delays in the different storage conditions are shown in Table 2. The differences up until 3 hour delay vary between -1.3 % and + 0.64% confirming their lack of statistical significance. After 4 hour delay in scanning, these percentages varied between - 6.1 and - 5.9 % confirming their statistical significance.

**TABLE 2**

**Differences (%) between the image densities after the different scanning times and in the different storage conditions when compared to the gold standard group for the Digora® system**

| Time | Method | | |
| --- | --- | --- | --- |
| | (A) Ambient | (R)Refrigeration | (S) Low Humidity |
| 10 min | - 1,19 | - 0,69 | - 0,46 |
| 30 min | - 1,22 | 0,09 | - 1,32 |
| 1 h | - 0,73 | - 0,20 | - 1,28 |
| 2 h | - 0,84 | 0,64 | - 0,48 |
| 3 h | - 0,75 | - 0,29 | - 1,02 |
| 4 h | - 6,02 | - 6,13 | - 5,92 |

### *Subjective study*

The median frequency of the subjective scoring by the three oral radiologists assessing the Digora® plates are shown in Tables 3, 4 and 5. Table 3 shows the results of the plates stored in *Storage Condition (A),* Table 4 shows *Storage Condition (R)* and Table 5 shows *Storage Condition (S*).

**TABLE 3**

**Median frequency of the scores used by the 3 evaluators after the different scanning times in storage condition (A) Ambient temperature for the Digora® system images, with the *p* values of the Mann Whitney U test**

| Time | Reasonable | Good | Excellent | *P* |
|---|---|---|---|---|
| Gold standard | 0 | 1 | 8 | |
| 10 min | 0 | 1 | 8 | 1 |
| 30 min | 0 | 2 | 7 | 0.6911 |
| 1 h | 0 | 1 | 8 | 1 |
| 2 h | 0 | 1 | 8 | 1 |
| 3 h | 0 | 0 | 9 | 0.6911 |
| 4 h | 0 | 0 | 9 | 0.6911 |
| Total Global | 0 | 6 | 57 | |

**TABLE 4**

**Median frequency of the scores used by the 3 evaluators after the different scanning times in storage condition (R) Refrigeration for the Digora® system images, with the *p* values of the Mann Whitney U test**

| Time | Reasonable | Good | Excellent | *P* |
|---|---|---|---|---|
| Gold standard | 0 | 1 | 8 | |
| 10 min | 0 | 0 | 9 | 0.6911 |
| 30 min | 0 | 1 | 8 | 1 |
| 1 h | 0 | 0 | 9 | 0.6911 |
| 2 h | 0 | 0 | 9 | 0.6911 |
| 3 h | 0 | 1 | 8 | 1 |
| 4 h | 0 | 1 | 8 | 1 |
| Global Total | 0 | 4 | 59 | |

**TABLE 5**

**Median frequency of the scores used by the 3 evaluators after the different scanning times in storage condition (S) Low humidity for the Digora® system images, with the *p* values of the Mann Whitney U test**

| Time | Reasonable | Good | Excellent | p* |
|---|---|---|---|---|
| Gold standard | 0 | 1 | 8 | |
| 10 min | 0 | 0 | 9 | 0.6911 |
| 30 min | 0 | 0 | 9 | 0.6911 |
| 1 h | 0 | 1 | 8 | 1 |
| 2 h | 0 | 0 | 9 | 0.6911 |
| 3 h | 0 | 0 | 9 | 0.6911 |
| 4 h | 0 | 0 | 9 | 0.6911 |
| Global Total | 0 | 2 | 61 | |

The results indicate that, irrespective of storage conditions or the length of time that scanning was delayed, the radiologists were unable to detect any statistically significant loss in image quality compared to the gold standard images.

## DISCUSSION

The Digora® digital system was the first storage phosphor system designed for intraoral use (1994) and since than, it has been widely used in clinical practice. The system has been widely studied by different workers who have reported many advantages, including: read-out of plates accomplished in about 25 seconds, immediate erasure of residual energy from the plate after read-out[7], superior quality images generally produced when compared to other systems[8,9], wider dynamic range than other systems[10], accurate caries detection [11,12].

In our previous study, scanning was delayed for six hours before the first readings were made and the Digora® system presented with significant objective loss of pixel density immediately. Although these differences were not evident in the subjective analysis, what happens to the plates during the first six hours could be of importance for multi-site research.

The results of this study showed that the objective loss of pixel density was only statistically different if scanning was delayed for 4 hours. For the first three hours no differences were detected – a possible important consideration in clinical practice and in multi-site research.

Loss of image density clinically was assessed by the subjective analysis. Using three different oral radiologists from the previous study the results were still the same, in that they were unable to detect any significant differences in the images over the four hour delay period. Subjectively, the loss of density found in the objective analysis was not evident within 4 hours.

The density differences for the Digora® system found in both this, and our previous objective studies could not have been detected in the subjective analysis, because, as reported by Van der Stelt in 2000, the human eye is unable to discern more than 100 gray levels[13]. Mauriello and Platin in 2001, reported that, in general, this value reaches no more than 32 gray levels[14]. The objective density differences detected represented approximately only 11 gray scale differences.

In conclusion, when using Digora® PSPs, there was no loss of image density within the first three hours, but after delaying scanning for four hours an objective loss of density was detectable on plates stored in all three different storage conditions. This might compromise multi-site research. However, subjectively this loss density after four hours was not detectable so clinical diagnosis should not be affected even if scanning is delayed.

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## 3.2 Capítulo 2

Artigo em fase final de correção e que será enviado para o periódico Dentomaxillofacial Radiology.

**RESPONSE OF PHOSPHOR STORAGE PLATES (PSP) WHEN SUBJECTED TO DIFFERENT EXPOSURE TIMES AND DELAYS IN SCANNING**

MGBQ Martins[1], EJ Whaites[2], Ambrosano GMB[1], F Haiter Neto*[1]

*[1]Department of Dental Radiology, Piracicaba Dentistry School, University of Campinas, Brazil; [2]King's College London Dental Institute at Guy`s, King`s College and St Thomas` Hospitals, London, UK*

***Correspondence to:**

**F Haiter Neto**
**Faculdade de Odontologia de Piracicaba – FOP/UNICAMP**
**Disciplina de Radiologia Odontológica**
**Av. Limeira, 901**
**Areião**
**Piracicaba – SP Brazil**
**CEP 13414-903**
**Tel: (19) 3412 5327**
**Fax: (19) 3412 5218**
**haiter@fop.unicamp.br**

## ABSTRACT

**Objectives:** To investigate objectively the response of DenOptix® phosphor storage plates when subjected to different exposure times and varying delays in scanning.

**Method:** Standardised images were obtained of an aluminium step wedge using a GE 1000 intra-oral X-ray unit and phosphor storage plates (PSP) from the DenOptix® (Gendex) digital system. The plates were initially subjected to exposure times of 0.2, 0.3, 0.4, 0.6 and 0.8 seconds and in each case scanned immediately. The plates were subsequently re-exposed using the same exposure times but scanning was delayed by 2, 4, 6, 12, 18 and 24 hours. The objective analysis was carried out by pixel density measurements and the data statistically analysed using the Tukey test.

**Results:** There were no statistically significant differences in the mean densities of the PSPs whether 0.2, 0.3 or 0.4 exposure times were used or whether scanning time was delayed up to 24 hours. However, when exposure time was increased to 0.6 secs there was a statistically significant difference in mean density if the plate was read immediately. If scanning was delayed for 2 hours or more this difference disappeared. If the exposure time was increased to 0.8 secs the difference in mean density was again significant and remained so until scanning was delayed by more than 6 hours.

**Conclusion:** The DenOptix system tends to be very stable when subjected to different exposure times and varying delays in scanning. However, exposure times

in excess of 0.6 secs can significantly affect image quality if scanning time is not delayed.

**Key words:** radiography, dental; digital images, phosphor storage plates, storage conditions

# RESPONSE OF PHOSPHOR STORAGE PLATES (PSP) WHEN SUBJECTED TO DIFFERENT EXPOSURE TIMES AND DELAYS IN SCANNING

## INTRODUCTION

Many advantages have been reported of using phosphor storage plates (PSPs) over conventional film including: dose reduction, elimination of chemicals used in film processing, reduction of working time from image exposure to image display, teletransmission capability and greater dynamic range.[1-5]

*Dynamic range* is the digital imaging equivalent to exposure latitude when using X-ray film. Both these terms describe the range of exposures over which a system produces diagnostically acceptable images. The effect of varying the exposure factors has been reported on the sensitometric properties, resolution, subjective image quality, clinical image quality and the dynamic range itself from the two best known PSP systems - the DenOptix® (Gendex) and the Digora® (Soredex) systems.[6-9] The effect of small variations in X-ray exposure on the relationship between the dynamic range, dose reduction and risk of over exposure has also been investigated.[10,11]

The main disadvantage reported for not converting to digital imaging has been the high initial cost of the various systems available.[12] One option of reducing costs that has been suggested is that different dentists can easily share one centrally located PSP scanner.[13,14] As result, individual phosphor plates may not be scanned immediately and many external factors such as temperature, humidity, and different light conditions could potentially affect the phosphor plate and degrade the quality of the final image obtained by the time the plate is scanned. Our previously reported study, aimed to assess the effects of different combinations of storage conditions and varying delays in scanning for up to 72 hours on digital images captured using both the DenOptix® and Digora® phosphor plate systems.[15] In 2005 Akdeniz *et al* published a paper which investigated the effect of delayed scanning when using the Digora® plates.[16] To our knowledge no previously published study has investigated the relationship between dynamic range and delay in scanning when using DenOptix® plates. Therefore, the aim of this study was to verify, by means on an objective study, the response of PSPs from the DenOptix® system when subjected to a wide exposure range as well as varying delays in scanning.

## MATERIAL AND METHODS

### *Test object and X-ray source*

An aluminium step wedge of 2-16 mm thickness, with increments of 2 mm was used as the test object. Exposure were made using a GE 1000 (General Electric Company, Millwaukee, WI, USA) intraoral X-ray unit operating at 70kVp, 10 mA and using a focus-detector distance of 40cm.

### *Digital equipment*

Digital images were acquired using the DenOptix® (Gendex Dental Systems, Milan Italy) equipment and three standard size (No.2) phosphor storage plates (41.0 x 31.0 mm). The plates were scanned at 300 dpi resolution, with a matrix size of 485 x 367 pixels and 8 bit gray sale.

### *Method*

Separate exposures were made of the aluminium step wedge using the three DenOptix® plates. The plates were initially exposed using an exposure time of 0.2 secs and then immediately scanned. The plates were cleared and then repeatedly re-exposed using gradually increased exposure times of 0.3s, 0.4s, 0.6s and 0.8s. For each exposure time, the plates were again scanned immediately following exposure. These immediately scanned images provided the gold standard. The plates were again cleared and the procedure repeated using the same five different exposure times but scanning was delayed for 2 hours after exposure. The entire procedure was repeated five more times with the scanning time delayed on each occasion for 4, 6, 12, 18 and 24 hours.

All images obtained were evaluated by the Gendex software (Vixwin 2000; Gendex Dental Systems). Density (pixel value) measurements were made using the appropriate tool from the software. The data was statistically analysed using the Tukey test for subsequent multiple comparisons.

# RESULTS

When the data were submitted to the Tukey test (Table 1), there were no statistically significant differences among the means densities except for immediately scanned images using the 0.6 second exposure and for the images obtained after exposure for 0.8 seconds when scanning was delayed up to 6 hours (lower case).

TABLE 1

Mean densities (pixel value) for the DenOptix® system

| Delay in Scanning (h) | Exposure time (s) | | | | |
|---|---|---|---|---|---|
| | 0.2s | 0.3s | 0.4s | 0.6s | 0.8s |
| 0 | 182.7 Aa | 181.7 Aa | 179.7 Aa | 148.0 Bb | 123.3 Cd |
| 2 | 183.3 Aa | 182.7 Aa | 179.7 Aa | 179.0 Aa | 146.7 Bc |
| 4 | 185.3 Aa | 181.3 Aba | 181.3 ABa | 178.3 Ba | 160.7 Cb |
| 6 | 185.3 Aa | 182.3 Aba | 179.3 Ba | 179.0 Ba | 158.7 Cb |
| 12 | 184.7 Aa | 183.3 Aba | 180.0 BCa | 178.7 Ca | 175.7 Ca |
| 18 | 184.3 Aa | 182.3 Aba | 181.7 ABa | 179.3 BCa | 177.0 Ca |
| 24 | 184.3 Aa | 182.7 Aba | 181.3 ABa | 179.3 Ba | 178.7 Ba |

General mean = 176.33; variance coefficient = 1.118 %
Similar letters in the horizontal (capital) and vertical (lower case) do not differ among themselves, but different letters do differ among themselves by the Tukey test ($P<0.05$).

When the data were submitted to the Tukey test for analysing the delay in scanning, statistically significant differences were found when there was an increase of exposure time of 0.6 and 0.8 seconds.

The actual percentage differences between the image densities obtained using the 0.4 seconds exposure time and the image densities obtained using different exposure times and after varying delays in scanning are shown in Table 2. Large differences in percentage were found when the plates were exposed for 0.6 and 0.8 seconds and scanned immediately. After a 0.8 second exposure substantial differences remained for 6 hours although they gradually reduced during this time period. The differences for all the others variable conditions only vary between -2.58 % and + 3.34% confirming their lack of statistical significance.

**TABLE 2**

**Differences (%) between the image densities after the different exposure times and delays in scanning when compared to the 0.4s for the DenOptix® system**

| Delay in scanning (h) | Exposure time (s) | | | | |
|---|---|---|---|---|---|
| | 0.2s | 0.3s | 0.4s | 0.6s | 0.8s |
| 0 | 1,669 | 1,113 | 0 | -17,641 | -31,386 |
| 2 | 2,003 | 1,669 | 0 | -0,390 | -18,364 |
| 4 | 2,206 | 0,000 | 0 | -1,655 | -11,362 |
| 6 | 3,346 | 1,673 | 0 | -0,167 | -11,489 |
| 12 | 2,611 | 1,833 | 0 | -0,722 | -2,389 |
| 18 | 1,431 | 0,330 | 0 | -1,321 | -2,587 |
| 24 | 1,655 | 0,772 | 0 | -1,103 | -1,434 |

## DISCUSSION

When the DenOptix® digital plates were evaluated in our previous study published in 2003,[15] it was shown that their behaviour was very stable and that they were essentially unaffected by different storage conditions and delays in scanning, when compared to the Digora® system. This initial study raised the question of how would the DenOptix plates behave if they were subjected to different exposure times, and could the time delay before scanning be increased, without affecting image quality, in order to provide more working time.

The mean densities found in our previous study (around 180) were very similar to those found in the present study when the exposure time of 0.4s was used (Table 1) confirming the stability of this system. However, large, significantly different, mean densities were achieved when the exposure time was increased to 0.6 and 0.8 seconds and the plates scanned immediately. This difference disappeared when the plates exposed for 0.6 seconds were delayed in their scanning by two hours. However, a difference persisted for 6 hours when the plates were exposed for 0.8 seconds, although it gradually decreased with the passage of time and the mean densities became closer to the other mean densities found in this study. These differences are confirmed when using the Tukey test. Moreover, it became even clearer when noting the percentage differences which varied between -11,48% to - 31,38.%

When the Digora® system was evaluated using basically the same methodology used in this study, Akdeniz *et al* recommended scanning the Digora® plates within 10 minutes after exposure because delaying longer may result in loss of image quality. [16] Based on the results of this study, it appears possible to scan DenOptix® plates at least one day after exposure when using low exposure times without loss of image quality. On the other hand image quality is compromised if exposure times are increased, but this loss of quality is considerably less if the scanning the plate is delayed.

The differences found between the two systems may be because the Digora® system presents a wider dynamic range as reported by Oliveira *et al.*[9] and/or because adjusting the gray scale range using the Digora® requires pre-scanning by the predetermined maximum exposure level.[6]

In conclusion, doubling the exposure time of DenOptix® phoshor plates from 0.2 to 0.4 secs does not affect the quality of the latent image or how long it remains in the plate for up to 24 hours. Increasing exposure times does not achieve more working time if a DenOptix® scanner is not immediately available. Exposure times in excess of 0.6 secs can significantly affect image quality if scanning time is not delayed.

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## 3.3 Capítulo 3

Artigo em fase final de correção e que será enviado para o periódico Dentomaxillofacial Radiology.

**THE INFLUENCE OF LIGHT CONDITIONS AND POSTPONED SCANNING OF IMAGE PLATES ON CARIES DIAGNOSIS**

MGBQ Martins[1], F Haiter Neto[1], WER Berkhout[2], K Syriopoulos[2], GCH Sanderink[2]

[1]Department of Dental Radiology, Piracicaba Dentistry School, University of Campinas, Brazil;
[2] Department of Oral Radiology, Academic Centre for Dentistry Amsterdam (ACTA), The Netherlands.

***Correspondence to:**

F Haiter Neto
Faculdade de Odontologia de Piracicaba – FOP/UNICAMP
Disciplina de Radiologia Odontológica
Av. Limeira, 901
Areião
Piracicaba – SP Brazil
CEP 13414-903
Tel: (19) 3412-5327
Fax: (19) 3412-5218
**haiter@fop.unicamp.br**

## ABSTRACT

**Objective:** To investigate the influence of postponed scanning of phosphor storage plates under different light conditions on the accuracy of the detection of proximal caries.

**Method:** Seventy-two premolars with sound, enamel and dentin caries were radiographed under standardized conditions using the DenOptix® (Gendex), Digora® (Soredex) and Vistascan® (Dürr Dental) storage phosphor plate systems. The phosphor plates were scanned immediately, 15 min, 30 min, 1 hour and 4 hours after they were exposed. During these periods, the plates were stored under three different conditions: total darkness, office and daylight conditions. Eight observers evaluated the images under standardized conditions. The medians obtained from the observers scores were used, Kappa test was performed as well as Wilcoxom and Friedman tests. Differences were considered statistically significant when $P < 0.05$.

**Results:** Histological examination of the 72 approximal surfaces showed: 20.8% sound, 25% enamel, 16.7% reaching the amelodentinal junction and 37.5% dentin lesions. For the DenOptix® system, significant differences were found after 15 min storage in daylight and after 30 min storage under office light conditions. For the Digora® only in daylight after 60 min storage significant differences were found. For the Vistascan® no significant differences were found at all.

**Conclusion:** The image quality of scanned phosphor storage plates is affected by the poor protection against light of the hygienic bags. Only the bags from the Vistascan® were able to protect the plates under all storage conditions.

**Key words:** radiography, dental; digital images, phosphor storage plates, storage conditions

# THE INFLUENCE OF LIGHT CONDITIONS AND POSTPONED SCANNING OF IMAGE PLATES ON CARIES DIAGNOSIS

## INTRODUCTION

For many years, the Digora® System (Soredex, Helsinki, Finland) and the DenOptix® System (Gendex, Milan, Italy) remained the two most common used phosphor storage plates (PSPs) systems in dentistry and reports are found in the literature on physical performance, sensitometric properties and resolution, subjective image quality and exposure range of those systems.[1-6] It is clear that, even though those two systems present the same photon detector system (PSPs), they do have a different behavior when evaluated. Recently, Dürr Dental launched another option for storage phosphor plates: the VistaScan® System.

For caries diagnosis, exposure time using the PSP can be relatively low without effect on image quality and diagnostic outcome, consequently reducing patient dose.[7] Comparisons of Digora® and the DenOptix® were found in several studies but until present no comparison including the VistaScan® system is found.[8-10]

In many dental offices the phosphor plate scanner is used to serve several operatories and the scanning of the plates is postponed until a more favorable moment. As a result, room light conditions may play an important role as visible light has a degrading effect. Molteni showed this effect using lead test objects in laboratory conditions.[11]

In a previous study the effect of different storage conditions and delays in reading of up to 72 hours on digital images captured using Digora® and DenOptix®' were evaluated, both objectively and subjectively.[12] In that study, temperature and humidity of different combinations of storage with no light effects were checked. It means that all the plates were stored in dark environments. Differences were found between the two systems and the necessity of investigating the influence of the visible light effects on caries diagnosis was needed.

Therefore, the aim of this study was to asses the influence of the delay in scanning PSPs and storage conditions on caries diagnosis using Digora®, DenOptix® and VistaScan® systems.

## MATERIAL AND METHODS

### *Test objects*

Seventy-two unrestored extracted human premolars were selected for this study. The selection criterion for the distribution of caries lesions was based on approximately 25% for each group of teeth as follows: sound, enamel caries, amelodentinal junction caries and dentine caries. Caries depths were estimated histological sectioning. The teeth were randomized and mounted in plaster to simulate a jaw section in groups of five (one additional premolar was added to create a normal contact point to the last premolar). For the evaluation only one surface per tooth was used. A grand total of 18 blocks was produced. For each radiograph, two blocks were used simulating a bitewing radiograph, resulting in 9 bitewing radiographs and consequently 72 surfaces were evaluated.

***Exposure settings***

The exposures were made with a Heliodent MD (Siemens, Bensheim, Germany) operating at 60 kV DC and 7 mA, 1,5 mm AL equivalent filtration and a half-value layer of 1.9 mm Al. The x-ray beam was collimated to a 3 x 4 cm rectangular field at the end of the spacer cone and a focus-receptor distance of 30 cm was used for all the exposures. A specially designed holder was used in order to allow standard projection geometry. A layer of 20 mm thick soft tissue equivalent material was placed between the cone end and the test objects. The exposure time was set at 0.16 seconds for all the exposures.

***Digital systems***

Three digital systems were used in the investigation: the DenOptix® (Gendex, Milan, Italy), the Digora® (Soredex, Helsinki, Finland) and the Vistascan® (Dürr Dental, Bietigheim-Bissingen, Germany) equipments and standard size number 2 phosphor storage plates from each digital system. The DenOptix® plates can be scanned at 150, 300 and 600 dpi and the 300 dpi was choosen. The Digora® plates were scanned at 360 dpi, where no other resolutions are available. The Vistascan® plates can be scanned in two different spatial resolutions: 10 and 20 Lp/ $mm^{-1}$. In this study, the 10 $mm^{-1}$ spatial resolution was used. Table 1 shows other specifications of the digital systems used.

**Table 1**

Specifications of the digital systems used in this study

| *Digital System* | *Active Surface* | *Matrix Size* |
|---|---|---|
| DenOptix® System | 41.0 x 31.0 mm | 485 x 367 pixels |
| Digora® System | 40.0 x 30.0 mm | 416 x 560 pixels |
| Vistascan® System | 40.0 x 30.0 mm | 808 x 619 pixels |

***Plastic barriers***

The manufacturers of the digital systems provide their own plastic barrier to protect the plates against external light. In this study the plates were packed in the plastic bags as provided by the manufacturers.

***Scanning procedure and storage conditions***

Scanning was performed according to the manufacturer instructions. The Digora® scanner was calibrated according to the manufacturer instructions and for DenOptix® and Vistascan® the default settings were used. One series of images was scanned immediately after exposure (0 hour) creating a set of images scanned under ideal conditions with neither effects of storage condition nor delay in scanning. More series of exposures were made of the tests objects using the same exposure factors, however, the storage phosphor plates were stored under different conditions and scanned with a certain delay in time.

The three storage conditions were:

1) Total darkness, which was achieved by storing the plates in a light tight plastic box;

2) Regular office condition (450 Lux) as achieved by placing the plates in the bags on a table in a dental office and

3) Daylight condition (5,120 Lux) achieved by placing the plates next to window exposing them to daylight, however not to direct sunshine.

Light measurements were made by means Minolta Auto Meter IV (Chiyoda-Ku, Tokyo, Japan)

Series of images were scanned at 15 and 30 minutes and 1 and 4 hours after exposure.

For the storage in total darkness, 15, 30 minutes and 1 hour scanning were omitted as previous study showed no effect on the image quality in the subjective analysis.[12]

***Images for the observer performance test***

In total 30 sets of images were made of the phantoms. In certain conditions the remaining information on the phosphor plates was to low to trigger the scanner to start a scanning procedure. In a few conditions the remaining image was so poor that it was excluded for further evaluation. Tables 2, 3 and 4 show the resulting images of the three digital systems used in the three storage conditions.

**Table 2 - Resulting images for Total Darkness condition**

| Total Darkness Condition | DenOptix® | Digora® | Vistascan® |
|---|---|---|---|
| 0 hours | + | + | + |
| 4 hours | + | + | + |

+ images used for evaluation

**Table 3 - Resulting images for Office condition**

| Office Condition | DenOptix® | Digora® | Vistascan® |
|---|---|---|---|
| 15 minutes | + | + | + |
| 30 minutes | + | + | + |
| 1 hour | + | + | + |
| 4 hours | -- | + | + |

+ images used for evaluation
-- no information on the plate

**Table 4 - Resulting images for Daylight condition**

| Daylight Condition | DenOptix® | Digora® | Vistascan® |
|---|---|---|---|
| 15 minutes | + | + | + |
| 30 minutes | - | + | + |
| 1 hour | -- | + | + |
| 4 hours | -- | - | + |

+ images used for evaluation
- poor image quality
-- no information on the plate

### *Evaluation sessions*

All the images were saved in 8-bit file format and showed in their original size at the monitor. Eight observers (one cariologist, one periodontologist and six dental radiologists) viewed the images in a room with dimmed light conditions. The images were displayed at a NEC MultiSync FP1370 21" (NEC, Tokyo, Japan) computer monitor with a resolution of 1280 x 1024 pixels and the monitor settings were optimized using the SMTPE (Society of Motion Picture and Television Engineers) test object.[13] The Emago/Basic version 2.01 computer program (Oral Diagnostic Systems, Amsterdam, The Netherlands) was used to display the images. The images were in a random order offered to the observers in nine sessions. The observers were not allowed to make any changes in brightness or contrast or use any other adjustment tool. The observers were asked to detect caries of the right approximal surface of the teeth by means of a four point scale with the following categories: 0 = no caries; 1 = lesion restricted to the enamel; 2 = reaching the amelodentinal junction; 3 = lesion extending into the dentine. For statistical analysis, the medians obtained from the observers' scores were used, Kappa test was performed between observers and Wilcoxom and Friedman tests were performed. Differences were considered statistically significant when $P < 0.05$.

# RESULTS

Histological examination of the 72 approximal surfaces showed: 20.8% sound, 25% enamel, 16.7% reaching the amelodentinal junction and 37.5% dentin lesions. When the Kappa test was performed, the values varied between: 0.48 - 0.79 for the DenOptix® system; 0.60 - 0.79 for the Digora® system and 0.62 - 0.81 for the Vistascan® system.

The results of the study are presented separately considering the three different conditions in which the plates were stored after exposure: *1.Total darkness condition; 2. Regular Office condition; and 3.Daylight condition.*

*Total Darkness condition*

The ranks and *P* values of DenOptix®, Digora® and Vistascan® for Total Darkness condition are presented on table 5. When the plates were stored under this condition, there were no statistically significant differences between the means values of the images scanned immediately after exposure (0 hour) and images scanned 4 hours after exposure for all the three systems.

***Table 5***

Ranks and *P values* of the three Digital systems for Total Darkness condition

| Digital System | Delay in scanning | Rank | *P* |
|---|---|---|---|
| DenOptix® | 0 hour | 1.48 | 0.5294 |
| | 4 hours | 1.52 | |
| Digora® | 0 hour | 1.46 | 0.3942 |
| | 4 hours | 1.53 | |
| VistaScan® | 0 hour | 1.53 | 0.1080 |
| | 4 hours | 1.46 | |

There are no median differences at the 0.050 level when compared to 0 hour time by Wilcoxom and Friedman tests

*Regular Office condition*

Table 6 shows the ranks and *P* values of the three systems for Regular office condition. At this condition, only the DenOptix® system presented statistically significant differences in the images scanned 1 hour after exposure. Also, for the DenOptix® system, 4 hours after exposure the remaining information on the phosphor plates was too low to trigger the scanner to start a scanning procedure.

**Table 6**
**Ranks and *P* values of the three Digital systems for Office condition**

| Digital System | Delay in scanning | Rank | *P* |
|---|---|---|---|
| DenOptix® | 0 hour | 2.76 A | 0.0059 |
| | 15 min | 2.67 A | |
| | 30 min | 2.51 AB | |
| | 1 hour | 2.06 B* | |
| Digora® | 0 hour | 2.85 | 0.8232 |
| | 15 min | 2.92 | |
| | 30 min | 3.07 | |
| | 1 hour | 3.14 | |
| | 4 hours | 3.02 | |
| VistaScan® | 0 hour | 2.99 | 0.9670 |
| | 15 min | 2.90 | |
| | 30 min | 3.09 | |
| | 1 hour | 3.01 | |
| | 4 hours | 3.01 | |

*The mean differences are significant at the .050 level when compared to 0 hour time by Wilcoxom and Friedman tests

*Daylight condition*

Table 7 shows the ranks and *P* values of the three systems for Daylight condition. In this condition, for the DenOptix® system, the remaining information on the phosphor plates was too low 30 min after exposure and 15 min after exposure statistically significant differences were found. For the Digora® system, there were no statistically significant differences but the 4 hours images presented poor image qualities which were excluded for evaluation. For the Vistascan® system, there no statistically significant differences.

**Table 7**
**Ranks and *P* values of the three Digital systems for Daylight condition**

| Digital System | Delay in scanning | Rank | *P* |
|---|---|---|---|
| DenOptix® | 0 hour | 1.65 | 0.0001 |
| | 15 min | 1.35* | |
| Digora® | 0 hour | 2.61 | 0.0970 |
| | 15 min | 2.70 | |
| | 30 min | 2.49 | |
| | 1 hour | 2.19 | |
| VistaScan® | 0 hour | 3.00 | 0.1653 |
| | 15 min | 3.17 | |
| | 30 min | 3.19 | |
| | 1 hour | 3.03 | |
| | 4 hours | 2.60 | |

*The mean differences are significant at the .050 level when compared to 0 hour time by Wilcoxom and Friedman tests

# DISCUSSION

Once the phosphor plate is read, it is flooded with light to erase any remaining image and to prepare it for next exposure. Since the latent image is erased by exposure to light, it is important to avoid exposing the phosphor plate to excessive amount of background light before it is scanned. [14] However, this may not always be possible in busy clinics and hospitals as well as in surgeries or laboratories where the plates need to be brought to a central scanning facility. This will result in a quite considerable delay in scanning and consequently on exposure to visible light. [11, 12, 14]

Previous studies investigated the scanning of phosphor plates regarding the delay, temperature and humidity and different light conditions. [11, 12, 14] A dry mandible and Al step wedges were used as test objects but caries diagnosis was not addressed as well as the VistaScan® System which was recently launched by Dürr Dental.

When the images of present study were stored in total darkness condition, the results are consistent with the ones found in 2003[12] and 2005.[14] It makes possible to affirm that this condition would be the only one that really protect the phosphor plates from any effect of visible light.

When considering the fact that the plates can be easily exposed to regular office light by any situation on a daily routine of general practitioner or a student, it is important to remind that the images obtained by the DenOptix® system in this study were partially affected in the first thirty minutes after exposure and totally affected 4 hours after exposure.

Regarding the extremely situation of having the plates exposed to a daylight condition, not only the DenOptix® system but also the Digora® system had their images affected for caries diagnosis. In this situation, the images obtained by the DenOptix® system were affected in the first 15 minutes after exposure. It is also important to mention that for both systems, caries diagnosis can be totally affected if the plates are scanned 30 minutes and 4 hours respectively.

The images obtained in this study with the VistaScan® system which was recently launched did not present to be affected in any of the delays and conditions studied. This behaviour was not expected as the VistaScan® system is also based on PSP system but if we simply check the plastic bags used by those manufactures, a possible answer can be found for the findings of this study. There is a strongly difference among the plastic bags of the three systems and this fact could be easily verified when tests were made switching the plastic bags of the three systems studied. Of course this situation would never happen in clinical practice as the general practitioner would only have available on PSP system but this fact can be easily happen in dental schools or hospitals where more than one PSP system is available.

In conclusion, the images obtained in this study were affected by the poor quality of plastic bags. If the fact of the delay of scanning must be taken into consideration, plates should be stored in a total darkness condition or even regular office condition for the Digora® and the VistaScan® since the light conditions were the same used in the present study. The extremely situation (daylight condition) should be avoided as we also must be aware of the fading of the plates.

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# 4. CONSIDERAÇÕES FINAIS

A partir dos dados estudados pelo presente trabalho, verificou-se que:

1. As imagens obtidas pelo sistema Digora® sofrem perda de qualidade de imagem a partir de 4 horas, após a exposição aos raios X, sendo que essas diferenças não são clinicamente observadas, desde que as placas sejam armazenadas em ambiente fechado, sem entrada de luz.

2. O sistema DenOptix® apresenta-se estável quando submetido a tempos de exposição adequados e altos tempos de exposição favorecem a perda da qualidade da imagem.

3. A qualidade da imagem das placas de armazenamento de fósforo é afetada pela qualidade dos invólucros plásticos disponíveis em cada sistema. Os invólucros do sistema Vistascan® são capazes de proteger entrada de luz nas condições utilizadas por este estudo.

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**ANEXO**

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**UNIVERSIDADE ESTADUAL DE CAMPINAS**

FACULDADE DE ODONTOLOGIA DE PIRACICABA

## CERTIFICADO

Certificamos que o Projeto de pesquisa intitulado "Influência do tempo e das condições de armazenamento em imagens obtidas por placas de armazenamento de fósforo", sob o protocolo nº **176/2003**, do Pesquisador ***MAURO GUILHERME DE BARROS QUIRINO MARTINS***, sob a responsabilidade do Prof. Dr. **FRANCISCO HAITER NETO**, está de acordo com a Resolução 196/96 do Conselho Nacional de Saúde/MS, de 10/10/96, tendo sido aprovado pelo Comitê de Ética em Pesquisa – FOP.

Piracicaba, 02 de março de 2004.

We certify that the research project with title "Influence of the time and storage conditions on images acqired using phosphor storage plates", protocol nº **176/2003**, by Researcher ***MAURO GUILHERME DE BARROS QUIRINO MARTINS***, responsibility by Prof. Dr. **FRANCISCO HAITER NETO**, is in agreement with the Resolution 196/96 from National Committee of Health/Health Department (BR) and was approved by the Ethical Committee in Research at the Piracicaba Dentistry School/UNICAMP (State University of Campinas).

Piracicaba, SP, Brazil, March 02 2004

Cinthia Machado Tabchoury

*Profa. Dra. Cinthia Pereira Machado Tabchoury*

Secretaria

CEP/FOP/UNICAMP

*Prof. Dr. Jacks Jorge Júnior*

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CEP/FOP/UNICAMP