Influence of the Display Monitor on Observer Performance in Detection of Dental Caries

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Abstract

Background and aims. Digital imaging continues to gain acceptance in dentistry and video display used for this becomes important. The aim of this study was to assess the influence of the display monitor on observer performance on caries detection.

Materials and methods. Artificial enamel lesions were created in 40 extracted teeth at random using 1/4 and 1/2 round burs. Teeth were mounted in dental stone blocks to simulate a hemi-dentition. Approximate exposures were recorded at 70 kVp using a Planmeca (Planmeca Co, Helsinki, Finland) digital imaging system. Three oral and maxillofacial radiologists rated each image on a five-point scale for the presence or absence of lesion. Radiographic images were viewed on the following monitors: (1) LG Flatron 700p (LG Electronics Co., South Korea); (2) Samsung Magicgreen (Samsung Electronics Corp., South Korea); (3) Hansol 710p (Hansol Electronics Corp., South Korea) and (4) Toshiba satellite laptop (Toshiba Computer Corp., Philippines). Examiners were allowed to magnify and adjust density and contrast of each image at will. Receiver Operating Characteristic (ROC) analysis was performed. Data was subjected to repeated measures analysis of variance and ordinal logistic regression to test for significance between variables and to determine odds ratios.

Results. Mean ROC curve areas ranged from 0.8728 for the LG monitor to 0.8395 for the Samsung. Repeated measures analysis of variance showed significant differences between observers ($P<0.0001$), lesion size ($P<0.0001$), examiner/monitor interaction ($P<0.033$) and examiner/block interaction ($P<0.013$). However, no significant difference was found between monitors.

Conclusion. This study suggests that observer performance is independent of the visual characteristics of the display monitor.

Key words: **Diagnostic imaging, digital radiography, perception.**

Introduction

Direct digital imaging continues to gain acceptance in dentistry. However, all the commercial systems currently available have, as a limitation, inferior spatial resolution compared to radiographic film. The spatial resolution has been reported to vary from 6 to 10 line pairs per millimeter (lp/mm)

depending on the system, whereas film is up to 20 lp/mm.[1,2] The effect of resolution on observer performance is equivocal. In a recent study that used simulated enamel lesions, it was reported that film outperformed a photostimulable phosphor (PSP) digital system.[3] The video display used for Picture Archiving and Communication Systems (PACS) in the medical radiography field has been reported to be the weak link of the system.[4] Factors which determine monitor fidelity, i.e. accuracy of reproduction, include monitor resolution (number of vertical lines, bandwidth, and refresh rate), bit depth, dot pitch, luminance, and display size. In addition to monitor fidelity, observer performances may also be limited by the resolving power of the human visual system.[2] It has been reported that the minimum contrast threshold of the human eye corresponds to a spatial frequency of 5 lp/cm (a 1 mm wide line paired with a 1 mm wide space) which would correlate to a monitor pixel size of about 1 mm.[4] Most current cathode ray tube (CRT) displays used with dental direct digital imaging systems have a pixel size of 0.3 mm, and the eye has been reported to become less sensitive to pixel sizes smaller or larger than 1 mm.[5]

For digital systems, resolution is determined by both image detector and monitor resolution.[5] Most commercially available monitors have resolutions (pixel matrix size) of 1024×768, but some high performance monitors are available that have pixel matrices as high as 2048×2048.[6] Most gray-scale monitors commonly used with dental digital imaging systems have a maximal luminance that ranges from 86 cd/m^2 to 240 cd/m^2, compared with 1542 cd/m^2 to 1713 cd/m^2 for typical film view boxes.[6] Background luminance levels may influence observer's ability to distinguish fine details and just noticeable differences on the display screen.[6,7]

Cederberg studied influence of CRT monitors in observer performance at caries detection and found that results were not statistically significant.[3] In another study, Cederberg et al studied the effect of different background lighting conditions on diagnostic performance of digital and film images in which bitewing exposures were made with D and E-speed films and PSP plates. Significant differences were found between ob-servers, lesion size, and image receptor but no significant difference was found with background lighting.[8]

In the present study, we assess the influence of the display monitor on observer performance on caries detection.

Materials and Methods

Artificial lesions confined to enamel were created on 27 approximal surfaces of 40 caries-free (as determined by visual inspection) extracted human teeth using either a 1/2 round (0.5 mm diameter) or a 1/4 round (0.2 mm in diameter) bur and sinking the head of the bur to the junction of the neck. Teeth were mounted in groups of eight in five stone blocks to simulate a hemidentition. Numbers of 1/2 or 1/4 round lesions were randomly distributed in each block.

Each block was imaged using a CCD imaging plate (Planmeca). The X-ray source was a Planmeca operated at 70 kVp and 8 mA (Planmeca). 3-mm thick of plexiglass sheets were placed between the object and tube to act as a scattering medium.[8] Each of the five blocks was imaged with a XCP instrument to obtain images with paralleling techniques.

Tree oral radiologists scored each of the five images displayed on four different monitors: (1) LG Flatron 700p (LG Electronics Corp., South Korea); (2) Samsung Magicgreen (Samsung Electronics Corp., South Korea); (3) Hansol 710p (Hansol Electronics Corp., South Korea) and (4) Toshiba satellite laptop (Toshiba Computer Corp., Philippines). The specifications of the monitors are shown in Table 1. Each image was scored for the presence or absence of approximal lesions on a five-point scale: 1= definitely present; 2= probably present; 3= cannot tell; 4= probably not present; 5= definitely not present. Observers were instructed to adjust density, contrast and magnification of digital images to their preference. All images were viewed using the Adobe Photoshop 7.0 software (Adobe, USA).

The mean score for the five blocks was used to construct ROC curves for each monitor type. Data was subjected to repeated measures analysis of variance (ANOVA) to test for differences between observers, lesion size, examiner/monitor interaction and ex-

aminer/block interaction. Ordinal logistic regression was used to estimate the extent to which the monitor affected the odds of detecting 1/2 and 1/4 round lesions. The absolute value of the difference between observer score (1-5) and whether a lesion was present (1) or absent (5) on each surface was used as the outcome (dependent) variable. Higher scores indicated greater degrees of disagreement (i.e. error) on the part of the observer. Odds ratios were calculated for differences in monitor, lesion size, and lesion size/monitor interaction.

Results

The mean ROC curve areas (AZ) for the four monitors were as follow: LG=0.87, Toshiba=0.85, Hansol=0.84 and Samsung=0.83

(Figure 1). No difference was found between monitors. The results of the ordinal logistic regression to estimate odds ratios for lesion size and monitor are shown in Table 2. Observers were one-third as likely (OR=0.334) to detect quarter-round lesions compared with detecting no lesion or half-round lesions; less than one-half as likely (OR= 0.474) to detect a half-round lesion compared with detecting no lesion; and approximately 70% more likely to detect half-round than a quarter-round lesion. The odds ratios for the monitors were not statistically different from unity, the value under the null hypothesis.
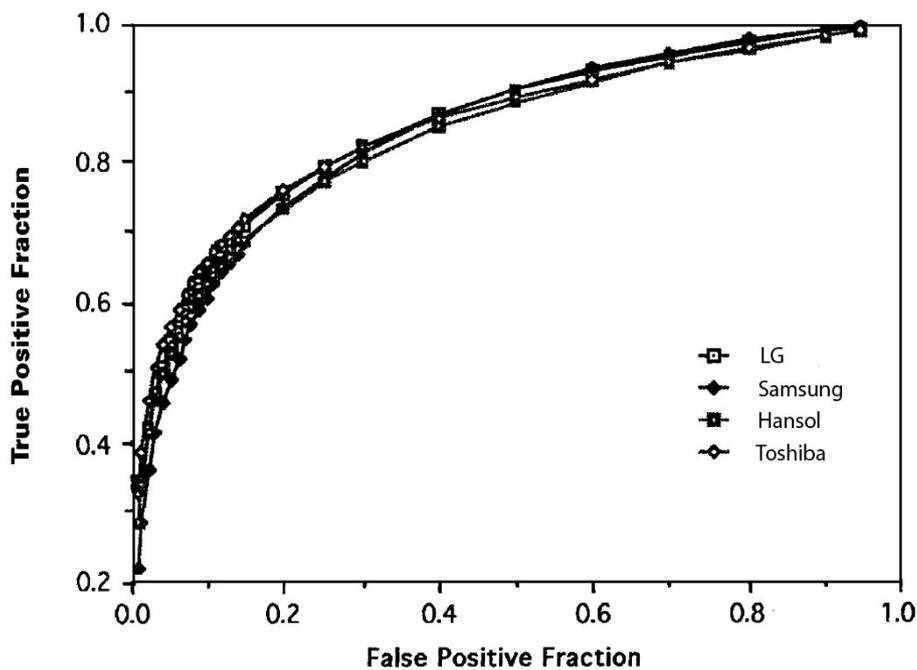

Figure 1. ROC curves for each monitor.

Table 1. Specifications of the four monitors and burs

Monitor &Burs	Parameter	Odds ratio	95% Confidence Lower limit	Interval Upper limit	Wald Chi-square	Pr> Chi-square
Monitor						
Toshiba	0.303	1.031	0.114	1.372	0.0431	0.8388
LG 700 DP	0.299	1.128	0.524	1.453	1.4235	0.8765
Hansol	0.2032	1.225	0.917	1.637	1.8873	0.1695
Samsung	-0.0189	0.981	0.738	1.305	0.0168	0.8969
Bur						
Half	-0.7469	0.474	0.37	0.608	34.5845	0.0001
Quarter	-1.0957	0.334	0.258	0.433	69.3042	0.0001

Table 2. Results for logistic ordinal regression

Type	Screen size	Resolution	Dot pitch	Luminescence
LG 700P	17 inches	1280×1024	0.27	264 cd/m^2
Samsung	17 inches	1280×1024	0.27	240 cd/m^2
Hansol	17 inches	1280×1024	0.26	250 cd/m^2
Toshiba	15 inches	1024×768	0.26	72 cd/m^2

Discussion

The display and manipulation of digital images on a computer monitor is an essential element of computed radiography. The quality of an image is a function of the physical parameters of the system. The image sensor, computer hardware and software and external factors such as extraneous light and screen reflection, as well as the inherent limitations of the human visual system, all influence image quality. This study was designed to determine whether monitors with a relatively superior fidelity could enhance observer performance. The four monitors tested in this study were chosen as a cross section of those commercially available monitors that would likely be used with dental direct digital imaging systems.[9]

Spatial resolution, screen size, bit depth, dot pitch and luminance are characteristics of monitors which may affect image quality. The spatial resolution of a monitor is most often expressed in terms of the size of the pixel matrix. High performance monitors are available with pixel matrices as high as 2048×2048. However, the resolvable pixel matrix of such monitors is considerably smaller.[6] Commonly used monitors available for most computer systems have a nominal resolution ranging from 640×480 to 1600×1200. Size of the monitor screen as well as type and memory size of the video card define or limit a monitor's resolution. All commercially available monitors are limited to a display of 256 gray shades. Monitors with a bit depth of 16 will be capable of displaying 65000 colors, but for radiographic images, gray levels are limited to 256. Wenzel found that indirectly acquired digital images displayed at a spatial resolution of 512×512 and 64 shades of gray was equal to, or in some cases more accurate than, the original radiograph for the detection of bone lesions.[10] The four monitors used in this study had almost the same resolution and gray scale display which was adequate for valid diagnosis, and as expected, did not influence the results of this study. Dot pitch is a factor that has an influence on image quality, but only when the difference between two monitors is significant. Difference of 0.01 for the monitors in this study is probably not perceptible considering the diagnostic task in question.

Modulation transfer function (MTF) measures the combined effects of sharpness and resolution. In practical terms, the ability of the display monitor to reproduce fine detail in an image depends less on the lumi-

nance it produces than on the MTF, fidelity with which the signal is recorded and the level of image noise.[2] Brettle et al found that PSP systems were limited to a resolution between 6.3 and 7.1 lp/mm.[11] The MTF of E-speed film is superior to that of PSP systems at high spatial frequencies.[12] It has been reported that larger simulated lesions are easier to detect than smaller ones.[3] Likewise, this study found that observers were 70% more likely to detect 1/2 round lesions compared with 1/4 round lesions. This difference in detection rates may be attributable in part to the differences in contrast seen with simulated lesions compared with natural caries.

Conclusion

A wide variety of choices are available to the practitioner when deciding on computer hardware for the dental office. This study suggests that observer performance is independent of the visual characteristics of the display monitor. In this study, the type and fidelity of the monitor used with a direct digital imaging system did not alter observers' diagnostic ability.

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