RESEARCH

Effect of ambient light level at the monitor surface on digital radiographic evaluation of approximal carious lesions: an in vitro study

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Objectives: This study investigated how ambient light affects the diagnostic accuracy of dental carious lesions on monitors used in dental practice. Specifically, the aim was to evaluate whether a monitor hood for blocking excess ambient light increases practitioners’ ability to accurately diagnose carious lesions on digital radiographs under bright ambient light conditions.

Methods: 7 observers evaluated approximal carious lesions on standardized digital radiographs of 100 teeth under 3 ambient light conditions: bright light (>1000 lx) and dim light (<50 lx) with no monitor hood; and bright light with a hooded monitor. Receiver operating characteristic curves were plotted for all observations. The criterion standard was a histological examination of the teeth. A paired t-test compared the effects of the three lighting conditions. The level of significance was set to p < 0.05. Weighted kappa statistics estimated intraobserver agreement.

Results: The diagnostic accuracy for dentine lesions was significantly higher in ambient light <50 lx than on monitors with and without a hood in ambient light >1000 lx. For all observers, diagnostic accuracy of dentine lesions under bright light was higher on a hooded monitor than on a monitor without a hood, but this difference was not significant. Intra-observer agreement varied from moderate to good.

Conclusion: Diagnostic accuracy of those carious lesions that reached into the dentine was significantly higher in ambient light <50 lx than in ambient light >1000 lx. A hooded monitor in bright light was not as effective as a monitor without a hood in dim light.

Keywords: data display; dental caries; diagnostic accuracy; digital radiography

Introduction

Digital dental radiography has been an alternative to film-based radiography for many years, yet some aspects of the digital technique have not been fully evaluated. Many technical parameters are difficult to evaluate and understand.1-3 Previous studies investigated digital detectors and concluded that they were neither better nor worse than analogue film.4-6 One study7 evaluated various types of monitors and found that, when specifically adjusted for the task of detecting carious lesions on radiographs, standard liquid crystal display (LCD) colour monitors are as good as more sophisticated monitors specifically designed for digital radiographic evaluation.

One factor that has been shown to influence the diagnostic accuracy of carious lesions is the level of ambient light [illuminance, measured in lux (lx)] in the room where digital radiographs are read.3,6-10 According to the American Association of Physicists in Medicine (AAPM),11 ambient light should be <50 lx (very dim) when evaluating digital radiographs on a standard monitor. By contrast, operating room lighting in a general dental practice is normally very bright (>1000 lx).12 Over the years, it has emerged that
general dental practitioners do not like to lower the level of ambient light to evaluate digital radiographs when the patient is in the room. This may be because it takes time to change the lighting level or because they believe that patients dislike dimmed light. The difference between ambient light levels of 1000 lx and 50 lx is great. Kutcher et al. studied whether a hood on a laptop computer display increased the ability to detect caries on digital radiographs. They concluded that the ability to detect caries by experienced clinicians may be improved by hooding the laptop display in a bright clinical environment. In line with the wish to increase image definition, dental suppliers have developed a hood for mounting on the display to reduce incoming light.

The overall aim of this study was to investigate how ambient light in the viewing room affects the diagnostic accuracy of dental carious lesions on monitors used in dental practices. The specific aim was to evaluate whether a device for partially blocking ambient light at the monitor surface in a room with bright light improved practitioners’ ability to accurately diagnose carious lesions on dental digital radiographs. The hypothesis was that diagnostic accuracy for carious lesions on digital radiographs did not differ for different ambient light levels measured at the monitor surface.

Materials and methods

This study evaluated 100 human teeth (40 premolars and 60 molars) that were selected from a large group of extracted teeth. On visual inspection, the 200 approximal surfaces of the 100 teeth were intact or had very small carious lesions. The teeth were chosen so that 50% were healthy and 50% had carious lesions with various extensions on the approximal surfaces. 1% had a visible cavity. Blocks of President putty (Coltène Whaledent AG, Cuyahoga Falls, OH) were made with the teeth mounted side by side, with three or four teeth in each block.

Each block was positioned with a device that standardized the distances between the block, the X-ray collimator and the digital sensor (Figure 1) before the radiograph was taken. A 1 cm-thick plate of poly(methyl methacrylate) was placed in front of the sensor and teeth to simulate soft tissue.

30 blocks were radiographed using a dental digital system (Schick CDR Wireless 2; Schick Technologies Inc., Long Island City, NY) and a Prostyle Intra X-ray unit (Planmeca Oy, Helsinki, Finland). Exposure settings were 60 kVp, 8 mA and 0.12 s. The distance from the X-ray focus to the object was 22 cm.

Seven observers, all general practice dentists with several years of experience in digital radiography, evaluated the radiographs according to approximal carious lesion grade. The observers rated their level of confidence about the presence of approximal carious lesions on a five-point scale:

1 = definitely not caries
2 = probably not caries
3 = questionable caries
4 = probably caries
5 = definitely caries.

A standard 19 inch LCD colour monitor with a luminance less than 250 cd m\(^{-2}\) was used to display the digital radiographs. This type of monitor is commonly used in dental practices. Before evaluation, monitor brightness and contrast were adjusted visually using AAPM test images task group 18 (TG18)-QC and TG18-CT. AAPM test images TG18-LN12-01, -09, and -18 were used to ensure that monitor luminance was unchanged for all evaluations. 3 sets of lighting conditions with varying illuminance at the monitor surface were evaluated: (a) ambient room light at 1000 lx (range, 1012–1057 lx); (b) 50 lx (range, 42–50 lx)—no hood was used on the monitor; and (c) bright light in the room and with the hood mounted on the monitor. The hood used in this study (Figure 2) was similar to one produced by a Swedish manufacturer from Olorin AB (Kungsbacka, Sweden). The difference was the material; the study hood was made of aluminium sheet metal instead of steel sheet metal. It was painted with matt black paint. The study hood was also sealed around the edges of the monitor to prevent light leaking in from the sides.

Each observer evaluated the 30 radiographs at 3 different times with at least 2 weeks between each evaluation. The first session was when the ambient light was > 1000 lx in the room, the second session was with bright light in the room and with the hood on the monitor and the third session was when the light in the evaluating room was < 50 lx. The radiographs were displayed randomly at each session.

Illuminance was measured with a light meter (Light-O-Meter P-11p; Unfors, Billdal, Sweden). Illuminance at the monitor surface when the hood was attached to the monitor in a room with bright (> 1000 lx) light was 309 lx on average (range, 299–325 lx); an average reduction of 70%.

Intraobserver agreement was determined by asking each observer to re-evaluate 60 approximal surfaces after at least 14 days. This evaluation was made in a room with ambient light < 50 lx and with the same monitor used in the other evaluations.
Histological evaluation
The teeth were cut in 1 mm slices with a low-speed saw and diamond blade [IsoMet® II-1180 Low Speed Saw and IsoMet Diamond Wafering Blade, 4 × 0.012 (10.2 cm × 0.3 mm), Buehler Ltd, Greenwood, IL]. Slices of each tooth were glued to a microscope slide with transparent glue. Each slide was evaluated by two observers—one of the authors (KH-H) and a specialist in oral pathology. The results were used as a criterion standard. Caries was defined as present when demineralization was observed as opaque-white to dark-brown colour changes. The 200 approximal tooth surfaces were graded on a scale from 0 to 3 where 0 = sound, no visible lesion; 1 = lesion confined to the enamel; 2 = lesion involving the enamel and enamel–dentine border but not the body of the dentine; and 3 = lesion involving the enamel and undisputedly the body of the dentine.

Statistical analysis
Receiver operating characteristic (ROC) curves were used to analyse all radiographic evaluations. ROCFIT software (Charles Metz, University of Chicago, Chicago, IL) calculated the areas under the ROC curves (Az). Data from the seven observers were pooled before analysis. A paired t-test was used to analyse if any difference between the three lighting conditions was found. Each radiographic evaluation in one situation was compared with the corresponding evaluation in the other two situations. The significance level was set to p < 0.05.

Weighted kappa statistics estimated intraobserver agreement. Values were interpreted using Altman’s adaptation of the Landis and Koch guidelines.

Results
Table 1 presents the histological results. Of the 200 surfaces, 100 were sound and 100 had a carious lesion. The two observers disagreed in 31% of the cases. Disagreement occurred only between healthy surfaces and surfaces with enamel lesions (Grades 0 and 1).

Table 1 Results of the histological evaluation, which served as a criterion standard (n = 200 approximal surfaces)

<table>
<thead>
<tr>
<th>Lesion (grade)</th>
<th>No. of surfaces</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound (0)</td>
<td>100</td>
<td>50.0</td>
</tr>
<tr>
<td>Enamel caries (1)</td>
<td>75</td>
<td>37.5</td>
</tr>
<tr>
<td>Border of enamel–dentine (2)</td>
<td>14</td>
<td>7.0</td>
</tr>
<tr>
<td>Dentine caries (3)</td>
<td>11</td>
<td>5.5</td>
</tr>
</tbody>
</table>

No significant differences in diagnostic accuracy for Grade 3 lesions was found on monitors with or without a hood in bright ambient light of 1000 lx (p < 0.062). Table 3 shows the Az for each observer in each lighting condition.

Discussion
This study found that dimmed light in comparison with bright light in the operating room improved the diagnostic accuracy in digital radiographs for carious lesions that had reached the dentine. It was also found that a hood on the monitor display in a room with bright light was not enough to result in the same diagnostic accuracy for carious lesions in the dentine.

Previous studies noted that general practice dentists encountered many problems with digital radiography. There are more factors to consider and technical matters to address with digital radiography than with film-based radiography. In one study, general practice dentists reported that the digital radiographic technique was more difficult to understand than film-based radiography and that management of the radiographs involved more work after exposure for the dentists, such as image enhancement and back-up problems.

Table 2 Mean areas (Az) under the receiver operating characteristic curves for seven observers. Radiographs were evaluated at three levels of luminance measured at the monitor surface

<table>
<thead>
<tr>
<th>Luminance (lx)</th>
<th>Az (mean)</th>
<th>All caries</th>
<th>Dentine lesion</th>
<th>Enamel lesion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>0.593</td>
<td>0.667</td>
<td>0.553</td>
<td></td>
</tr>
<tr>
<td>309 (1000 + hood)</td>
<td>0.601</td>
<td>0.714</td>
<td>0.565</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.603</td>
<td>0.758</td>
<td>0.587</td>
<td></td>
</tr>
</tbody>
</table>

(p < 0.020). No significant difference in diagnostic accuracy of Grade 3 lesions was found on monitors with or without a hood in bright ambient light of 1000 lx (p < 0.062). Table 3 shows the Az for each observer in each lighting condition.

No significant differences in diagnostic accuracy for enamel lesions were found between the three lighting conditions.

The weighted kappa values for intraobserver agreement varied from good to moderate (0.45, 0.48, 0.49, 0.56, 0.56, 0.61, 0.68).

Table 3 Areas (Az) under the ROC curve of the seven observers in the study for Grade 3 carious lesions (dentine lesions). Radiographs were evaluated at three levels of luminance at the monitor surface

<table>
<thead>
<tr>
<th>Observer</th>
<th>1000lx</th>
<th>309lx (1000 lx + hood)</th>
<th>50lx</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.688</td>
<td>0.691</td>
<td>0.769</td>
</tr>
<tr>
<td>2</td>
<td>0.701</td>
<td>0.791</td>
<td>0.791</td>
</tr>
<tr>
<td>3</td>
<td>0.602</td>
<td>0.683</td>
<td>0.737</td>
</tr>
<tr>
<td>4</td>
<td>0.733</td>
<td>0.732</td>
<td>0.732</td>
</tr>
<tr>
<td>5</td>
<td>0.646</td>
<td>0.686</td>
<td>0.763</td>
</tr>
<tr>
<td>6</td>
<td>0.613</td>
<td>0.703</td>
<td>0.767</td>
</tr>
<tr>
<td>7</td>
<td>0.684</td>
<td>0.714</td>
<td>0.747</td>
</tr>
<tr>
<td>Total</td>
<td>4.667</td>
<td>5.000</td>
<td>5.306</td>
</tr>
<tr>
<td>Mean</td>
<td>0.667</td>
<td>0.714</td>
<td>0.714</td>
</tr>
<tr>
<td>SD</td>
<td>0.0480</td>
<td>0.0380</td>
<td>0.0380</td>
</tr>
</tbody>
</table>

ROC, receiver operating characteristic; SD, standard deviation.
Many studies in recent years\textsuperscript{3,8,9} have concluded that it is essential to optimize observation conditions for reading digital radiographs on a display monitor. Ambient light level in the room is a vital factor for optimizing diagnostic accuracy. Brennan et al.\textsuperscript{19} study in the medical field also concluded that careful control of the ambient light level is required to ensure diagnostic accuracy.

One question raised by dentists was whether dimming operating room luminance, but not as low as recommended by the AAPM, would be sufficient to improve diagnostic accuracy.\textsuperscript{11} Numerous devices for screening off ambient light from monitor surfaces are on the market. The question was whether use of a monitor hood is an alternative for dentists when dimming the light in the operating room is considered too time-consuming or too inconvenient. The results indicate that, even though the hood reduced incoming light to the monitor surface, the reduction was insufficient to improve the diagnostic accuracy of approximal carious lesions on digital radiographs to the level obtainable in 50 lx ambient light.

Many factors contribute to image quality. In this study we did not calibrate the observers before the evaluation sessions because we wanted to mimic the clinical situation as much as possible. All observers were general practice dentists with $>5$ years' experience in practice. According to the results of the Hellén-Halme et al.\textsuperscript{20} study, 5 years' experience ensured increased diagnostic accuracy for carious lesions in digital radiographs. A previous study\textsuperscript{8} showed that it is essential to use an adjusted monitor when evaluating radiographic images for carious lesions. Therefore, AAPM test images\textsuperscript{11} were used to calibrate the study monitor for brightness and contrast.

In studies like this, it is important to ensure that the sample size and the number of observers are adequate. In a previous study by Hintze et al.,\textsuperscript{21} it was concluded that the number of observers and evaluated surfaces reached a level where increases in either variable ceased to affect the uncertainty of the results. We chose the specific number of teeth and observers according to the study of Hintze et al.\textsuperscript{21}

A histological evaluation of serial tooth sections served as the criterion standard. The Wenzel and Hintze study\textsuperscript{13} evaluated this method and found it to be a reliable standard for determining the diagnosis of dental caries. The only observer disagreement occurred when distinguishing between healthy surfaces and surfaces with small enamel lesions. The teeth in this study had no or very few carious lesions. The ability to detect carious lesions on dental radiographs was classified according to lesion grade. For instance, large carious lesions are easier to detect than enamel caries. 6\% of the teeth had carious lesions that extended into the dentine. This figure corresponds to Swedish national findings\textsuperscript{22} for the frequency of carious dentine lesions in young people, i.e. patients up to the age of 20 years. A carious lesion in the enamel is a diagnostic challenge for dentists. Many studies\textsuperscript{2,3,7,18} have concluded that both intra- and interobserver agreement for carious lesions in the enamel is low. It was also concluded\textsuperscript{2,3,7,18} that despite many efforts to optimize the technical settings in dental digital radiography, it was still difficult to obtain good results of the diagnostic accuracy for enamel lesions.

In conclusion, diagnostic accuracy for the detection of approximal dentine lesions in ambient light $\leq 50$ lx was significantly higher than for ambient light $>1000$ lx (recommended level for dental surgeries). Use of a monitor hood in ambient light $>1000$ lx did not improve diagnostic accuracy to the same level achieved in ambient light $<50$ lx.

References


