



## A Comparison of the Accuracy of Digital and Conventional Radiography in the Diagnosis of Recurrent Caries

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### Abstract

**Aim:** The purpose of this laboratory research was to compare the accuracy of digital and conventional bitewing radiographs in the diagnosis of recurrent caries under class II amalgam restorations.

**Methods and Materials:** This study involved 82 posterior intact teeth in which class II amalgam boxes were prepared. Carious lesions were simulated in half of the proximal boxes in the intersection between the facial or lingual wall and the gingival floor or midway between the facial and lingual walls. The other half of each tooth specimen served as a control. The prepared boxes were then restored with a Tytin FC (Kerr, USA) amalgam. The teeth were radiographed in the bucco-lingual direction to obtain images comparable to bitewing. Digital radiographs made with an intraoral CCD sensor and conventional radiography with dental E film were used. Three expert observers evaluated both types of images for the diagnosis of recurrent caries.

**Results:** Sensitivity and specificity values for direct digital radiography were 73 and 95 percent at the buccal and lingual line angles, respectively, and 29 and 90 percent at the mid-gingival floor, respectively. These corresponding values for conventional radiography were respectively 63 and 93 percent at the buccal line angle, 61 and 93 percent at the lingual line angle, and 44 and 95 percent at the mid-gingival floor. The total sensitivity and specificity values were 58 and 93 percent for digital radiography and 56 and 93 percent for

conventional radiography. The overall accuracy was 76 percent for digital and 75 percent for conventional radiography. No significant difference in specificity or sensitivity was found between the digital and conventional radiography ( $p=0.104$ ). Separately, no significant difference was seen between the buccal line angle and the mid-gingival floor, but a significant difference was seen between the two methods in the lingual line angle ( $p=0.004$ ).

**Conclusion:** The digital and conventional bitewing radiographs had similar diagnostic accuracy for the diagnosis of recurrent caries. Lesions located at the buccal or lingual line angle were more easily detected than those at the mid-gingival region.

**Clinical Significance:** Although there was no significant difference between digital and conventional radiography in the diagnosis of recurrent caries, digital radiography requires less ionizing radiation, making this method of imaging suggested for routine dental practice.

**Keywords:** Conventional radiography, digital radiography, recurrent caries, amalgam restorations

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## Introduction

Today the focus is often on monitoring the progression of primary caries, whereas recurrent caries under existing restorations require early intervention to avoid potentially more destruction of otherwise healthy tooth structure. Also secondary caries are considered by some to be the main reason for restoration failure.<sup>1,2</sup> However, secondary caries are difficult to diagnose accurately and continue to remain a problem in dental practices.<sup>3,4</sup>

Despite its many shortcomings, radiography in conjunction with a clinical examination provides a relatively easy and reliable approach for identifying recurrent caries.<sup>5-8</sup> Studies have shown that the bitewing radiographs are useful for detecting incidences of secondary caries.<sup>9,10</sup> Direct digital intraoral radiography is now more common in dental offices and this technology opens new possibilities for radiographic image treatment.<sup>11,12</sup> However, with the widespread use of digital radiographic systems, there have been concerns about quality, safety, and diagnostic properties of these imaging systems. Therefore, the need exists to assess the diagnostic accuracy of digital radiography as compared to conventional analog films to determine just how reliable digital imaging is. One study suggested that digital imaging systems were capable of yielding diagnostic performances comparable to those of conventional films for various other diagnostic tasks.<sup>1</sup>

Considering that dental amalgam is the main restoration material for posterior teeth in many countries and more carious lesions were observed on restoration with amalgam, this study was intended to focus on the detection of recurrent caries under amalgam restorations.<sup>13</sup>

The objectives of this project were to compare the diagnostic accuracy of the conventional analog films with direct digital bitewing radiographs and evaluate the effects, if any, of the location of the carious lesion on diagnostic accuracy.

## Methods and Materials

In this *in vitro* study, we estimated the required sample size based on the results of a pilot study. According to Power Analysis and Sample Size statistical software (PASS 2004 from NCSS, Utah,

USA), a sample size of at least 82 restorations would provide an appropriate statistical power at the 80.4 percent level with a 95 percent confidence level.

Consequently, intact teeth were selected after being examined with a sharp explorer on all surfaces. Class II amalgam cavities were prepared in all 82 teeth. Caries were simulated at the intersection of the lingual or facial wall and the gingival floor or midway between the facial and lingual walls of each proximal box. For inducing the lesions a #1/2 round carbide bur (0.6 mm in diameter) was used to create a round defect on half of the prepared surfaces. The other half of the tooth served as each tooth's own control.

All the lesions were 0.6 mm in depth and width. All the defects were filled with wax impregnated with plaster using a 3-to-1 ratio to reduce the contrast at the edges of the simulated caries. All of the simulated lesions were similar in size and density. Then the boxes were restored by amalgam. The teeth were coded and the location of each simulated lesion was recorded on a form. Then the teeth were divided into groups of three and mounted in acrylic-resin casts with the proximal surfaces in contact.

An intraoral Planmeca Model PM-2002 radiographic unit (Planmeca Oy, Helsinki, Finland) was used for radiography. The receptor was a Trophy CCD sensor for direct digital method and the Ekta speed Agfa analog films with the conventional method. The beam voltage and intensity were 57KVP, 0.16 second, and 8 mA for digital radiography and 57 KVP, 0.25 second, and 8 mA with analog radiography.

The teeth were radiographed in a bucco-lingual direction to obtain images comparable to bitewing radiographs directing the beam vertical to the contact surfaces of the crowns. To minimize the darkroom artifacts, developing of all the conventional films was performed simultaneously and under the same conditions. No interaction with the direct digital images was allowed.

The images were separately viewed by three experienced evaluators: two specialists in dental and maxillofacial radiology and one expert in aesthetic and operative dentistry. These evaluators had more than 18 years of experience. Each evaluator was instructed to mark with a (+)

if they detected a carious lesion and record a minus sign (–) if no lesion was noted. The actual location of each simulated lesion was previously coded on a form to be used as the gold standard. For each location, if two or three of the observers reported the presence of recurrent caries, it was considered to be diagnosed. Otherwise, no lesion was considered to be diagnosed.

Sensitivity and specificity values were calculated for the two experimental variables of interest: (1) type of radiography and (2) location of the simulated lesions. A chi-square test was used to identify any significant differences between the two radiography methods and the gold standard.

## Results

Data analysis was carried out by SPSS 13 software (SPSS Inc., Chicago, IL, USA). According to the analysis, direct digital and conventional radiography showed no significant difference in the diagnosis of recurrent caries under amalgam restorations ( $p=0.104$ ) (Table 1).

Separately, no significant difference was seen in the buccal line angle and mid-gingival floor, but in digital radiographs the lesions at the buccal line angle displayed a slightly higher detection rate. The chi-square test confirmed that the difference was significant ( $p=0.004$ ) (Table 2).

Furthermore, the sensitivity and specificity of diagnosis were calculated. It was seen that specificity rates were much higher than sensitivity rates. However, there was no significant difference between the total sensitivity and the specificity values from direct digital and conventional analog radiographs. The total sensitivity and specificity values were 58 and 93 percent in digital radiography, respectively. The same values for sensitivity and specificity with analog radiography were 56 and 93 percent, respectively.

The effect of lesion location on its detection also was demonstrated in this study. Sensitivity and specificity of direct digital radiography for lesions at line angles were higher than these values in analog radiograph. But at the mid-gingival floor these values were higher with the analog images. In direct digital radiography, sensitivity and specificity values were 73 and 95 percent at the line angles and 29 and 90 percent at the mid-gingival floor. The same values for conventional radiography were 63 and 93 percent at the buccal line angles, 61 and 93 percent at the lingual line angles, and 44 and 95 percent at the mid-gingival floors. The sensitivity and specificity values are listed in Tables 3, 4, and 5 as percentages.

Lesions located at the buccal and lingual line angles were found to be easier to detect compared with those located at the mid-gingival floor.

**Table 1. Comparison of digital and conventional radiographs in diagnosing recurrent caries.**

		Conventional		Total
		No Caries	Caries	
Digital	No Caries	140	17	157
	Caries	29	60	89
Total		169	77	246
$p=0.104$				

**Table 2. Comparison of digital and conventional radiographs in recurrent caries diagnosis, lingual line angle.**

		Conventional		Total
		–	+	
Digital	No Caries	38	3	41
	Caries	16	25	41
Total		54	28	82
$p=0.004$				

**Table 3. Sensitivity and specificity values in conventional radiographs in different sites.**

	Buccal line angle	Lingual line angle	Mid-gingival floor
Sensitivity	63.4%	61%	43.9%
Specificity	92.7%	92.7%	95.1%

**Table 4. Sensitivity and specificity values in digital radiography in different sites.**

	Buccal line angle	Lingual line angle	Mid-gingival floor
Sensitivity	73.2%	73.2%	29.3%
Specificity	95.1%	95.1%	90.2%

**Table 5. Total specificity, sensitivity, and accuracy values in conventional and digital radiographs.**

	Conventional	Digital
Sensitivity	56.1%	58.5%
Specificity	93.5%	93.5%
Accuracy	75%	76%

The total diagnostic accuracy noted in this study indicated that the proportion of all true diagnosed cases to the sum of true and false diagnosed cases was 76 percent for direct digital versus 75 percent for conventional, analog radiography.

## Discussion

The results from this study indicated there was no significant difference between the direct digital and analog radiography in the diagnosis of recurrent caries under dental amalgam restorations.

The spatial resolution, contrast resolution, and marginal sharpness of the radiographs are very important in diagnosing small recurrent carious lesions, and considering that the new digital radiographic systems are more accurate than before, CCD sensors gave a higher spatial resolution compared to other digital sensors. This outcome was not far from what has been predicted.<sup>14</sup> Of course, in this study no image enhancement operations were used. Had image enhancements, such as magnification or contrast enhancement, been used, then perhaps the results would have been different.

Because the CCD sensor is more sensitive to the radiation than is analog film, less radiation

exposure is required with digital radiography.<sup>14</sup> Therefore, according to the manufacturer's guideline, in the digital radiography, the exposure time was reduced from 0.25 second to 0.16 second, which would translate into a reduction in the radiation dose to the patient.

The sensitivity of both direct digital and conventional, analog radiographs does not appear to be very acceptable (56 percent, 58 percent), but the specificity was relatively high in both systems (93 percent). The results of the present study are comparable to those of most other studies on radiographic recurrent caries diagnosis. The findings of these other studies indicated high specificities with moderate sensitivities, but those studies were performed in different manners, with different types of fillings, and with different radiographic methods.<sup>1,9,10</sup> Rudolphy et al.<sup>9</sup> reported sensitivity and specificity of 73 and 90 percent in molars and 80 and 95 percent in premolar teeth with conventional radiographs for the diagnosis of secondary caries in class II amalgam restoration.

In the present study the sensitivity was lower, which may be attributed to the small size of the simulated caries or by the type of teeth used. Nair et al.<sup>1</sup> found the sensitivity for digital and conventional radiographic diagnosis to be 44

and 40 percent, respectively, with corresponding specificity of 76 and 85 percent. Differences of these results with those reported in the present study may be related to the type of restoration material used. Previous reports concluded that the closer the radiopacity of the enamel and the restorative material, the easier it is to detect recurrent carious lesions.<sup>1,15</sup> Alternatively, with increased contrast between the adjacent surfaces, as between dental amalgam and tooth structure, visual perception errors may occur that can impede lesion detection and reduce the level of sensitivity.<sup>1</sup>

As seen in other studies, despite low sensitivity, specificity values are relatively high in both the digital and conventional systems (93 percent).<sup>1,9,15</sup> If recurrent caries are not detected on a computer monitor or in dental film, it is probable that the recurrent caries do not exist. Usually as the sensitivity of a diagnostic method increases, its specificity decreases, leading to unnecessary treatment of false positive cases.<sup>16,17</sup> Fortunately, the specificity of both radiographic systems seems high enough to avoid false positive outcomes and unnecessary treatment.

The overall accuracy of conventional analog (75 percent) and digital radiography (76 percent) demonstrates that the bitewing radiography is not 100 percent reliable for diagnosing recurrent dental caries alone. A dental history and an actual clinical examination (direct observation) also are needed to ensure a more reliable and correct diagnosis.<sup>18,19</sup> However, there are clinical situations when radiography is the only possible way to identify recurrent caries. Thus, techniques like digital subtraction may be preferred in such circumstances.<sup>11,20</sup>

The effect of lesion location on achieving an accurate diagnosis has been evaluated. Lesions located more peripherally (at line angles) are easier to detect than the lesions located more centrally (mid-gingival floor). Nair et al.<sup>1</sup> found that lesions located at the buccal line angles or mid-gingival floor are easily detected. They also believed that a lesion located more peripherally, with little overlap of restorative material, is easier to identify, an outcome noted in the present study as well.

It must be emphasized that in this study bitewing radiographs were taken at an angle of approximately zero (0) degrees vertical angulation

and without any simulated soft tissue. Furthermore, the simulated carious lesions in the present study were created using a round bur that created very sharp borders in the radiographs. These variables may have made the results somewhat better than they would have been under actual *in vivo* conditions.

## Conclusion

Both the digital and conventional analog bitewing radiographs had similar levels of accuracy for the diagnosis of recurrent caries. Lesions located at the buccal or lingual line angles are more easily detected than those found at the mid-gingival region.

## Clinical Significance

Although there was no significant difference between digital and conventional radiography in the diagnosis of recurrent caries, digital radiography requires less ionizing radiation, making this method of imaging suggested for routine dental practice.

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