Observers Agreement in Perception of Non-Cavitated Approximal Dental Caries by Intraoral Digital CCD Radiography at Different Exposure Parameters and Corresponding Required Radiation Dose

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Abstract

Objectives: To evaluate the diagnostic accuracy of Charged Coupled device (CCD) in detection of Non- Cavitated Approximal caries at different exposure parameters in relation to radiation dose in vitro.

Study Design: Seventy-eight surfaces of extracted teeth were inserted in acid gel to create non-cavitated proximal caries with different depth, and then Radiographs have been taken to all teeth by CCD sensor. Radiographs were interpreted by three observers. The lesions were classified as (N) No lesion, (D1) Less than ½ enamel thickness, (D2) more than halfway of enamel but not involve DEJ, (D3) Dentin caries. Teeth were randomly selected for histological analysis after consensus from three oral and maxillofacial radiologists as Gold standard. The corresponding radiation dose was measured by unfors meter device at different exposure parameters.

Results: The histological examination showed that the distribution of lesions was 39.8% Sound, both enamel lesions are equal 17.8%, Dentin lesions 24.6.

The sensitivity and specificity of CCD to detect normal surfaces were 0.95, D1 was 0.37, D2 was 0.74 and D3 was 0.86. As the lesions depth increased, the sensitivity increased.

The higher image quality was produced by using exposure parameters (70 KvP, 160 ms) and (70 KvP, 200 ms). While, (60 KvP, 200 ms) and (60 KvP, 250 ms) produced the worse image quality.

Conclusion: Regard the balance between the higher diagnostic accuracy of digital images and minimum radiation dose: using exposure parameters as (70 KvP, 160 ms) is considered the best image quality and relative dose (81 mSv). While, (70 KvP, 125 ms) and (66 KvP, 160 ms) are little bit lower quality and corresponding dose are (63), (73) respectively. Although (70 KvP, 200 ET) produce higher image quality but its relative dose is high (101mSv).

Keywords: CCD: Charged Coupled Device, CR: Computed Radiography, DR: Digital Radiography

Introduction

Radiography after detailed clinical findings is considered as a routine diagnostic approach for caries detection. Unfortunately, there is not a quite sensitive and precise method available for the early detection of non cavitated caries at the present time. Accurate diagnosis of primarily, non-cavitated caries is a high significance condition since disease progression can be easily ceased early, and tooth structure can also be preserved with minimal invasion only by utilizing conservative and not by restorative treatment [1,2].

Although researchers are seeking tools with sufficient sensitivity and specificity for early detection of Approximal caries. Nevertheless, radiography is still considered as the most common approach [3,4]. However, few studies have been implemented on non-cavitated Approximal caries detection. Furthermore, sensitivity of imaging systems is supposed to be more for cavitated caries diagnosis [5-7].

Intra-oral digital Radiography has been adopted by dentists and is widely used for diagnosis of Approximal caries. Recent developments in the digital imaging systems and introduction of new types of digital sensors with advanced software are increasing the clinical advantages; leading to many dentists replacing the conventional film with digital sensors [8-10].
Over the past recent years, diagnostic accuracy of digital radiography systems for caries detection has been compared mutually and with conventional film system. Some studies consider the image quality of conventional image receptor comparable to that of the systems with charge coupled devices (CCD) [11-13]. Other studies reported superiority of the digital CCD systems over conventional radiographs [14-17].

Most modern CR and DR systems now effectively offer substantial patient dose reduction compared to screen-film radiography. Unfortunately, the reverse is also possible. There is the risk of substantially increasing the patient dose, possibly without being aware of it, or of decreasing diagnostic information because of impairment image quality [18]. Therefore, Reduction of is patient dose according to the ALARA principle is not only a question of selecting the right sensor, but also requires selection is appropriate imaging parameters [19-21]. The purpose of present study to detect the diagnostic accuracy of CCD in detection of Approximal caries in different exposure parameters in vitro with corresponding relative dose.

Materials and Methods

1. Teeth Selection

• A total of 52 extracted human posterior teeth (78 proximal surfaces with sound surfaces) excluded non-contact outer proximal surfaces and 5 contact proximal surfaces to include 73 proximal surfaces in contact.

• The teeth were embedded in rubber base blocks in an anatomical position to establish Approximal surfaces in contacts. Each block consisted of four teeth (included 6 proximal surfaces in contacts. Which numbered from surface 1 to 6, surface 1 represented to first contact left one and surface 6 represented to first contact right surface).

• Whole 73 interdental contact surfaces were classified to create lesions with different depths as 29 normal surfaces, 13 surfaces prepared to create D1 carious lesion (less than ½ enamel thickness), 13 surfaces to be D2 carious lesion (more than ½ enamel thickness but not involve DEJ. 18 surfaces to be D3 (involve DEJ and dentin carious lesion).

• All teeth included surfaces needed to be normal were masked by varnish, then immerse for 14 days into acidified gel demineralizing solution (mixing 0.1M lactic acid and 0.1M NaOH in proportions to give a PH of 4.5, then add 6% (w/v) hydroxyethyl cellulose to gel) (Figure 1) for production of D1 artificial lesions. Then surfaces were cleaned and masked the whole teeth surfaces except surfaces needed to create D2 and D3 lesion. Which immersed again into gel for next 14 days, then masked all surfaces except D3 lesions and inserted into gel for next 14 days.

2. CCD System

• Standardized images of all blocks were obtained using Trophy intra-oral X-ray unit and CCD sensor size 2 in prepared rubber base block to fix the distance. Plexy- glass plate was placed between tube and teeth to simulate soft tissue (Figure 2).

• Images were taken using the following exposure parameters (Table 1).

• The effective dose was measured in each exposure by unfors meter device for further correlation between the effective dose and image quality.

Figure 1: Photo of teeth inside the gel to create lesions

Figure 2: Phantom showing trophy intra-oral X-ray unit and CCD sensor size 2 in prepared block to fix the distance

Figure 3: Periapical radiographs by CCD sensor at different setting (top image 70 KvP, 125 ET) (bottom image 70 KvP, 160 ET)

Figure 4: Histological photo of surface 4
3. Evaluation of Radiographic Images
   • All radiographs were interpreted by three observers independently to examine included Approximal surfaces of all teeth. All teeth surfaces were interpreted for presence of carious lesions on proximal surfaces using a five-point confidence rate scale: 1= definitely no lesion, 2= probably no, 3= questionable, 4= probably carious lesion, and 5= definitely carious lesion.

4. Gold Standard
   • All included surfaces (73 surfaces) were examined by 3 observers counseling to classify the included Approximal surfaces.
   • Randomly selected 20 different approximal surfaces for histological analysis for emphasizing the observers counseling reports.
   • During histological analysis, tooth crowns were separated longitudinally (mesio-distal direction) at the proximal surfaces. Each tooth surface was examined and any lesions were measured for depth using the following criteria: H0= sound, H1= caries less than outer half of enamel, H2= up to DEJ but not involved it, H3= caries in the outer half of dentin.

5. Statistical Analysis
   • Observers counseling reports which were emphasized by histological analysis served as the gold standard for all selected Approximal surfaces.
   • The diagnostic accuracy of intra-oral CCD sensor was evaluated independently for three readers from the area under the receiver operating characteristic curve (ROC), inter and intra-observer agreement were assessed, the values obtained for area under the curve were analyzed by pairwise comparison of ROC curve.

Results
   • According to the gold standard of total 73 surfaces, showed that 29 surfaces (39.8%) sound, equal 13 surfaces (17.8%) for each enamel carious lesions, and 18 surfaces (24.6%) of dentin carious lesions.
   • The mean sensitivity, specificity, AUC scores for all three readers combined for caries detection in relation with corresponding effective dose is presented (Table 1 and ROC curve). The higher image quality by using exposure parameters (70 Kvp with ET 160 and 200), while the worse quality with (60 Kvp and ET 200 and 250). While, the remaining exposure parameters have equivalent AUC. Regarding the effective dose; the highest dose with exposure parameter (60 Kvp and ET 320) and the lowest dose with (70 Kvp, ET 125).
   • (Table 2) show the fractions of accurate predictions of depth for all readers. Which, indicating to increase the accurate predictions as increase the lesion depth. Moreover, using exposure parameters (70 Kvp with ET 160 and 200) are considering the most consistently good performers.
   • Intraobserver agreement for each observer, calculated using Kappa coefficients, was very strong, ranging between 0.8 to 0.9. Interobserver Kappa coefficient, ranging from 0.61 to 0.78.

Table 1: Sensitivity and Specificity for All Readers in Relation to Dose

<table>
<thead>
<tr>
<th>Mode</th>
<th>Sensitivity* (true positive rate)</th>
<th>Specificity* (1 - false positive rate)</th>
<th>AUC (Area under ROC curve)</th>
<th>95% CI for AUC</th>
<th>Corresponding dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1(60 Kvp, ET 200)</td>
<td>0.735</td>
<td>0.678</td>
<td>0.790 D</td>
<td>0.761 - 0.819</td>
<td>75.6</td>
</tr>
<tr>
<td>G2(60 Kvp, ET 250)</td>
<td>0.856</td>
<td>0.678</td>
<td>0.845 C</td>
<td>0.821 - 0.870</td>
<td>96.25</td>
</tr>
<tr>
<td>G3(60 Kvp, ET 320)</td>
<td>0.856</td>
<td>0.713</td>
<td>0.895 B</td>
<td>0.875 - 0.915</td>
<td>122.9</td>
</tr>
<tr>
<td>G4(66 Kvp, ET 160)</td>
<td>0.864</td>
<td>0.759</td>
<td>0.908 B</td>
<td>0.889 - 0.927</td>
<td>73.03</td>
</tr>
<tr>
<td>G5(66 Kvp, ET 200)</td>
<td>0.833</td>
<td>0.816</td>
<td>0.899 B</td>
<td>0.879 - 0.918</td>
<td>91.75</td>
</tr>
<tr>
<td>G6(66 Kvp, ET 250)</td>
<td>0.871</td>
<td>0.851</td>
<td>0.911 B</td>
<td>0.893 - 0.930</td>
<td>114.4</td>
</tr>
<tr>
<td>G7(70 Kvp, ET 125)</td>
<td>0.856</td>
<td>0.851</td>
<td>0.914 B</td>
<td>0.896 - 0.932</td>
<td>63.3</td>
</tr>
<tr>
<td>G8 (70 Kvp, ET 160)</td>
<td>0.864</td>
<td>0.885</td>
<td>0.927 A</td>
<td>0.911 - 0.944</td>
<td>81.1</td>
</tr>
<tr>
<td>G9 (70 Kvp, ET 200)</td>
<td>0.879</td>
<td>0.908</td>
<td>0.933 A</td>
<td>0.917 - 0.949</td>
<td>101.9</td>
</tr>
</tbody>
</table>
Table 2: Fraction of Accurate Predictions of Depth for All Readers

<table>
<thead>
<tr>
<th>Mode</th>
<th>True Depth = 3</th>
<th>True Depth = 2</th>
<th>True Depth = 1</th>
<th>No Lesion Present</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exact Match</td>
<td>2 or 3</td>
<td>1, 2, or 3</td>
<td>Exact Match</td>
</tr>
<tr>
<td>G1</td>
<td>0.76</td>
<td>0.54</td>
<td>0.64</td>
<td>0.28</td>
</tr>
<tr>
<td>G2</td>
<td>0.83</td>
<td>0.65</td>
<td>0.74</td>
<td>0.41</td>
</tr>
<tr>
<td>G3</td>
<td>0.87</td>
<td>0.69</td>
<td>0.74</td>
<td>0.33</td>
</tr>
<tr>
<td>G4</td>
<td>0.89</td>
<td>0.69</td>
<td>0.69</td>
<td>0.44</td>
</tr>
<tr>
<td>G5</td>
<td>0.87</td>
<td>0.67</td>
<td>0.72</td>
<td>0.33</td>
</tr>
<tr>
<td>G6</td>
<td>0.89</td>
<td>0.69</td>
<td>0.87</td>
<td>0.41</td>
</tr>
<tr>
<td>G7</td>
<td>0.89</td>
<td>0.63</td>
<td>0.87</td>
<td>0.36</td>
</tr>
<tr>
<td>G8</td>
<td>0.89</td>
<td>0.69</td>
<td>0.77</td>
<td>0.44</td>
</tr>
<tr>
<td>G9</td>
<td>0.91</td>
<td>0.69</td>
<td>0.87</td>
<td>1.00</td>
</tr>
<tr>
<td>Total</td>
<td>0.86</td>
<td>0.66</td>
<td>0.74</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Table 3: Inter-Rater Reliability Scores, using Cohen’s Kappa

<table>
<thead>
<tr>
<th>Readers Compared</th>
<th>Observed Agreement</th>
<th>k</th>
<th>95% CI for k</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 &amp; 2</td>
<td>0.900</td>
<td>0.784</td>
<td>0.729 - 0.838</td>
</tr>
<tr>
<td>1 &amp; 3</td>
<td>0.809</td>
<td>0.610</td>
<td>0.546 - 0.673</td>
</tr>
<tr>
<td>2 &amp; 3</td>
<td>0.870</td>
<td>0.732</td>
<td>0.675 - 0.788</td>
</tr>
</tbody>
</table>

Discussion

This in vitro study used consensus confirmed by histological analysis of approximal caries as ultimate validation criterion. The sensitivity value of CCD Sensor to detect approximal lesions was improved with the depth of the lesion, as lesion shifted from enamel to dentin, the sensitivity value ranged from 0.37 in small enamel lesions to 0.86 in dentin lesions. This finding is in accordance with previous studies done by Wenzel and Haiter-Neto, demonstrating failure in small lesions detection by intra-oral digital detectors, which had sensitivity value ranged from 0.13 to 0.21, meaning that all used digital systems failed to detect the smallest enamel approximal lesions [8,10,22].

Among the studies performed on non cavitated carious lesions. Previous study done by Alireza Mirshekar, et al. which demonstrated the higher sensitivity and specificity of intra-oral digital CCD Sensor to detect non cavitated approximal caries, which in line with our study [23]. That detected the higher sensitivity and specificity of CCD Sensor to detect proximal lesions especially by using exposure parameters (70 KvP, ET 160) and (70 KvP, ET 200).

Whereas, in Wenzel study, Diagora optime digital system displayed higher sensitivity but had a lower specificity, not accordance with our study, which used XDR sensor with pixel size is 19 microns. This provides a spatial resolution 26.3-line pairs/mm and radiation dose ranged from 63.3 to 114.4 msv during different selected exposure parameters. While in Wenzel’s study used Diagora optime with spatial resolution 15-line pairs/mm and dose approximately equal to film, meaning there is a significant dose reduction by using XDR’s sensor in our study [8].

Our study finding demonstrated a good agreement between CCD findings and gold standard that regard to higher XDR spatial resolution and XDR designed with the Caries/Endo filter. This filter extends hard tissue contrast by adaptively adjusting contrast to the local regions within the radiograph. This maintains sufficient detail in all regions while locally boosting contrast to the signal-to-noise limit for that region.

However, in Alireza study, there is a poor agreement between CCD findings and gold standard. This due to increase noise level in CCD images despite the use of anti-noise item in software [23]. Some studies have demonstrated that despite advances in spatial resolution in new generations of solid states, the difference between modalities was still non-significant for the overall accuracy [22,24,25].

The strong point of our study, that overcome limitations of previous studies, is correlation between the different exposure parameters and corresponding effective dose [23]. Which demonstrated as the following; the highest sensitivity, specificity and AUC gained by exposure parameters (70 KvP, ET 160) and (70 KvP, ET 200) with corresponding effective doses 81msv and 101 msv respectively. Then, exposure parameters (70 KvP, ET 125) and (66 KvP, ET 160) with corresponding effective doses 63 msv and 73 msv respectively.

In conclusion, our study demonstrated that the detection of non cavitated approximal caries by CCD sensor improved with the depth of lesion (as the depth of lesion increased, the sensitivity increased). Moreover, the preferred image quality with corresponding effective doses are; exposure parameters 70 KvP, 160 ET and 70 KvP, 125 ET with exposure doses 81 msv and 63 respectively.
Acknowledgement
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References

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