In vivo comparison of two intraoral digital sensors for approximal caries detection among senior dental students.

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Summary

Aim
The purpose of this study was to examine the diagnostic accuracy of a CCD and CMOS sensor concerning on approximal caries detection.

Methods
A clinical study with 24 radiographs with 70 approximal sites was exposed with the CCD and CMOS sensor. The radiographs obtained from the two sensors were viewed separately for diagnosing approximal sites. Ten students viewed the x-rays and analysed the approximal surfaces and registered the presence of carious lesion as well as the severity of the caries according to the depth of a lesion, ie as sound sites or enamel, dentin, pulp or secondary caries. Two radiologists view all the radiographs and theirs diagnosis were applied as gold standard. The sensitivity and specificity regarding the two sensors were then calculated and compared with gold standard.

Results
According to the mean value of the sensitivity and specificity based on ten students’ results, the CCD sensor had a slightly higher value then that of CMOS. However the difference was not statistically significant.

Conclusions
No significant difference could be observed between the two different sensors on approximal caries detection.
Author’s contribution

A continual collaboration between both authors has been conducted throughout this study. The assignments have not been divided but designed and executed equally by both.
Introduction

Caries is a common global disease that afflicts all ages and cause both general and individual problems. If caries is undetected and progress to manifest caries or pulpitis it can cause extensive damage of a tooth, which may affect the quality of life functionally and aesthetically. It is the most common reason for tooth ache and loss of teeth (1). Treatment of caries related damages costs Swedish society a great amount of money each year (2).

Caries progression is a dynamic process. Treatment planning is depended on several factors, for example patient oral hygiene, eating habits, radiographic and clinical diagnosis. A correct diagnose is fundamental, especially for those initial caries since they may be controlled and treated with non invasive treatments (1).

Over the past decades in industrialized countries continuous inspection of children’s dentition present a remarkable improvement of their oral health (3, 4). With information from radiographic images, carious lesions can be detected in an early state. Bitewing radiography helps to detect lesions that are otherwise hidden from visual examination (5, 6). With bitewing a higher value of diagnostic yield of approximal caries is received compared to standard panoramic modalities (7). Combined bitewing with clinical examination this worldwide disease is better controlled and treated (1).

Shift from analog to digital in dental clinics occurred gradually in the past decade and has many advantages. One study reported that digital technique reduced total number of retakes since image processing is possible and allows dental practicing to enhance contrast and density, faster image display and avoiding chemical processing (8).

Constant innovation of digital techniques is shown in production, reaching for optimal quality and less x-ray exposure. Various digital systems are available on the market today. These digital image receptor may be classified into three types according to techniques that are applied for acquiring images; phosphor plate (PSP), charged couple device (CCD) and complementary metal oxide semi-conductor (CMOS). The PSP needs
to be scanned after exposure whereas the images will be displayed directly on the monitor after exposure with CCD and CMOS techniques. The last two systems were invented around 1970 (8). Because of the better and more descriptive images with CCD it became the leading digital sensor in dental practices until now. Both sensors convert x-ray images into electronic signals and eventually to digital signals by means of analogue-digital converter. The difference between the CCD and CMOS techniques lies in how the electronic signal in each pixel is transferred. The CCD sensor has often just one output node for all charged pixels. When the pixels are exposed, signals from the output node are converted into voltage, buffered and leave the chip as an analog signal. For CMOS, every charged pixel is converted to voltage on its own. When exists, also amplifiers and noise-correction are separately done before going off-chips as digital bits. Earlier this resulted in a complex design of sensor, affecting the area for light capture and therefore image quality. CMOS can be designed smaller, cheaper and need less power when exposing than CCD. (9, 10)

Furthermore a wireless device using CMOS technique is presented. Thus improved CMOS technique attracts many manufacturers. Therefore clinical studies employing different digital sensors are of importance to validate the diagnostic accuracy.

When analyzing radiographic images, a great difficulty is to diagnose approximal caries lesion in the early state. The image quality has a great impact on the accuracy of caries detection. Numerous studies have been conducted, comparing detection and diagnosis of caries between analog- and digital technique. The results present high agreement between the two systems or slightly higher resolution with analog techniques though not of clinical importance (6, 7, 11, 12). Studies in vitro reported diagnostic accuracy to be comparable between PSP and CCD systems for approximal caries lesions (12, 13). Another in vitro study presents similar results, comparing older with newer versions of PSP and CMOS (14).

Most clinics use one of the digital techniques provided. For many reasons a comparable study between CCD and CMOS is desirably since these sensors are applied at
department of image and functional odontology, School of dental medicine (THS) at Karolinska Institute (KI), Huddinge.

Aim

The aim of this study was to compare diagnostic accuracy in terms of sensitivity and specificity applying CCD and CMOS sensor for approximal caries detection in vivo. The null hypothesis is that the newly developed CMOS sensor may have higher diagnostic accuracy than the CCD for caries detection in vivo.
Materials and methods

*Patient collection*
This was ethically approved by the Etic committee at Karolinska Institutet (diarienumber 2011/515-31/2). The patients were collected from the department of image and functional odontology, Institute of dental medicine, KI in Huddinge. The images were taken by senior dental students while being supervised by an experienced dental nurse. The patients came with referral from adult dental clinic at dental school. The inclusion criterion was at least one detectable approximal caries lesion on premolar or molar presented on bitewing radiographs during patients’ examination. The qualifying patients were asked whether they would like to be included in a research project where four additional bitewings will be taken with another sensor. A consent paper was signed by those who approved a participation in the study. A total number of five patients were examined with both sensors.

*Radiographic examination*
We conducted a radiographic examination with approximately four bitewings applied for each two different digital systems. A CCD (Planmeca oy, Finland) and a CMOS (Planmeca oy, Finland) based intra-oral system were used. The distance between x-ray focus to object was around 23 cm and it may varies a little between patients due to the clinical situation. The exposure parameters were set to 66 kV and 8 mA for both CCD and CMOS. The exposure time schedule was presented in the following table.

<table>
<thead>
<tr>
<th>EXPOSURE TIME:</th>
<th>CCD</th>
<th>CMOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premolars</td>
<td>0.16 s</td>
<td>0.12 s</td>
</tr>
</tbody>
</table>
Parallel technique was employed for all the images. We declined radiographs that were suboptimal due to overlapping at the approximal surfaces. A total number of 24 bitewings including 70 surfaces were included in the study.

*Radiographic assessment*

All radiographs were exported into a PowerPoint presentation. All CCD images were in one separate presentation and all CMOS in another. The orders of the bitewings were randomly arranged within the two PowerPoint presentations. The images were numbered in ascending order to facilitate the observers in viewing x-ray images. Since the sensors design differs, the edges of utilized radiographs were clipped so that the observers did not have a possibility to identify image type. Survey papers were designed for each presentation.

Ten randomly selected senior dental students from Karolinska Institutet, were asked to view and diagnose these image series at two occasions, CCD respectively CMOS, with one week in between. The students were unaware of which system they examined first. Viewing conditions during analyzing on computer screen were dimmed light and no possibility to adjust brightness or contrast. The monitors applied were standardized calibrated concerning light intensity and contrast. The students’ were asked to perform the diagnosis by grading the existence of caries in the following scale:

- **D1** – caries confined to the outer half of enamel
- **D2** – caries extended to the enamel-dentin border without clear spreading
- **D3** – caries extended clearly into dentin but confined to the outer half of dentine
- **D4** – caries into inner half of dentin
- **S** – secondary caries

*Data analysis*
Since this is a clinical in vivo study, a histopathological verification of caries progression was not possible. Therefore an expertise opinion was used as gold standard. Two experienced dentists specialized in oral radiology consulted each other while examined CCD and CMOS in one occasion. Same viewing conditions as analyzing students and both were unaware of images’ origin, therefore blinded. A diagnose for selected approximal surfaces were determined. Each dental students result was compared with gold standard and the sensitivity and specificity were calculated for both systems. The calculations were made in SPSS (statistical package for the social science).

*Calculation*

Sensitivity and specificity for each student was obtained from CCD and CMOS through \[
\frac{\text{true positive}}{\text{true positive} + \text{false negative}}
\] which gave the sensitivity value and \[
\frac{\text{true negative}}{\text{true negative} + \text{false positive}}
\] that gave the specificity value.
Results

In total 70 approximal surfaces 21 sites were diagnosed as caries according to the gold standard. Of the 21 caries sites 13 among these were secondary caries. Since the majority of caries lesions found were secondary caries lesions we did not take progression classified as enamel or dentin caries in consideration. We categorized into two groups of “all approximal caries” including enamel, dentin, secondary and sound proximal surfaces (group 1), and “secondary caries” including secondary caries and sound proximal filling sites (group 2).

The results from each student were calculated in sensitivity and specificity for the two different sensors and gave a mean which then were put in relations to gold standard to give a perception of the accuracy of the students' diagnostics.

Gold standard were the 1,0 reference (100%). Sensitivity and specificity in group 1 all proximal caries lesions and sound sites for CCD and CMOS is presented in figure 1. The mean of sensitivity were 0,84 and 0,8 for CCD for CMOS respectively. The specificity had a mean of 0,85 for CCD and 0,81 for CMOS (table 1). Since the majority of caries lesions were secondary lesions, a comparison of secondary caries detection were also performed between the two digital sensors. The sound sites were those caries free surface adjacent to fillings. This gave a comprehension of the students' ability to distinguish the carious site from healthy in sites holding a filling or crown. The sensitivity and specificity for secondary proximal caries are presented in figure 2 and gave a mean of 0,9 with CCD and 0,78 with CMOS, whereas the specificity gave a mean of 0,83 respectively 0,79 (table 2). Thus, CCD had a tendency to have slightly higher value compared to that of CMOS, however this was not statistically significant (p<0.01).
Figure 1. Shows the diagnostic diversity of 10 students' in approximal caries registration in terms of sensitivity and specificity were the CCD sensor gave a higher statistical value.

Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCDsens</td>
<td>10</td>
<td>.62</td>
<td>1.00</td>
<td>.8380</td>
<td>.11233</td>
</tr>
<tr>
<td>CCDspec</td>
<td>10</td>
<td>.57</td>
<td>.94</td>
<td>.8549</td>
<td>.11335</td>
</tr>
<tr>
<td>CMOSsens</td>
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<td>.57</td>
<td>1.00</td>
<td>.7951</td>
<td>.14260</td>
</tr>
<tr>
<td>CMOSspec</td>
<td>10</td>
<td>.53</td>
<td>.94</td>
<td>.8118</td>
<td>.12347</td>
</tr>
<tr>
<td>Valid N (listwise)</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 1 shows the statistical minimum, maximum and mean values concerning sensitivity and specificity of all approximal surfaces in both CCD and CMOS sensors.
Figure 2 shows the diagnostic diversity of 10 students’ in secondary approximal caries registration in terms of sensitivity and specificity which shows a wider spread. The CCD sensor gave a higher statistical value.

Table 2 shows the statistical minimum, maximum and mean values concerning sensitivity and specificity of proximal secondary caries lesions and sound fillings in both CCD and CMOS sensors.
Discussion

In detecting and diagnosing approximal demineralization we have intraoral radiographic images as an important complement. Completed in vitro studies present no statistically significant differences between various digital systems likewise conventional films for diagnosis of proximal caries, proving the caries progression with histology samples (6, 7, 11, 12, 13, 14).

This study was conducted in vivo which results in no histology samples possible and an impact on the projection and quality of x-rays taken. Apart from the sensor types, we experienced in the present study the importance of image projection as well as skillness of different operator on the accuracy of caries diagnosis. Nevertheless we include only those images that had optimal projection and standardized viewing conditions for all the students in order to exclude factors that may influence caries detection.

No clinical examination was taken place. Gold standard was used when analyzing the results. Instead of histopathology verification, two experienced dentists specialized in oral radiology consulted each other while examined both CCD and CMOS images. It is well known that initial caries would be easily missed with bitewing examination compared with histopathological analysis, which leads to that the sensitivity may be overestimated in the present study. Thus the results from the present study shall be interpreted with caution.
Our study demonstrates no apparent difference in diagnostic accuracy between CCD and CMOS. Because of low amount initial caries and majority of secondary caries in this sample, enamel caries was not separated from dentin caries. Hence, two results are presented. Sensitivity and specificity for all approximal surfaces and likewise for restored surfaces only. Notably but not statistically significant was the slightly higher value for CCD compared to CMOS. Since the new CMOS sensor is more sensitive than CCD in respect of dose response function the possibility of radiation reduction with CMOS sensor is favorable for the patients. CCD expose with 0.2 s while CMOS expose with 0.16 s in the molar region. In long run the total reduction will be of importance and may result in recommendation of CMOS in clinic use.

Our results showed a high variation between students’ ability of caries diagnosis regardless of image type. It becomes more remarkable considering five years of same education for the students diagnosing. Most likely the individually practical training results in various patient experiences. Also, earlier study describe the commonly inconsistency between and within dentists (12).

Due to the time limitation of and the lack of “optimal patients” the present study shall be considered as a pilot study. More patients with decay teeth at different stages should be included in the future study.

**Conclusion**

No significant difference could be seen between the two different sensors. CCD had a slightly higher sensitivity and specificity compared to CMOS. A notable difference in diagnosis accuracy was observed between students.
Reference


6. Clinical and radiographic diagnosis of approximal and occlusal dental caries in a low risk population. Verónica Galcerá Civera 1, José M Almerich Silla 2, José


14. A comparison of older and newer versions of intraoral digital radiography systems. Francisco Haïter-Neto, DDS, PhD; Andrea dos Anjos Pontual, DDS;