Comparison of analogue and digital radiographs for approximal caries detection among dental students in Sweden and China

Minston, PW
Wennberg, JR

Supervisor
Xie-Qi Shi
DDS, Associate Professor
Department of Oral Radiology
Institute of Odontology
Karolinska Institutet
Summary

Aim
The objective of this study was to investigate diagnostic performance on approximal caries detection among Swedish and Chinese dental students using analogue and digital radiographs in vitro.

Methods
46 extracted premolars and molars were mounted in blocks and exposed with two intra-oral systems, one CCD based digital technique and one with conventional films. 10 Swedish and 10 Chinese senior dental students diagnosed the approximal sites of the teeth exposed on the digital and analogue images. A 5-point diagnosis confidence scale was applied for caries registration for all the observers. Subsequently, the teeth were sectioned and histo-pathologically analyzed in order to obtain a gold standard. The data were analyzed in terms of sensitivity and specificity. Furthermore, receiver operating characteristic (ROC) curves were plotted for evaluation of diagnostic accuracy of the two radiographic methods for the two groups of students.

Results
In accordance to mean values of the sensitivity and specificity the Chinese students had slightly higher sensitivity scores than their Swedish counterparts, whereas they had somewhat lower specificity results. The results apply for both imaging modalities. Neither between the two groups of students nor between the two image modalities in diagnostic performance of approximal caries was found to be statistically significant (p>0.05). However, the area under ROC-curves indicated that the diagnostic variation between individual students was more prominent than the difference between the two groups of students.

Conclusions
A perceptible difference between analogue and digital radiographs in diagnostic performance for caries detection could not be verified. The two different intra-oral x-ray systems were equally accurate. Chinese and
Swedish students showed similar outcomes in their diagnoses. However, the individual results between the students fluctuated remarkably, rather than between the two student groups where no patterns could be observed.
Authors’ contributions

The two authors, named on the first page, have produced this paper in total collaboration. The research has been conducted jointly and therefore the workload has not been divided in a regular manner.
Introduction

One of the most globally widespread chronic diseases is caries, which can afflict humans an infinite number of times at all ages (Selwitz et al 2007). Fortunately, a reduction in prevalence of dental caries in the dentition of children in industrialized countries over the past decades is well-documented due to improved knowledge of caries prevention (Petersson et al 1996, Marthaler 2004). However, much of the available evidence today indicates that caries, unless carefully controlled, will continue to develop and progress throughout life (Fejerskov et al 2008). Recent studies confirm active caries in adolescents and young adults, even in countries with well-established and progressive oral health services e.g. Sweden (Mejare et al 2004). If initial carious lesions are undetected and progress to manifest caries it will cause extensive damages which can lead to major problems for the individual, affecting quality of life both functionally and aesthetically. Hence, the diagnosis of dental caries is fundamental to the practice of dentistry. The accepted methods for detecting carious lesions comprise visual inspection and bitewing examination.

During the last decade digital intra-oral techniques have been developed rapidly. As a result of this, the conventional analogue technique has inevitably succumbed to the digital emergence. It is important to note that there are advantages and disadvantages with both digital and analogue imaging systems. Digital radiographs are theoretically more sensitive at visualizing low contrast differences such as carious defects, but have somewhat poorer spatial resolution than analogue radiographs which in turn may effect detection on changes in high dynamic ranges such as fillings and crown margins (Blendl et al 2000). Numerous studies have been conducted, comparing diagnostic performance of analogue images to digital images for caries detection. The majority of these studies concluded that digital images performed as well as film based images for caries detection (White et al 1997, Ariji et al 1998, Tyndall et al 1998, Syriopoulos et al 2000).

In the field of dentistry, all regions of the world have not been digitized to the same extent; some countries have, more or less, completely abandoned the analogue realm, whereas other countries still have not got
accustomed to the digital techniques. The dental schools of Sweden have been completely digitized, and hence the students practice in daily clinical work with only digital radiographs. In China, on the other hand, the conventional technique is still predominant at the dental schools. The above mentioned difference in the Swedish and Chinese radiological training gives rise to an essential question; does it influence the students’ ability in diagnosing caries applying the radiographic technique with which they are not familiar?

Apart from the difference in application of digital technique between the two universities, the contrast in terms of caries prevalence in the two countries should be taken into consideration. According to the latest report from the Chinese Stomatology Association (CSA), dental caries in China remains a pressing issue with the caries rate being 77 % for deciduous teeth and up to 65 % for permanent teeth, whereas the caries prevalence in Sweden is about 41 % for patients of 19 years of age who receive dental treatment at the Swedish Dental Service (Folktandvården) according a report by the Swedish National Board of Health and Welfare (Socialstyrelsen 2006). There are no national data spanning caries rate among Swedish adults.

The fact that conventional films are often considered being sharper than their digital counterpart makes one prone to assume that the results of the Chinese students may yield a notable rate of false positive scores for digital images, whilst the Swedish students may show an inclination in diagnosing a remarkable number of sites as false negative on films. It is rational to believe that the scores of the students will be most accurate when observing x-rays produced by the system they use most frequently, i.e. digital images for Swedish students and analogue images for Chinese students, respectively.

**Aim**
The aim of the present study is two folds:

1: To compare diagnostic performance of analogue and digital radiographs for approximal caries detection in vitro.
2: To investigate observer performance on approximal caries detection between Swedish and Chinese students for the two radiographic techniques respectively.

Materials and Methods

Ethical aspect

The present study is an in vitro study in which human extracted teeth is applied. Since the extracted teeth cannot be associated to individuals no conflicting ethical aspects exist although human biologic material was used.

Tooth samples

In order to carry out the study in vitro 14 clinics within the Swedish Dental Service (Folktandvården) were contacted. Approximately 100 extracted teeth were accumulated, of which 46 were considered appropriate for the conduction of the research; to be included the teeth had to be premolars or molars and have relatively intact crowns. The teeth were mounted in groups of 4 in 11 blocks and groups of 2 in 1 block using impression material (Provil©). The teeth were placed as close as possible to simulate their interapproximal contacts as under in vivo condition.

Digital and analogue radiographs

The 12 tooth blocks were exposed with a CCD based intra-oral system (Planmeca oy, Finland at Department of Oral Medicine, Karolinska Institutet) and with conventional analogue radiographs (Kodak E-speed) at Peking University (Hospital of Stomatology). A 10mm thick soft tissue equivalent plastic compound was applied between the tooth blocks and the collimator to stimulate soft tissue for both types of radiographs. Parallel technique was applied at both occasions to obtain images with non-overlapped approximal surfaces. For the digital radiographs, the radiographs were acquired using the Planmeca™ X-ray unit. The exposure parameters were set to 66 kV, 8 mA and 0.16 s with a focus to object distance of 23 cm for all exposures. For the analogue radiographs X-ray unit was employed. The corresponding exposure parameters were 70kV, 8mA and 0.25s with a focus to object distance of 23 cm.
Viewing and evaluation

Two survey papers were composed based on the digital and analogue radiographs, where the observers were asked to diagnose the coronal section of the approximal sites in regards to the absence or presence of carious lesions. The two sets of images were viewed under the same viewing conditions, i.e. dimmed light, by 20 senior dental students; 10 from each country. The survey sheets were completed under supervision. The order of the analogue images was randomized so that it would be different to that of the digital images. Furthermore, no information was provided to the observers in terms of caries prevalence in this study sample. When scrutinizing the analogue images both the Chinese and Swedish students used a so-call Mattson-kikare with a magnification factor of 2. For viewing the digital radiographs a pre-adjusted diagnostic monitor was applied and the observers were not allowed to adjust the brightness or contrast of the computer screen. The diagnoses of the students were classified on a 5-point confidence scale, i.e. definitely not caries (1), probably not caries (2), uncertain (3), probably caries (4) and definitely caries (5). If the student had denoted 4 or 5 it was requested to indicate whether the lesion was confined to the enamel (E) or spread to the dentin (D).

Histology analysis

All the 46 teeth were numbered and embedded separately in plastic. Before the sectioning, the mesial and the distal surfaces were registered for each tooth. Then a sequential slice was sectioned in mesiodistal direction taken perpendicular to the occlusal surface for each tooth using a water-cooled diamond saw. For each tooth around 5-7 slices were obtained with a thickness of around 300 µm per slice. Histo-pathological analysis was carried out applying a optical microscope at a magnification of 16. The lesions were defined by the extension of a whitish decalcified zone or a brown zone in the approximal surface-pulpal direction. The extension of the approximal caries was registered as sound, enamel and dentin caries.

Sensitivity, specificity, ROC analysis

As stated above, the diagnoses made by the students were based on a 5-point confidence scale, and hence did not result in simple yes or no answers
regarding the presence of caries. For this reason a threshold value, a so-called cut-off was chosen. If this would be applied to a clinical situation it would mean that all values above the selected cut-off would result in a preventive or operative treatment, as it would indicate the existence of caries. The general concept is that raising the cut-off results in a cut down of the frequency of false-positive diagnoses whereas the frequency of false-negative diagnoses increases, and vice versa (Fejerskov et al 2008). As the prevalence of caries was relatively low among the teeth included in this study the cut-off was set to a high level at 3 on the 5-point scale; thus all the values up to 3 were interpreted as sound. This decision was made to induce a low proportion of false-positive diagnoses. A high threshold inevitably also results in a lower rate of true-positive diagnoses, but considering the low prevalence of caries the diagnoses were predicted to be favoured by a significant elimination of false-positive diagnoses at the cost of a probable few omitted true-positive diagnoses through a stringent cut-off.

Sensitivity ([true positive]/[true positive + false negative]) and specificity ([true negative]/[true negative + false positive]) were calculated for the two systems and the two groups of students in relation to the chosen cut-off. The observer agreement scoping the analogue and digital images was analyzed.

Furthermore, the data were assessed with respect to diagnostic accuracy in terms of ROC analysis using the Statistical Package for the Social Sciences (SPSS). ROC curves were plotted, where sensitivity (y-axis) is presented as a function of [100%-specificity] (x-axis) for each possible cut-off. The area under the curve (AUC) is the measure that indicates the diagnostic accuracy, as it is the average value of sensitivity for all possible values of specificity. The closer the AUC value is to 1, the better the accuracy is. A value below 0.5 is equivalent to taking a chance (Park SH et al 2004). This value is usually drawn as a so-called reference line. The areas under AUC were calculated for each student and for the two image types.

Student t-test was performed to analyse whether there were any statistical differences between the two groups of the students for the two types of the image modalities respectively. Paired T-test was used to analyse diagnostic performance between digital and film radiographs.
Results

In total 92 approximal sites were sectioned of which 60 were sound and 32 exhibited caries (15 enamel and 17 dentin carious lesions, respectively). The number of total surfaces and the caries rate in the present study are relatively low. Consequently, in the compilation of the data all types of lesions were collectively categorized plainly as caries with no respect to the progression, i.e. whether they were characterized as enamel or dentin lesions.

The results of the average performance of each student with respect to sensitivity and specificity for the two types of radiographs were summarized as mean values for each student group. As for the digital images the Chinese students scored 35.6 % for sensitivity and 91.0 % for specificity, whilst the Swedish students attained 25.6 % and 95.6 %, respectively. The corresponding results for the film images were 37.7 % and 89.3 % for the Chinese students and 30.0 % and 94.1 % for the Swedish students. Thus, there is a minor difference between the two student groups; the Chinese students scored slightly better than their Swedish counterparts in terms of sensitivity, but on the other hand they had somewhat poorer results when it came to specificity, and vice versa.

Figures 1-4 show ROC-curves that depict the accuracy for the two imaging modalities based on the diagnoses of the students. The mean values for the two students group and for the two image types were 0.634 (China Digital), 0.647 (Sweden Digital), 0.645 (China Film) and 0.637 (Sweden Film).

Paired t-tests showed no statistically significant difference of the area under curve (AUC) between the two types of radiographs for both Chinese and Swedish students (p=0.636 and p=0.696). Student t-tests indicated no statistically significant difference between the two groups of students in terms of the AUC (p=0.592 for digital radiographs and p=0.691 for film radiographs).
Figure 1 ROC-curves based on the results of the Chinese students for the digital images.

Figure 2 ROC-curves based on the results of the Swedish students for the digital images.
Figure 3 ROC-curves based on the results of the Chinese students for the film images.

Figure 4 ROC-curves based on the results of the Swedish students for the film images.
Discussion

It is crucial to emphasize the importance of a rather accurate diagnosis of caries. The treatment that is opted for is based on how extensive and progressive the operator interprets the carious finding. Swedish dental students are trained to address initial lesions confined to the enamel with prophylactic care, while invasive measures are to be applied on lesions that have reached to the dentin. Naturally, it is of great significance to distinguish sound teeth from those which have been demineralised so that therapies are not planned where there is no such indication. As mentioned earlier, this study only took approximal surfaces into account for diagnosis of caries, as a radiological examination usually is required in addition to a clinical inspection to diagnose those sites.

A number of studies that have drawn the conclusion that there is no apparent difference in diagnostic accuracy between digital and conventional film imaging modalities among dental professionals (White et al 1997, Ariji et al 1998, Tyndall et al 1998, Syriopoulos et al 2000). Our present study confirmed previous studies with respect to comparison between film radiographs and digital radiographs for approximal caries detection.

There are minor differences in mean values between the two groups of students for the two different intra-oral x-ray systems, which should be deemed trivial. On the other hand, a large variation in caries detection was noticed between individual students regardless of image types. There are students that are more than twice as good as their peers in diagnosing caries. It is clear that the radiological analytical performance of the students has not been influenced by whether they have been trained in Sweden or China, but rather by other factors. In fact, it has been shown in other studies that it is common with inconsistency between and within dentists (Syropoulos et al 2000). However, it was unexpected that students with the identical training in radiology at the same institution would manifest such a wide range of discrepancy.

The specificity scores are very accurate, whereas the sensitivity rates are not as promising. This applies to both student groups and imaging modalities. Since the caries rate is rather low in this sample, enamel caries
was not separated from dentin caries. Nevertheless, it is logical to assume that the majority of the undetected caries primarily were initial caries, which means the sensitivity for enamel caries detection would be even lower than the above mentioned result. That is in accordance with a study which concluded that the use of radiographs is a very poor method in diagnosing initial lesions (Hintze et al 1994). That fact is alarming as it denotes that initial caries is easily missed. Consequently preventive care may not be considered when there is a need for it. Thus, this is something dental practitioners should bear in mind when examining patients.

One of the hypotheses presented in the introduction assumed that the results of the Chinese students would yield a notable rate of false positive scores for digital images, whilst the Swedish students would show an inclination in diagnosing a remarkable number of sites as false negative on films. However, this “theoretical difference” did not seem to affect clinical diagnosis on caries detection between the two image types.

It was noted that the Chinese students have a slightly higher sensitivity value while the Swedish students have a slightly higher specificity value. This may partially be due to the fact that the caries prevalence in China is notably higher than that in Sweden, which leads to over diagnosis on samples that have lower caries rate.

Conclusions
A perceptible difference between analogue and digital radiographs in diagnostic performance for caries detection could not be verified. The two different intra-oral x-ray systems were equally accurate. Chinese and Swedish students showed similar outcomes in their diagnosis. However, the individual results between the students fluctuated remarkably, rather than between the two student groups where no patterns could be observed.
Acknowledgements

First and foremost we would like to express our tremendous gratitude to our supervisor Dr. Xie-Shi Qi for her guidance, encouragement and patience. Without her the research would not have been feasible. We also wish to thank the head of the Department of Image and Functional Odontology at Karolinska Institutet, Dr. Karin Näsström, for her munificent support. Furthermore, we are eternally thankful to our supervisor during our visit at The Hospital of Stomatology in Beijing, Dr. Gang Li, for receiving us with open arms. Last but not least we would like to express our acknowledgements to the 20 Chinese and Swedish students who generously devoted some of their free time to scrutinize the images and fill in the survey papers.
References


Selwitz, RH, Ismail AI, Pitts NB. Dental caries. 2007; 396, Issue 9555: 51-59

