Observer reliability in approximal caries detection using digital radiographs and digital fibre optic transillumination, DIFOTI

Klas Åhlund
Odontologiska institutionen
Karolinska institutet

Abstract

Major changes have occurred in the disease pattern of caries. Early detection of lesions and their progress are key factors in management of the disease. In this context there is a need for modification of traditional diagnostic methods and the introduction of new methods for caries detection and quantification.

The aim of the present study was to study observer reliability of digital radiographs and digital fibre optic transillumination, DIFOTI, in terms of inter and intra observer agreement in detection of approximal caries.

In this study 52 premolar teeth were selected. They were visually intact or had a variety of caries lesions on approximal surfaces. The teeth were captured with a digital radiograph and by DIFOTI. The images were then examined by 6 observers. They were given two criteria to examine the teeth by. Criteria 1: Observer confidence in finding a lesion. Criteria 2: Observer diagnosis of caries extension. Kendall coefficient of concordance, Kappa, was used for statistical analyses.

The Kappa values for radiographs and DIFOTI in criteria 1 was 0.38 and 0.62 respectively. In criteria 2 the Kappa values for radiographs and DIFOTI was 0.29 and 0.38 respectively. The observers detected enamel caries lesions in 20% of the radiograph images and in 42% of the DIFOTI images. They detected dentine caries lesions in 2% of the radiograph images and in 13% of the DIFOTI images.

The DIFOTI method seems to show good qualitative properties, but weaker quantitative properties. However, the validity of the method is yet to be determined.

Introduction

Modern management of dental caries has three major components: prevention, control, and treatment, and is based on appropriate diagnosis of the disease and detection of pathological changes, i.e., lesion formation in its earliest stages. In Scandinavian dental schools, preventive and restorative dentistry have for many years been integrated in the undergraduate curriculum as one subject, Cariology, and this is reflected in the textbooks from the 1960s, 1979s, and 1980s (1, 2). In North American textbooks of operative dentistry, however, this concept has only recently been introduced (3). The importance of chairside application of basic theoretical concepts has been emphasised in textbook for dental practitioners (4).

Current treatment strategy in Scandinavia is based on diagnosis of caries activity, identification of the main causal and predisposing factors in the individual case, and assessment of the actual caries risk (5). Diagnosis of dental caries is often regarded as synonymous with detection of the clinical signs of tissue damage caused by the disease, i.e., carious lesions and cavities. For practical clinical purposes, the diagnosis should express the individual patient’s caries activity, which is a compound diagnosis derived from immediate past experience, lesion progression, and the clinical appearance of the lesions or cavities. Caries activity is evaluated on the basis of data obtained from clinical examination and assessment of factors associated with the pathogenesis of the disease. The most important clinical parameters are the lesion sites, typical or atypical, and the appearance of individual lesions, and whether the disease process at these sites is active or arrested.
In recent years there has been a pronounced change in the epidemiology and disease pattern of dental caries (6, 7, 8). However, despite the dramatic decline of caries incidence, particularly in children and young adults, the disease is far from eradicated. The following major changes have occurred in the pattern of the disease. Progression of enamel caries is now slower, and allows preventive intervention before the stage of irreversible destruction of tooth substance has been reached. There is also a pronounced reduction in lesion development on the smooth surfaces, which are readily accessible to fluoride (9, 10, 11, 12). In dental practice of today, much of the decay for which clinical intervention is required occurs around existing restorations and/or in the occlusal surfaces of the teeth, particularly the complicated fissure systems of the molar teeth. The occlusal fissures of the first permanent molars are generally the first sites in the permanent dentition to develop caries (13).

As the prevalence of dental caries has decreased, lesion detection has become more difficult. Dental radiographs are inadequate for detecting decay in the occlusal surfaces until the lesion is well advanced through the enamel and into the dentine (14). The clinician relies on visual observation of discoloration, and clinical judgement based upon experience, and on tactile sense, by probing with an explorer.

It is hypothesised that the occlusal lesion is initiated on the fissure walls and is therefore obscured by superimposed sound tissue. Additionally, there is evidence that an effect of regular use of fluorides is greater opacity of enamel, which may obscure underlying lesions in dentine, so-called “hidden lesions” (15). More research is clearly needed on “hidden caries”, especially longitudinal clinical studies in which the long-term fate of these lesions can be documented (16).

Variation in caries diagnosis and treatment decisions is a well-recognised phenomenon (17, 18, 19, 20). For the clinician, a major shortcoming in caries management strategies based on risk assessment is the lack of methods, which can reliably establish the extent of the subsurface decay (14, 21, 22, 23, 24, 25).

With modern methods, lesion detection is possible at a stage long before frank cavitation, and is an important component in timely and appropriate preventive measures. In view of these changes, caries diagnosis has a critical impact on treatment decisions: incorrect diagnosis may easily result in incorrect treatment decisions, particularly with respect to operative intervention. With respect to dentinal caries, the diagnosis of the disease and the detection of early lesions should be regarded as cornerstones of cost-effective dental health care delivery and quality of care (26).

Despite the decline of caries incidence in children over the past 20 years (6, 27), there remains a proportion of the population which is susceptible to caries, either already caries active or at high caries risk. These individuals require intensive preventive measures. In Scandinavia, the measures most commonly applied in the clinical setting comprise a prophylaxis (professional tooth cleaning) followed by an application of fluoride varnish (28). The outcome is often difficult to evaluate with conventional clinical methods. In clinical practice, objective, reliable quantitative data on the outcome of efforts to arrest disease activity, e.g. longitudinal monitoring of lesion response to preventive measures, would allow flexibility in selecting intervention appropriate to the individual patient, before lesions progress to a stage requiring expensive invasive therapy.

Caries lesions occur in a variety of anatomic locations and have unique aspects of configuration and rate of spread. These differences make it unlikely that one single diagnostic method will have adequate sensitivity and specificity to detect caries at all sites. Multiple diagnostic tests would increase the overall efficacy and precision of caries diagnosis. Thus there is a need to develop and test a number of different approaches to lesion detection and quantification and to conduct comparative studies of such methods.
New techniques for caries detection and quantification have been developed and evaluated (23, 26, 29, 30, 31), and some are now commercially available.

Traditional diagnostic methods, such as visual inspection, appear to have very low sensitivity and high specificity in diagnosing occlusal caries (13, 32, 33). Attempts to improve the sensitivity have been done. In a study by Ekstrand and co-workers (34), sensitivity and specificity for detection of dentinal lesions ranged between 0.92-0.97 and 0.85-0.93, respectively. One conclusion from the study was that although good results were obtained regarding sensitivity and specificity as well as operator agreement, the method takes time to learn. Although improvements of visual inspection with new scoring systems seem promising (34, 35, 36), further clinical validation is still necessary.

For detection of occlusal dentinal lesions, the sensitivity of the explorer is reported to be only about 0.5 – 0.6 (9). A number of reports have demonstrated that probing with a sharp explorer may cause damage to newly erupted teeth or create a cavity at the site of a superficial carious lesion, and its use has been questioned by several authors (9, 37, 38). Loesche and co-workers (39) showed in a study on intraoral transmission of pathogenic micro-organisms, that by probing, sterile fissures might be inoculated after previous contact with an infected fissure. The use of film radiograph for caries detection has a long history since. It is still the most widely used diagnostic technique for caries detection in dental practice. Bitewing radiography was found useful for dentinal caries detection on both occlusal and approximal surfaces. However, it has no value for occlusal enamel caries detection and limited value for approximal enamel caries detection. One drawback of bitewing radiography is that it is associated with the unavoidable hazards of ionizing radiation. Major development in this field is the introduction of digital technique, which dramatically reduces the patient exposure to radiation. However, as long as diagnosis is based on radiographic examination, some exposure to radiation is unavoidable.

Fibre-optic Transillumination, FOTI, is a qualitative method that has been used since the 1970s. In FOTI, white light from a cold-light source is passed through a fibre to an intraoral fibre-optic light probe that is placed on the buccal or lingual side of the tooth. The surface is examined using the transmitted light, seen from the occlusal view. Demineralised areas appear as darker compared to the surrounding sound tissue. The contrast between sound and carious tissue is then used for detection of lesions. FOTI has been evaluated in a number of studies for detection of posterior approximal carious lesions (40, 41, 42, 43), and has shown low to good sensitivities and good specificities. Côrtes and co-workers (44) showed in an *in vitro* study that a combination of FOTI and visual inspection was useful for determination of occlusal lesion depth.

By interpretation of the digital image of a tooth through computer image analysis, researchers have attempted to improve the performance of FOTI (45, 46, 47). This quantitative method, Digital Fibre Optic Transillumination, DIFOTI, has been evaluated in a few studies, and the initial results indicate that both the sensitivity and the specificity are very high. The DIFOTI is a method for hard tissue diagnostics. A fibre optic handpiece sends out a broad white light from a cold-light source through the tooth. A digital image is then captured. The image shows a combination between the tooth surface and the tooth shone through by the light.

The aim of the present study was to study observer reliability of digital radiographs and digital fibre optic illumination in terms of inter and intra observer agreement in detection of approximal caries.
Material and methods

Teeth

52 extracted premolar teeth were selected. They were visually sound or had a variety of approximal carious lesions, cavitated and non-cavitated. To clean the teeth, they were placed in 10% sodium hypochlorite solution for 20 min, followed by rinsing in distilled water for 20 min. The teeth were then kept in thymol saturated saline to prevent dehydration.

Laboratory setup

The teeth were arranged in groups of four and mounted in plaster blocks to simulate the position in the mouth (figure 3). Reproducible radiographs were obtained by placing the plaster blocks in a holder specially designed to provide standardised projection geometry during exposure. The focus-to-film distance was 21 mm. A 15 mm thick soft tissue equivalent plastic compound was placed in front of the blocks. A Prostyle Intradental unit (Planmeca, Helsinki, Finland) and a DIXI intra oral system were employed to acquire the digital radiographs.

The DIFOTI images were obtained using a DIFOTI (Electro-Optical Science, New York, USA) (Figure 1, 2). Two images per surface were captured, one from a buccal view and one from a lingual view. The radiographs and DIFOTI images were displayed on a SVGA graphics computer screen. The screen and light setting were not altered during the observation period.
Observers
The 6 observers selected were all experienced in caries diagnostics. They were given the same instructions prior to evaluating the images. They were informed about the DIFOTI, how it works and how it displays the images (figure 4). The observers were also shown DIFOTI test images prior to evaluating the DIFOTI images included in the study. They were all already well experienced in viewing digital radiographs.

Observer instructions:

1. The research room on floor 7, Department of Cariology, should be used for monitoring the images.
2. Each observer protocol should be marked with observer number and criteria 1 or 2, before the observer start filling in the form.
3. The windows must be covered with a dense blanket or similar, to prevent sunlight reflections.
4. The indoor light should be turned on.
5. For monitoring the images, the computer screen closest to the window should be used.
6. The distance from the observer to the screen should be approx. 40-50 cm. It is not allowed to step back to get a different view of the images.
7. It is not allowed to change any of the screen settings, such as contrast and colour.
8. Please try to make a decision on all the images. Use the comment column or the back of the observer protocol to comment any problems you might have, or if you find something wrong with the images.
9. Please note that the teeth are arranged randomly in their blocks. Their contact areas may be displaced somewhat, and they are not next to the teeth they were at before extraction.

Criteria
The observers were asked to evaluate the images twice, and by two set criteria (table 1). This was performed for both the radiographic and the DIFOTI images (figure 5). The observers monitored the images with a mean of two months between the monitoring sessions. The diagnostic outcome for Criteria 1 was recorded 1 as the observer confidence in finding a lesion. For Criteria two the outcome was recorded as the observer confidence in measuring the extension of the lesion.

Table 1: Criteria

<table>
<thead>
<tr>
<th>Criteria 1: Observer confidence</th>
<th>Criteria 2: Observer diagnosis</th>
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<tbody>
<tr>
<td>of caries existence</td>
<td>of caries extension</td>
</tr>
<tr>
<td>0. Definitely not caries</td>
<td>0. Sound</td>
</tr>
<tr>
<td>1. Probably not caries</td>
<td>1. Enamel caries limited to the outer half of the enamel</td>
</tr>
<tr>
<td>2. Questionable</td>
<td>2. Enamel caries in the inner half of the enamel</td>
</tr>
<tr>
<td>3. Probably caries</td>
<td>3. Dentinal caries in the outer half of the dentine</td>
</tr>
<tr>
<td>4. Definitely caries</td>
<td>4. Dentinal caries in the inner half of the dentine</td>
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</table>
Results
The results were statistical analysed using Kendall coefficient of concordance, Kappa. Kappa values are regarded as 1: perfect agreement; 0.75-1 excellent agreement, 0.45-0.75 good agreement and <0.45 poor agreement.

Original data analysis:
The Kappa values for the DIFOTI images were 0.25 for criteria 1 and 0.31 using criteria 2. Accordingly, for the digital radiograph images, the Kappa values were 0.07 using criteria 1 and 0.27 using criteria 2. (Figures 6, 7)
Modified data analysis:

Criteria 1

A modified data analysis was performed considering the fact that the observers are not research oriented and had not experience ROC analysis, but also to simulate observer considerations during clinical situations. The results were divided into two groups, one group in the cases where the observers found no caries (0+1+2), and a second group in the cases where the observers found caries (3+4). According to this modified data analysis, the kappa values for DIFOTI and digital radiographs were 0.62 and 0.38 respectively.

Criteria 2

The data for Criteria 2 were divided into three groups to fit the clinical situation. One group in the cases where the observer found the tooth to be sound (0), a second group in the cases where they found enamel caries (1+2), and a third group in the cases where they found dentinal caries (3+4). According to this modified analysis, the kappa values for DIFOTI and digital radiographs regarding Criteria 2 were 0.38 and 0.29 respectively.

Figure 6: Extrapolated observer recordings of Criteria 1. The most common choice of class (0-4) for each site.
Figure 7: Extrapolated observer recordings of Criteria 2. The most common choice of class (0-4) for each site.

According to modified criteria 2, based on the majority answers from 6 observers, the percentage of enamel and dentinal caries was calculated. The observers diagnosed 42% enamel caries on the DIFOTI images, while they diagnosed 13% enamel caries on the radiograph images. Further, they diagnosed 20% dentinal caries on the DIFOTI images and 2% dentinal caries on the radiograph images. (Table 2)

Table 2: Results

<table>
<thead>
<tr>
<th>Criteria 1</th>
<th>Radiographs: 0.38</th>
<th>DIFOTI: 0.62</th>
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<tbody>
<tr>
<td>Criteria 2</td>
<td>Radiographs: 0.29</td>
<td>DIFOTI: 0.38</td>
</tr>
<tr>
<td>Detected lesions (%)</td>
<td>enamel</td>
<td>dentine</td>
</tr>
<tr>
<td>Radiographs:</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>DIFOTI:</td>
<td>42</td>
<td>13</td>
</tr>
</tbody>
</table>
Discussion
As can be seen on figure 6, the radiography staples seem to get higher towards the left, which indicates that the observers tend to detect little or no caries. At the same time the DIFOTI staples seem to get higher towards the right, which indicates that the observers tend to detect more caries on the DIFOTI images compared to the radiography images. On figure 7 there is a similar pattern. As the radiography staples get higher towards the left, the DIFOTI staples get higher towards the right. This indicates that the observers tend to find more sound surfaces on the radiography images and more larger caries lesions on the DIFOTI images.

One possibility why the observers tend to detect more caries lesions on the DIFOTI images is that it is easier to spot smaller lesions on the DIFOTI images. The quality of both the digital radiology images and the DIFOTI images are of course of great importance. A weakness could be that even though the observers got an introduction to the DIFOTI device, it was still a new experience for them. As any new caries detection device, it takes a while getting used to.

The DIFOTI could be a useful tool for caries detection in the future. Since it is not associated with pain for the patient, and is easy and fast to operate, it could be an attractive tool for caries diagnostics on children. It does not expose the patient or the operator to radiation. However, it can not completely replace the radiology images, since it can not show features covered with gingival tissue. There is also a need for further studies in the field of DIFOTI.

Although significant promise is associated with these new technologies, there is not enough evidence currently available for any of the reviewed diagnostic techniques to be recommended as a substitute for traditional diagnostic techniques. However, as adjuncts to visual inspection and bitewing radiography for assistance in caries diagnosis, longitudinal application of any of these new methods may provide quantitative information on mineral changes in the carious lesions as a basis for the evaluation of caries activity and risk assessment. In doing so, the dentist should always remain responsible for the interpretation of the information and the quantitative measurements should always be weighted against other relevant information.

Conclusions
The results reveal that the DIFOTI tends to detect more caries lesions both in enamel and dentine than digital radiographs. However, the accuracy of the two techniques can not be revealed at the moment.
The DIFOTI method seems to show good qualitative properties, but weaker quantitative properties. The validity of the method is yet to be determined.

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References


