Review Article

Dental Caries Diagnostic Methods

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ABSTRACT

Dental caries, a progressive bacterial damage to teeth, is one of the most common diseases that affects 95% of the population and is still a major cause of tooth loss. Unfortunately, there is currently no highly sensitive and specific clinical means for its detection in its early stages. The accurate detection of early caries in enamel would be of significant clinical value. Since, it is possible to reverse the process of decay therapeutically at this stage, i.e. operative intervention might be avoided. Caries diagnosis continues to be a challenging task for the dental practitioners. Researchers are developing tools that are sensitive and specific enough for the current presentation of caries. These tools are being tested both in vitro and in vivo; however, no single method will allow detection of caries on all tooth surfaces. Therefore, the purpose of the present review was to evaluate different caries diagnostic methods.

Keyword: Dental Caries, Diagnosis, Radiography

INTRODUCTION

A diagnostic method for dental caries should allow the detection of the disease in its earliest stages and for all pathologic changes attributable to the disease to be determined from early demineralization to cavitations. Unfortunately, none of the currently accepted clinical caries diagnostic methodologies have the ability to account for the dynamics of dental caries, including the possibility of reversal. Rather, clinicians are forced to measure a dynamic process as a dichotomous variable of the presence or absence of disease using clinical criteria (e.g. color, softness, resistance to removal), which are all rather subjective, and tools (e.g. sharp explorer and dental radiographs) which are becoming less useful.

Although, no single method is currently developed that will allow detection of caries on all tooth surfaces, these technologies have the potential to offer higher specificity and sensitivity with respect to caries detection and quantification as well as to facilitate the

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development of more effective preventive interventions.[1] This article aims to review some dental caries diagnostic methods available including:

CLINICAL VISUAL INSPECTION

The coronal carious lesion starts as a clinically undetectable subsurface demineralization. With further progression, it will (eventually) become clinically detectable, and can, then, be classified according to type, localization, size, depth, and shape.

The visual method, a combination of light, mirror, and the probe for detailed examination of every tooth surface, is by far the most commonly applied method in general practice worldwide. Although sensitivity is low and specificity is high, it may be possible to detect noncavitated enamel lesions (D1) on the free smooth surfaces (buccal and lingual), most anterior proximal surfaces, and the opening of some fissures; clinically detected cavities limited to the enamel (D1, D2); dentin lesions (D3) with cavitations into the dentin on the buccal and lingual surfaces, but there is limited detection of posterior approximal and occlusal lesions.

A major shortcoming is this method was very limited for detecting noncavitated lesions in dentin or posterior proximal and occlusal surfaces.

The technique of temporary elective tooth separation as an aid to diagnosis of caries in proximal smooth surfaces is now regaining popularity, albeit with less traumatic methods that seem acceptable to most patients and dentists. This method permits a more definite assessment of whether radiographically detectable proximal enamel (D1, D2) and dentin lesions (D3) are cavitated.

Temporary elective tooth separation, complemented by a localized impression of the opened interproximal space, allows a more sensitive diagnosis of cavitations than does the purely visual separation method. [2]

Ekstrand et al. evaluated the visual and tactile assessment of arrested initial enamel carious lesions and showed that dentists were not able to reliably and reproducibly determine the subtle visual and tactile differences between active and inactive enamel lesions.[3]

In another study, Sheehy performed a comparison between visual examination and a laser fluorescence system for In vivo diagnosis of occlusal caries and concluded that since the laser fluorescence instrument can not be expected to differentiate caries from hypomineralizations, it should be used as an adjunct to a clinical examination. [4] On the other hand, there are some questions about the use of dental explorer to probe suspected carious lesions. Hamilton reported that until to the time those facts emerge from acceptable long-term clinical trials, dentist should feel comfortable using the dental explorer to probe suspected carious lesions.[5]

FIBER OPTIC TRANSILLUMINATION METHODS

Fiber optic transillumination (FOTI) allows for the detection of carious lesion because of the changes in the scattering and absorption of light photons resulting from a local decrease of transillumination due to the characteristics of the carious lesion. [6] Enamel lesions appear as gray shadows and dentin lesions appear as orange-brown or bluish shadows. [7] In an in vitro study, FOTI, performed along with visual examination, had higher specificity both for enamel and dentinal lesions and had a better correlation with histology. [8] Rousseau reported on the development of a fiber-optics-based confocal imaging system for the detection and potential diagnosis of early dental caries. A novel optical instrument, capable of recording axial profiles through caries lesions using single-mode optical fibers has been developed which may provide additional diagnostic information for a general practitioner. [9]

Digital Imaging Fiber Optic Transillumination (DIFOTI) is a relatively new methodology that was developed in an attempt to reduce the perceived shortcomings of FOTI by combining FOTI and a digital CCD camera. Images captured by the camera are sent to a computer for analysis using dedicated algorithms. The use of the CCD allows instantaneous images to be made and projected, and images taken during different examination can be compared for clinical changes among several images of the same tooth over time. [1]

However, Caution must be taken, when interpreting a proximal DIFOTI image that is taken at a view similar to that of a conventional bitewing radiograph. Although, the images may look similar, proximal lesions can be detected using DIFOTI only by careful angulation, remembering that the resulting image is that of a surface or what is near the surface. This also may explain why the DEJ is not always seen with conventional radiography, when the incident beam is transmitted through the entire tooth, often masking early changes in the surface. However, this method is much better for evaluating lesion depth at the proximal surface. In addition, another possible drawback of DIFOTI is the inability to quantify lesion progression, even though images can be compared over time. [10] One in- vitro study indicated that the method has higher sensitivity than does a radiographic examination for detecting lesions on interproximal, occlusal and smooth surfaces.[11]

CARIES INDICATOR DYES

In 1972, it was suggested that caries-detector dyes could help differentiate infected dentin from affected dentin. However, more recent studies have shown that these dyes are non specific protein dyes that stain collagen in the organic matrix of less mineralized dentin, whether it is infected or not, rather than being specific for the pathogenic bacteria. [10]

Al-Sehaibany et al. evaluated the use of caries detector dye in the diagnosis of occlusal carious lesions. The purpose of their study was to compare the accuracy of diagnosis of carious lesions in the occlusal pit, fissure, and groove system of lower molars examined by two methods: the caries detector dye versus traditional tactile examination using a dental explorer. Histological cross sections confirmed a ratio of 1:1 (100%) accuracy by caries detection dye in diagnosing decay underlying the occlusal surface. Concurrent examination of the same occlusal surface by traditional explorer examination was only reliable in a 1:4 ratio (25%). [12]

FLUORESCENT METHODS

Quantitative light induced fluorescence (QLF)

QLF is based on the auto-fluorescence of teeth. When teeth are illuminated with high intensity blue light, they will start to emit light in the green part of the spectrum. The fluorescence of the dental material has a direct relation with the mineral content of the enamel. No threshold for the detection of white spot lesions using light scattering techniques has been determined, but lesions with a depth of only 25 μm have been measured in vitro. The restriction of light scattering for caries diagnosis to smooth surfaces is a significant drawback to this technique, although, there is continuing research to develop a QLF system to detect occlusal caries. [13]

Kuhnisch et al. evaluated the in vivo detection of non-cavitated caries lesions on the occlusal surfaces by visual inspection and quantitative light-induced fluorescence. It was concluded that QLF detects more non-cavitated occlusal lesions and smaller lesions compared to visual inspection. However, taking into consideration time-consuming image capturing and analysis, we can understand that QLF is not really of practical use in the dental office. [14]

Laser induced fluorescence

In 1998, Hibst and Gall described the successful use of red light (655nm) to differentiate between sound and carious tissues and on this basis, the Diagnodent system (DD) was developed. When using light with an excitation wavelength of 655nm, we can detect that more intense fluorescence in the 700-800nm wavelength region is observed from a carious lesion compared with a sound spot on enamel. DDS utilizes a 655-nm 1-mW laser diode excitation light source that is modulated to differentiate it from ambient light. The light is transmitted though a descending optical placed close to the measured surface, thereby illuminating it with the laser light. Carious tooth structures emit fluorescence above 680 nm when encountering this light and this fluorescence is detected and quantified by the DD unit as a number between 0-99. [15] The laser fluorescence device represents high reliability in the detection of occlusal caries in teeth and its performance is similar to direct visual and radiographic examination. So, the DIAGNOdent may be a useful adjunct to conventional methods for occlusal caries detection. [16-18]

ELECTRICAL CONDUCTANCE MEASUREMENTS (ECM)

The idea of an electrical method of caries detection dates back to 1878, while it is believed to have first been proposed by Magitot. The basis of the use of ECM is observations which show that sound surfaces possess limited or no conductivity, whereas carious or demineralized enamel should have a measurable conductivity that will increase with the increase of demineralization. By decreasing thickness and increased porosity, the performance of electrical resistance has been reported to be as valid as or better than traditional means of diagnosing fissure caries. [19]

Based on the differences in the electrical conductance of carious and sound enamel, fiber to a hand-held probe. The probe is two instruments were developed and tested in the 1980. The Vanguard Electronic Caries Detector (Massachusetts Manufacturing Corp., InterLeuven laan, Cambridge, MA) and the Caries Meter L (G-C International Corp., Leuven, Belgium). Both instruments measure the electrical conductance between the tip of a probe placed in the fissure and a connector attached to an area of high conductivity (e.g. gingiva or skin). The measured conductance, which was a continuous variable, was ,then, converted to an ordinal scale: 0 to 9 for the vanguard system and four colored lights for the caries Meter L (green = no Caries, yellow = enamel caries, orange = dentine caries and red = pulpal involvement). To prevent polarization, both systems used a low- frequency-alternating voltage, 25Hz and 400Hz, respectively. Moisture and saliva were removed by a continuous stream of air in the vanguard system to prevent surface conductance. Conversely, to assure a good electrical contact and minimize the effect of saliva, the Caries Meter L requires that the pits and fissures be moistened with saline. Electrical conductivity has been shown to have an overall satisfactory performance in detecting occlusal caries in vitro and in vivo and approximal caries in vitro. [13]

X RAY- BASED IMAGING

Intra Oral Radiography (INR)

The history of dental radiography begins with the discovery of the x- ray. The x- ray revolutionized the methods of practicing medicine and dentistry by making it possible to visualize internal body structures. [17] Radiography is useful for the detection of dental caries because the caries process causes tooth demineralization. The lesion is darker than the unaffected portion and may be detected in radiographs. An early carious lesion may not have yet caused sufficient demineralization to be detected in radiographs. It is often useful to mount successive sets of bitewing radiographs in one film holder to facilitate comparison and evaluation of evidence of progression.

Intra oral radiography can reveal carious lesions that otherwise might go under detection during a thorough clinical examination.

On the other hand, early carious lesions are difficult to detect with radiographs, particularly, when they are small and limited to the enamel. Therefore, clinical and x-ray examinations are necessary in the detection of dental caries.

Posterior bitewing radiographs are the most useful x-ray projections for detecting caries in the distal third of a canine and the interproximal and occlusal surfaces of premolar and molars. [20] However, Virajsilp V et al. reported that the reliability of DIAGNOdent is very high and its diagnostic validity is higher than that of bitewing radiography for proximal caries detection in primary teeth. [21]

Now, for the purpose of carious lesion detection, intra oral radiography is a standard procedure and is essential for diagnosing inter proximal caries. [22, 23]

Extra Oral Radiography (EOR)

Extraoral radiographic techniques for proximal caries detection have been studied and proven to be inferior to intraoral techniques. However, the main focus was on conventional panoramic radiography.

Clifton et al. used multidirectional tomography and panoramic radiography as well as intra-oral D-speed film for combined assessment of proximal and occlusal caries. It was concluded that when proximal surfaces were evaluated alone, D-speed film was significantly better. For occlusal caries, there was no statistically significant difference between multi directional tomography and D-speed film. [24]

One study has demonstrated that scanogram images have the potential to be the first practical extraoral imaging modality for proximal caries detection. Influencing factors to be discussed are the sample, exposure techniques, resolution and contrast enhancement. In this study, the performance of screen-film and enhanced digital scanograms were not statistically different from Insight film for proximal caries detection. Unenhanced digital scanograms exhibited a statistically significant lower diagnostic accuracy than Insight film. [25]

including image manipulation and a reduction in radiation required to obtain a diagnostic image. [1] In addition, Alkurt MT showed that the diagnostic performance of E- and F- speed films and direct digital radiography are similar for proximal caries detection. [26]

Three dimensional x-ray imaging

Since the discovery of the x-ray in 1895 and its application to dentistry, radiographic imaging of oral anatomy has consisted primarily of viewing 3-D structures collapsed onto a two-dimensional (2-D) plan. This form of imaging, known as transmission radiography, is characterized by a point source of radiation producing a beam which passes through the patient and strikes a relatively flat image receptor (usually a film). This produces essentially an attenuation map of the structures through which the beam has been transmitted. While the dental profession has relied on this method for obtaining information about the hard tissues of the oral cavity, it inevitably superimposes anatomy and metallic restorations which confound the problem of identifying and/or localizing diseases or objects in three dimensions. Moreover, studies have shown that intra-oral films produced in this way are not sensitive for the detection of caries, periodontal, and periapical diseases as it was previously thought.

Increasing the diagnostic yield for caries may be possible with three-dimensional (3D) imaging methods. However, general dentists currently use two-dimensional (2D) images, and although CT/MRI modalities exist for hospitals, there are no systems for general practitioner caries diagnosis. The choices for 3D imaging of dentoalveolar diagnostic tasks are currently limited to different forms of local CT including x-ray microtomography (XMT), tuned aperture computed tomography (TACT) and super-ortho-cubic CT. [27]

X-ray microtomography

X-ray microtomography is a miniaturized version of computerized axial tomography with a resolution of the order of micrometres. In the biomedical field, it is particularly useful in the study of hard tissue because of its ability to accurately measure the linear attenuation coefficient. From this, the mineral concentration can be computed, which is one measure of bone quality. Using microtomography we can form three-dimensional images of bone from which structural parameters can be derived which could not be measured using conventional histomorphometry. [28]

Digital radiography

The use of digital radiography addresses two primary disadvantages of dental film, Daatselaar et al. described the development of a bench top local CT device which is able of producing spatial and contrast resolutions necessary for improved detection of interproximal caries as well as other dentoalveolar conditions. The authors concluded that ‘local CT reconstruction are feasible’ and ‘the resolution of the local CT images produced from basis projections that were acquired using standard dental CCD sensor was diagnostically suitable. This makes local CT a potential technique for the diagnosis of interproximal caries. [29]

Transverse microadiography(TMR)

TMR or contact- microradiography is the most practical and widely accepted method used to assess de- and re- mineralization of dental hard tissues in studies. It is a highly sensitive method to measure the change in mineral content of enamel and dentine samples. In TMR, the tooth sample to be investigated is cut into thin slices (about 80 μm and 200 μm for dentine samples). A microradiographic image is made on high resolution film X-ray exposure of the sections together with a calibration step wedge. The microradiogram is digitized by a video camera or photomultiplier. The mineral can be automatically calculated from the gray levels of the images of section and step wedge. Parameters of interest are mineral loss (Delta Z in Vol %. μm), lesion depth (Lesd in μm), ratio or average loss of mineral content in the lesion area (Delta Z/ Lesd in Vol %), the mineral Vol % and position of the subsurface layer and lesion body.The accuracy of TMR for enamel and dentine in lesion depth is about 200 Vol %. μm in deltea Z. With mineral details of approximately 2-3 µm can be detected. The time required for making 5 scans plus evaluation is 3-4 minutes (which is less than 1 minute for a scan). The time required for acquiring step wedge data is one minute or less depending on the number of step wedge steps. Statistical analysis of many scans is supported. [30]

Longitudinal Micro Radiography (LMR)

LMR is a method to determine mineral loss in tooth slice samples in vitro. In this method, a microradiogram of a slice of a tooth is prepared. Mineral content is then computed by performing measurements of the optical density of the microradiogram and by comparing these values with that of an aluminum step wedge. LMR is based on the same principle as TMR. In contrast to TMR, where a transversal slice of the tooth is created, LMR is based on longitudinal slices. The LMR system is highly automated. Scanning the sample is performed using a XY scanning table and all calculations are performed automatically. [29]

Tuned Aperture Computed Tomography (TACT)

It has been shown in controlled in vitro studies that it can enhance the clinician's ability to detect and localize disease, anatomically significant structures and abnormalities. TACT promises to overcome some of the current limitations of conventional dental technologies and increases the 3-D information currently available in ways that can influence significantly the diagnosis and management of dentoalveolar diseases and abnormalities.

With TACT, the patient has to remain motionless only during each individual exposure. The time between exposures is determined by convenience, diagnostic task, economics or other factors, because delays have no impact on the accuracy of the reconstruction. This approach also permits the signal-to-noise ratio to be tuned interactively to the needs of the examination.[31]

Harse et al. performed a study to compare the difference in the accuracy of proximal caries detection by extraoral tuned aperture computed tomography (TACT), intraoral TACT, and film radiography. It was concluded that extraoral TACT was not statistically different from intraoral TACT or film radigraphs for proximal caries detection. This suggested that extraoral TACT may have some clinical utilities. [32]

Computer- Aided Radiographic Method (CARM)

Computer- aided radiographic method exploits the measurement potential of computers in assessing and recording lesion size. In the new Trophy 97 system, artificial intelligence software (Logicon caries detector) is integrated: approximal carious lesions are diagnosed and evaluated with the aid of unique histologic database, allowing graphic visualization of the size and progression of the lesion.

At both D1 and D3 thresholds, computer-aided methods offer high levels of sensitivity for approximal lesions. Earlier soft wares paid some trade off high with specificity, but newer methods also have high values for this measure. [33] Furthermore, Wenzel reported that the major advantages may be the significant dose reductions and the ability for image quality manipulation. [34]

Terahertz Pulse Imaging (TPI)

Terahertz pulse imaging (TPI) is s relatively new imaging technique that has been demonstrated in both non-biological applications. Although, the TPI system is a new technique for imaging caries using non ionizing impulses of terahertz radiation, (an electromagnetic radiation) and its ability to detect early stages of caries lesions in various sections of teeth and a hope in future when this technique could indicate caries in all areas of teeth. Terahertz systems are relatively expensive and do not offer the resolving power of radiographic examination. This system also needs more researches to make it possible to be inserted into the mouth for in vivo studies, while it is expected that technological developments will improve the systems to bring them within easy reach of dentists. The coherent detection scheme of system will be safer than those employing X-rays. Unlike radiography TPI also delivers a spectrum of different frequencies for each pixel measured. This offers the possibility of using that spectrum for diagnosis that goes beyond simply measuring mineralization levels. [35]

Pickwell et al. compared terahertz pulsed imaging (TPI) with transmission microradiography (TMR) for depth measurement of enamel demineralizations. It was concluded that TPI measured demineralization in the range of 47% of that the TPI system uses only micro-watts of radiation of a type that is non-ionizing.

Because the exposure levels from this system are orders of magnitude smaller than exposure levels that occur naturally, this of TMR depth plus an intercept of micron, whereas further calculations allowed the TMR depths to be determined to within 5% using TPI. [36]

These are some caries diagnosis methods used today. In this era of evidence based dentistry, systematic reviews and validation studies of caries detection methods have been addressed in some studies but there is still need for more studies in the future to clearly determine the best and most accurate ways of caries diagnosis.

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