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# Recent Approaches in Carious Tooth Diagnosis

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***Abstract***
*The development of a caries lesion is the result of a complicated interplay of many factors. The term caries is used to embrace both the disease process and its consequences, ie the damage caused by the disease process. A large component of the daily work of dental personnel comprises caries diagnosis, risk assessment (identifying tooth surfaces, individuals or populations groups at risk of developing caries) and early treatment of caries lesions, particularly in children and adolescents. These tasks are so closely related that a caries diagnosis is followed by risk assessment, which in turns forms the basis of treatment decisions. Dental caries is a highly prevalent chronic disease of the teeth that affects individuals globally. When considering the inclusion of initial lesions in the clinical assessment, it is evident that only a few individuals remain unaffected by dental caries. In recent years, there has been a noticeable shift in the patterns of dental caries progression. The rate of advancement of non-cavitated lesions appears sluggish. This characteristic enables the implementation of preventive measures when the lesions are most likely to be halted. Integrating conventional techniques with more advanced and precise methods can enhance the diagnosis of caries and facilitate the monitoring of non-surgical treatments by clinicians.*

***Key words:*** *Caries diagnosis, radiograph, dyes, computed radiography, tactile sensation, digital radiography*

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**Recent Advances in Carious Tooth Diagnosis**

Dental caries is a highly prevalent chronic disease of the teeth that affects individuals globally. When considering the inclusion of initial lesions in the clinical assessment, it is evident that only a few individuals remain unaffected by dental caries. In recent years, there has been a noticeable shift in the patterns of dental caries progression.[1] The rate of advancement of non-cavitated lesions appears sluggish. This characteristic enables the implementation of preventive measures when the lesions are most likely to be halted. Integrating conventional techniques with more advanced and precise methods can enhance the diagnosis of caries and facilitate the monitoring of non-surgical treatments by clinicians.[1]

General criteria for an ideal caries detection method include following : Ideal caries detection method should capture the whole caries progress, from the earliest stage to the cavitation stage,

It should be accurate, precise, easy to apply, useful for all surfaces of the tooth including caries adjacent to restorations, assess the activity of the lesion, sensitive, allowing lesions to be detected at early stages

Early diagnosis of the caries lesion is important because the carious process can be modified by preventive treatment so that the lesion does not progress. If the caries disease can be diagnosed at an initial stage (e.g. white spot lesion) the balance can be tipped in favor of arrestment of the process by modifying diet, improving plaque control, and appropriate use of fluoride.Using noninvasive quantitative diagnostic methods it should be possible to detect lesions at an initial stage and subsequently monitor lesion changes over time during which preventive measures could be introduced.[2]

**METHODS FOR CARIES DIAGNOSIS**

**VISUAL INSPECTION**

The visual examination facilitated using a dental mirror and a ball-ended explorer should be performed gently on clean and dry teeth. International Caries Detection and Assessment System (ICDAS) and Nyvad Criteria are the most used scoring systems. They are used to clinically diagnose and evaluate caries based on a visual-tactile assessment. Caries detection according to the visual-tactile examination method depends on the visual appearance and surface characteristic of the lesion.

**TACTILE SENSATION**

The use of a sharp probe or explorer has been recommended for at least two decades that this technique be limited or replaced for detection of fissural or smooth surfaces. It is recommended that only a ball-ended probe is used, especially to check enamel surface integrity/roughness. The explorer and the dental floss are used for tactile examination..

**RADIOGRAPHY**

The limitations of radiography are in the detection of occlusal carious lesions, especially in their early stages. Sensitivity and accuracy have been reported as low, especially for lesions within the enamel, and so radiography should be used in conjunction with other detection methods, such as transillumination. The validity of results are affected by clinician experience and training, with more experienced clinicians having lower sensitivity and higher specificity when compared to undergraduate students. The detection capabilities of digital radiography are reported to be similar to that of film based methods and have the benefit of reduced radiation exposure and also the ability to readily transfer the images.The use of subtraction radiographic methods have been reported to increase the accuracy and reproducibility compared to visual assessment of the images.Computer assisted detection using bitewing radiography can improve accuracy, especially when lesions are deeper than half way through the enamel.

**XRAY-BASED IMAGING-**

**CONVENTIONAL RADIOGRAPHS**

Conventionally, intra-oral periapical (IOPA) and bite wing radiographs are two types of popularly employed techniques. Occlusal and panoramic views are employed for detecting other pathological lesionsof the oral cavity and for educating the public through a broader view of the oral cavity.[3]

Periapical radiographs are primarily useful for detecting changes about the roots and in between the teeth. However, if parelleling technique is used for obtaining periapical radiograph, the usefulness of this projection for detecting caries in both anterior and posterior teeth is increased.

**Intra oral Radiography**: Radiography is useful for the detection of dental caries because the caries processcauses tooth demineralization. The lesion is darker than the unaffected portion and maybe detected in radiographs. An early carious lesion may not have yet caused sufficientdemineralization 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

**Extra Oral Radiography:** 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.

**Intraoral bitewing radiograph**

The usage of intraoral digital radiography technology provides the benefit of quicker examination and image manipulation than the film radiograph technique. It allows the manipulation of image characteristics (such as contrast, brightness, sharpness, and other parameters) to improve images' clarity for better diagnosis and monitoring .

**Digital radiography**: A digital radiograph shows an image formed and represented by a spatially distributed set of discrete sensors and pixels. Digital, filmless, techniques for intraoral radiography have been developed for several important reasons like: Conventional film absorbs only a few percent of the x-rays that reach it, utilizing very little of the radiation to which the patient has been exposed, Poor darkroom procedure can lead to both unnecessarily high doses of radiation and loss of diagnostic information, Development of films is time consuming and the developer and fixing solutions are hazardous to the environment. Digital radiography has offered the potential to increase the diagnostic yield of dental radiographs. It has manifested itself in subtraction radiography. A digital radiograph is comprised of a number of pixels. Each pixel carries a value between 0 and 255, with 0 being black and 255 being white.The values in between represent shades of grey, and it can be

quickly appreciated that a digital radiograph, with a potential of 256 grey levels has significantly lower resolution than a conventional radiograph that contain millions of grey levels.

**COMPUTER AIDED DIAGNOSIS:**Computer-aided radiographic methods exploit the measurement potential of computers in assessing and recording lesion size. Automated analysis providing sensitive and objective observation of smaller lesions which otherwise are not perceptible to naked eye, monitoring the lesion and quantification of small lesions. Its limitations are:a need for standardization of exposure geometry, higher sensitivity but lesser specificity, time consuming and high cost. [The use of Computer-aided diagnosis (CAD) of disease is well-established in medical radiology, having been utilized since the 1980's at the University of Chicago and other medical centers for assistance with the diagnosis of lung nodules, breast cancer, osteoporosis and other complex radiographic tasks.[4]

**Cone beam computed tomography(CBCT)**

Cone beam computed tomography (CBCT) is a modified type of medical computed tomography that uses a cone-beam of radiation rather than the conventional fan beam. The main advantage of the CBCT is that it provides three-dimensional (3-D) images that allow better observation and evaluation of target tissues. Furthermore, CBCT generates images in lesser radiation doses and at a lower cost than conventional medical computed tomography . Several studies were conducted to evaluate the performance of CBCT in the detection of enamel and dentin caries lesions. They concluded that CBCT could be used as a valuable tool in proximal caries detection . Compared to intraoral radiography, CBCT showed higher sensitivity in both enamel and dentin caries detection. Since the CBCT can detect caries at a lower rate of demineralization, aside from its ease of use, the CBCT produces 3D images that are free of distortion and superimposition. Also, the images could be examined in different sections and planes, which could provide additional useful information . Nonetheless, the CBCT is not widely available, which restricts its use in routine dental examinations. Furthermore, because the CBCT emits more radiation than intraoral radiography, it is not recommended for regular caries detection.

**CARIES DETECTING DYES**

In 1972, it was suggested that cariesdetector 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. If an object is hard to distinguish from its background, the color induced by the dye can make it easier to visualize, or, if several objects have a similar appearance, coloring a dye may discriminate between them and allow identification. The observation of the coloring can be either qualitative or quantitative. For a qualitative assessment it is sufficient to observe a color change or differentiate the colored objects from the uncolored ones. For a quantitative assessment, either the amount of staining or the intensity of the colour has to be measured. The amount of staining can be determined for instance by counting the number of stained cells and comparing this with the number of unstained cells, or a measurement of the area of staining compared with the unstained area. The intensity of the color can be determined by measurement of absorption or fluorescence, which in way is opposite quantities. Absorption can be measured by quantitating the decrease of light intensity at a particular wavelength, and fluorescence by quantitating the increase in light intensity at a particular wavelength. In cariology most often the visual appearance of the dyes is observed because traditionally, for diagnosis identification if far more important than quantification. Quantification of carious lesions has been recognized as an important tool for evaluating the level of mineralization.

**FIBRE OPTIC TRANSILLUMINATION**

The qualitative method known as fiber-optic transillumination (FOTI) was first used in the 1970s. It is a straightforward, non-invasive, painless operation that the patient is not at risk from repeating. It is effective at finding proximal lesions and can be utilised to identify caries on all surfaces. About occlusal dentine lesions, a recent review found a mean sensitivity of just 14 and a specificity of 95, while for proximal lesions, a sensitivity and specificity of 4 and 100%. The FOTI approach has some drawbacks; it is subjective rather than objective. No continuous data output is made. It is impossible to capture what is viewed as an image. It works because of the different index of light transmission for decay, sound tooth structure and healthy periodontium. Since the carious tooth structure has a lower index of light transmission than sound tooth structure, an area of decay shows up as a darkened shadow that follows the spread of decay along the path of dentinal tubules.Fibre optic transillumination uses high intensity white light that is presented through a small aperture in the form of a dental handpiece. The tip is 0.5mm;light source is by a 150 watt halogen lamp set at maximum intensity. The probe is applied perpendicular to the buccal and lingual surfaces and its position and angulation varied to obtain maximum light scattering through the lesion.[5]

**DIGITAL IMAGING**

Digital image is an image composed of a series of sensors and pixels distributed orderly . The advantages of digital imaging over conventional radiography is as follows ;

- The radiation dose is approximately 60-90% lower,
- The image receptor is often larger,
- The image is immediately available,
- The image can be electronically transferred,
- Magnification, contrast, brightness can be adjusted,
- There is no need for processing solutions, protecting the environment and lowering the costs.

**XERORADIOGRAPHY**

Xeroradiography is a relatively new method for recording the images without a film, based on an electrostatic process similar to that used in some photocopying machine. Features like pronounced edge enhancement (differentiating areas of different densities especially at the margins or edges), a choice of positive and negative displays, good detail, and wide exposure latitude make xeroradiography attractive.

This technique uses the xeroradiographic copying process for recording images produced by X-rays. Xeroradiography is twice as sensitive as D-Speed films. This technique offers the opportunity ofedge enhancement. Edge enhancement helps distinguishing the areas of different densities at the margins or edges.

**FLUORESCENCE**

This is a well-known dental diagnostic method. When the quantitative light-induced fluorescence (QLF) technology was first introduced in 1995, it was immediately put to use tracking the progression of caries lesions . Since then, numerous studies have shown that the QLFTM system can identify and track caries in both children and adults in real time.To distinguish between caries and surrounding sound enamel, QLF uses the natural fluorescence of the teeth, which is determined by the light absorption and scattering characteristics of the teeth. With demineralization, the auto fluorescence of tooth tissue decreases. QLF quantifies the percentage fluorescence change in demineralized enamel relative to surrounding sound enamel and correlates it with the amount of mineral lost during demineralization. When viewing caries lesions with QLF, they appear dark.

**LIGHT FLUORESCENCE:** Autofluorescence of the tooth alters as the mineral content of the dental hard tissue changes. The QLF method can also measure and quantify the red fluorescence (RF) from microorganisms in plaque. The QLF equipment is comprised of a light box containing a xenon bulb and a hand piece, similar in appearance to an intraoral camera, light is passed to the hand piece via a liquid light guide and the hand piece contains the band pass filter. Live images are displayed via a computer and accompanying software enables patient's details to be entered and individual images of the teeth of interest to be captured and stored. QLF can image all tooth surfaces except inter- proximally. Once an image of a tooth has been captured, the next stage is to analyze any lesions and produce a quantitative assessment of the demineralization status of the tooth The qualitative light-induced fluorescence (QLF) technique can quantify small alterations in teeth based on autofluorescence, which occurs when the tooth is exposed to 405 nm visible blue light. The QLF device is composed of a light-emitted diode (LED), an inductor filter, and a metal oxide semiconductor sensor. The fluorescent images of the tooth are digitalized and quantitatively assessed concerning the adjacent healthy tooth structures.

**LASER FLUORECENCE:**

Laser fluorescence (LF) is a noninvasive device used to detect caries lesions and estimate their depth by exposing the tooth to a non-ionizing laser . It consists of a tip that emits monochromatic red light at 655 nm wavelength and a sensor to detect the backscattered fluorescence from the examined tooth and produce a two-dimensional hyperspectral image.Carious teeth generate fluorescence proportional to the degree of caries, whereas clean and healthy teeth produce no or little fluorescence. It was proposed that these fluorescence changes are caused by protoporphyrin, a photosensitive pigment found in carious tissues as a consequence of bacterial metabolic activity . Laser fluorescence (LF) has been found to tend to higher specificity than sensitivity for enamel caries detection. The performance of the LF is better with larger lesions .

**DIAGNODENT**

This is a laser fluorescence system that detects changes in the tooth structure due to demineralization. These structural changes cause an increase in the fluorescence at specific excitation wavelengths. The intensity of the fluorescence depends upon the wavelength of the light as well as the structure and condition of hard dentinal tissues. DIAGNOdent with a laser diode that generates a pulsed 655 nm laser beam via a central fiber is transported to the tip of the device and into the tooth. When the incident light interacts with tooth substance, it

stimulates fluorescent or luminescent light at longer Stokes shiftedwavelengths. The intensity of fluorescence is a function of the degree of demineralization or bacterial concentration in the probed region. In fact, the full fluorescence mechanisms of the DIAGNOdent is still only partly understood.

**ELECTRONICS CARIES MONITOR**

The demineralization reaction has been shown to impact the electrical conductivity of the tooth. The bulk resistance of dental tissue is measured using the ECM device. Higher conductivity has been documented in caries teeth due to increased porosity within caries tooth structure and the presence of saliva within these pores. These result in a reduction of electrical resistance. Electronic caries monitor (ECM) measures the electrical bulk resistance of dental tissue using a single, fixed-frequency alternating current. Both enamel and exposed dentin surfaces can be measured. A probe is used to send electricity through the tooth and body to a counter-electrode, which is typically kept in the patient's hand. Because the body has low resistance in comparison to dental tissues, the resistance value typically closely represents that of the tooth near the probe contact point.

**ULTRASONICS**

The first use of ultrasound in dentistry was by Baum et al. in 1963.Ultrasound was first used in 1956 for medical purposes. Ultrasound devices exhibit a greater degree of sensitivity in detecting proximal caries when compared to bitewing radiographs. The principle behind the technique is that sound waves can pass through gases, liquids and solids and the boundaries between them.Images of tissues can be acquired by collecting the reflected sound waves. In order for sound waves to reach the tooth they must pass first through a coupling mechanism, usually water and glycerine33 The pulse echo ultrasonic waves mean that any impulse generated in the transducer is transmitted into a medium (tooth) and then reflected back to the transducer if it strikes at any discontinuity. Sound and demineralized can be differentiated from their echo position on the CRT. Sound waves with frequencies (20 kHz) higher than those heard by humans are used in ultrasound technology.

**OPTICAL COHERENCE TOMOGRAPHY**

Optical coherence tomography (OCT) is an interferometric technique that establishes cross-sectional images of biological structures without the negative effect of ionization radiation exposure. It uses coherent light with a near-infrared wavelength that has maximum depth of penetration through the biological tissues . The first use of OCT in dental research was done by Colston et al. in 1998 . In dentistry, OCT is used for many applications such as caries detection, evaluation of marginal integrity of tooth restoration, and tooth crack diagnosis . Optical coherence tomography (OCT) is a noninvasive tool that creates real-time 3D images at micrometer resolution through light reflection and backscattering based on the optical absorption and scattering properties of the examined tissue. The OCT imaging depth is significantly impacted by the medium's translucency. Structures that do not transmit light and deeper structures are irrelevant for OCT imaging.

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