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Research Article

Changing Concepts in the Diagnosis of Dental Caries: A Review

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Abstract

Dental caries is an infectious and transmissible disease of teeth which results in localized dissolution and destruction of calcified tissues and this microbiologic disease is caused by the dental plaque, an oral biofilm, and by exposure to fermentable carbohydrates. It has also proven to be the most prevalent dental disease in children and adolescents. Caries diagnosis is the perception that integrates information attained by clinical examination of the teeth, use of caries diagnostic aids and communication with the patient and their biological facts. There are traditional methods as well as recent advancements for the diagnosis of dental caries. Visual inspection, tactile examination with an explorer, and radiographic examination are the typically used traditional methods. The various recent advancements have made diagnosis of dental caries possible through the use of Electrical resistance, Fibre-optic transillumination (FOTI), Digital Imaging Fibreoptic Transillumination (DIFOTI), Pulsed laser caries detector (DIAGNOdent), Ultra-violet illumination, Endoscope or Videoscope, Ultrasonic imaging and Dye penetration method. These defined techniques have been proved to be very useful in detecting even the earliest stages of carious lesions. Thus, by implementing these refined diagnostic techniques coupled with the traditional methods, a dental clinician implicitly changes his/her threshold for caries lesion detection.

Keywords: *Dental Caries; Diagnosis; Dentist; Traditional Methods; Recent Advancements*

Introduction

Dental caries has been known eternally as a communicable, infectious disease of teeth which results in localized dissolution and destruction of calcified tissues and this microbiologic disease is caused by the dental plaque, an oral biofilm, and by exposure to fermentable carbohydrates. The existing literature has also shown that it is the most predominant dental disease among children and young adults as well. But as Dentistry advanced in the twentieth century, rates of tooth decay have been dwindling gradually due to fluoride use, oral health awareness, and newer techniques for early diagnosis. The preventive and treatment modalities for caries, when it occurs, are progressively changing according to the time and place [1].

Diagnosis is an art or an act of recognizing a disease from its presenting signs and symptoms. Caries diagnosis is thus the idea that integrates information attained by clinical examination of the teeth, use of caries diagnostic aids, direct communication with the patient and their biological facts [2]. The fundamental purpose of using caries diagnostic methods is to be able to detect and classify lesions in a way that can help the selection of the most appropriate type of intervention for the patient in question.

Methods of diagnosing dental caries

Recently, the patterns of disease presentation have reformed. Since the advancement of early, non-cavitated lesions appears to be slower, preventive strategies can be implemented easily to arrest any further decay [2]. Traditional methods combined with the recent advancements in caries diagnosis may improve and also help the dental professionals in monitoring the treatments. The various methods of diagnosing Dental caries are discussed below.

Traditional methods of diagnosis of dental caries

Visual inspection, tactile examination using an explorer, and radiographic examination are the common traditional approaches

used for caries diagnosis. These conventional methods are still used in dental practice; however, most of these methods have been upgraded as a result of paradigm shifts or the development of new diagnostic equipments [3].

Visual and tactile examination

Visual examinations are assisted by the usage of compressed air. Early white spot lesions are also be labeled as "hidden carious lesions", a term used to describe carious lesions that are undetectable on visual, tactile and radiographic examination. These lesions are detectable only when dried as they appear as a chalky white area while drying. A lesion clearly visible on a wet tooth has probably infiltrated most of the way through the enamel or may be into the dentine [4].

The visual examination is combined with tactile examination, carried out with a dental explorer. The conventional tactile examination is no longer recommended, due to creditable scientific evidence that if a demineralised surface, known as a white-spot lesion, is still intact it has the potential to remineralise. Any structural damage to the white-spot demineralised surface due to forceful or faulty tactile examination can prevent that lesion from remineralization [5].

Dentistry has likewise presented a simplistic model of the microscopic characteristics of fissure anatomy which is also incorrect. It is now recognized that fissures in teeth are complex structures, with areas of subsurface restrictions, hypocalcification and restrictions within the fissure that can effectively hide areas of sub-surface hypocalcification and that may be the genesis of decay. So, the various diagnostic aids available should be used to diagnose caries at the earliest possible stage [2].

Radiographic examination

The observation of teeth and other oral structures through the use of radiographs remains the "gold standard" for the diagnosis of dental caries. The use of radiographs supports in the quantification of bone height, inspection of body structures, and apical radiolucencies. It is a routine procedure for dental clinicians as a part of their dental practice to expose and interpret radiographs. Thus, it is very important for the dentists to follow a good technique, so that the radiographs produced can be accurately interpreted and repeating of radiographs is avoided, a situation that can be stressful for the patients as it requires additional exposure to harmful X rays [6]. Radiographs have been proved to be boon to the profession with the advent of numerous new techniques.

Radiographic methods encompass the following techniques.

Conventional radiography [7]

Two types of techniques are majorly employed:

1. Intra-oral periapical radiography
2. Bite-wing radiography.

Periapical radiographs are particularly helpful in detecting changes about the root portion and in the interdental areas. Paralleling technique usage upsurges the credibility of this projection for the detection of dental caries in both anterior and posterior teeth. Bitewing radiographs are very important in diagnosing incipient lesions at contact points. Additionally, when used as adjuncts the bitewing significantly increases the accurateness of the diagnosis of pit and fissure caries.

Xeroradiography [7]

This technique is similar in function to the photocopying machine. Selenium particles are the materials that are used to layer its plate. A latent (negative) image is formed when X-rays are passed onto the film and then this negative image is converted to a positive image. The competency to have both positive and negative prints simultaneously is the prime feature of xeroradiography technique. A phenomenon of "Edge Enhancement" is possible since it is twice as sensitive as conventional D-speed film. Differentiating the zones of different densities particularly at the margins or edges is mentioned to as Edge Enhancement. Main disadvantages of this technique are varying exposure times and development of films should be within 15 minutes.

Digital imaging [8]

Digital imaging, also recognized as computerized digital radiography, is formed by the use of the spatial distribution of pixels and the different shades of grey of each of the pixels. Thus, the digital radiographic imaging devices interface with a computer to digitize the digital radiographic image into pixels that are then anticipated on a computer monitor.

Digital radiographs are taken by using a sensor that is positioned in the same site that dental film would be placed, rather than using traditional radiographic films for captivating X rays. Then image can be observed on a computer monitor or can be saved, transferred to another site, or printed for future use. Digital imaging equipment is similarly accessible for captivating panographic and cephalometric views extra-orally.

Computer image analysis [9]

Recently researchers have generated a computer-based software system which is capable of diagnosing approximal caries and even helps in making decisions about restorative care. These softwares have been proved useful for automated interpretation of digital radiographs to standardize image assessment. Software such as "Caries Finder" has been found to be capable of raising the overall accuracy by increasing the consistency of treatment decisions over the course of time. Image analysis systems can act as a significant tool in reducing the number of restorations in intact teeth surfaces.

Subtraction radiography

It is a method of reducing the structural noise for increasing the delectability of changes in the radiographic pattern. It needs two identical images. The subtracted image is thus a combination of these two images. The capability of digital subtraction to record least differences is directly proportional to the degree of matching of the two images [8]. Taken images can be superimposed on each other, which marks it as an excellent way for tracing the overall progress of the carious lesion over time. Thus, it is helpful not just for caries diagnosis but also for caries management.

Electrical resistance

Due to the high inorganic content of sound enamel it remains an insulator of electricity. Enamel demineralization causes increased porosity in the tooth surfaces. Saliva fills these spaces and forms conductive pathways for the flow of electrical current. The quantity of occurred demineralization and electrical conductivity are directly proportional towards each other. Electrical resistance is the measure of the electrical conductivity through these tiny spaces or porosities.

An instrument termed "Van Guard electronic caries detector" has been designed to measure electrical conductivity of the tooth. The electrical conductivity of tooth is expressed numerically on a scale from 0-9, which directs from sound tooth to an increased degree of demineralization. A modified form of this instrument 'Electronic Caries Monitor' spots caries at a single point on tooth. Furthermore, it can also monitor the whole occlusal surface for caries by enwrapping the surface with a conducting medium before probe tip placement.

Diagnostic methods based on visible light

These diagnostic approaches work on the ideologies of light transmission through teeth. Scattering is the method in which the direction of photon is altered without the loss of any energy. Every time the probability of scattering is found to be more than absorption in a sound tooth. Both scattering and absorption occur more frequently in the dentin along the light path rather than in the enamel. However, in a white spot carious lesion, scattering is more prominent than in sound enamel. The penetrating photons alter their direction more frequently in carious enamel and before they reach dentin, they get back-scattered. Thus, a reflected lesion seems whiter than the surrounding sound parts of the tooth [11].

Optical caries monitor [11]

Because of the strong scattering of light within the lesion, white spot lesions usually appears paler than the adjacent sound enamel. This phenomenon of strong scattering can be measured and quantified using newer fiber optic technology. The measured quantity stands as the 'scattering coefficient' (Spitzer and Ten Bosch, 1975). Optical Caries Monitor comprises three parts - a light source, measuring and reference units, and a detection part. The light is transmitted over a fiber bundle to the tip of the handpiece. The tip is placed opposing to the tooth surface and the reflected light is collected through different fibers in the same tip. The scattering coefficient values remain correlated with histological, lesion depth and with mineral loss per unit area at the deepest point of the lesion surface (Brinkman., *et al.* 1988).

Fiber optic trans illumination (FOTI)

Carious lesion has a lowered index of light transmission so usually an area of caries seems to be a darkened shadow that tracks the spread of decay through the dentin and Fiber Optic Trans Illumination works on this principle. FOTI has been used since the 1960s, in common medical procedures. In the field of dentistry, it was first used as a better source of light for surgical retractors. Friedman

and Marcus first suggested the use of FOTI for the diagnosis of dental caries in the 1970s [12].

It has been presented as a quantitative diagnostic process by which teeth are transilluminated. For examination, the probe tip is positioned in the embrasure underneath the contact point of proximal surface through either buccal or lingual surface of teeth to be examined. Observation of the marginal ridge is done from the occlusal surface. In case of any breakage in the integrity of the marginal ridge, its shadow which extends to the dentino enamel junction (DEJ) beneath the marginal ridge will become evident. This technique is simple and faster than other traditional methods of radiography.

Digital imaging fibreoptic transillumination (DIFOTI)

Transillumination has been used over last 30 years for the diagnosing dental caries. The digital imaging fibreoptic transillumination (DIFOTI) system significantly has improved traditional transillumination to more advanced diagnostic levels.

A digital charged couple device camera is used for capturing the image which is subsequently sent to a computer for analysis with dedicated algorithms. The images are saved and used for longitudinal evaluation of dental caries. When teeth are transilluminated, the areas of demineralized enamel or dentin carry out scattering of light, and incipient lesions thus appear as darker areas in the taken images. The DIFOTI is used for preventive management of initial dental caries, and the information obtained can be utilized by the dental professional to assist the patients on focusing their high risk areas in the oral cavity. The DIFOTI is not advanced enough and is inefficient to determine depths of lesions but it easily detect interproximal caries on surface as well as radiographs.

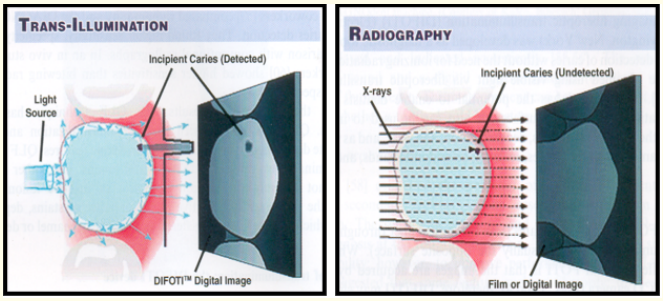

Figure 1: *Digital imaging fibreoptic transillumination (DIFOTI).*

Pulsed laser caries detector- DIAGNOdent

DIAGNOdent is a battery-powered device that is based on laser fluorescence to diagnose dental caries. The diagnostic probe tip is placed on the surface of the tooth and a pulsed laser beam with a wavelength of 655 nm is then transmitted while probing along the pits and fissures of the teeth. When presence of carious tooth structure is sensed, fluorescent light with an altered wavelength is produced. An acoustic signal is generated as the new wavelength of light which is transmitted back to the power box, and a numeric reading is displayed on the monitor. Further readings at recall appointments help to determine if the DIAGNOdent value has increased, decreased or stabilized [13].

Processing

After absorbing the light it induces infra-red fluorescence of organic and inorganic matter of the tooth. This fluorescence is concentrated at the top of the handpiece and transferred back to the DIAGNOdent unit. The fluorescence is converted into an acoustic signal which is presented as a numerical reading ranging from 0-99. Increased fluorescence is a confirmation for dental caries, mostly when the reading is ≥ 20 [14].

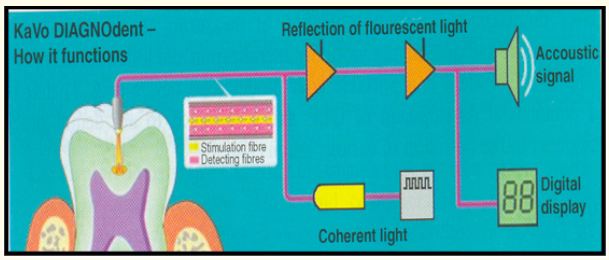

Figure 2: *DIAGNOdent.*

Interpretation of results

The numerical scale readings can be inferred as:

- 0 to 14 indicates no caries, or enamel caries on histology, limited to the outer half of the enamel thickness.
- 15 to 20 indicate histological caries spreading beyond the outer half, but confined to the enamel.
- 21 to 99 - Histological dentinal caries.

DIAGNOdent is helpful in diagnosing more so “occult or hidden” caries, which are remineralizable white spot lesions.

Ultraviolet illumination

Ultraviolet light (UV) helps in increasing the optical contrast between the carious region and the surrounding sound tooth tissue. Under the UV light illumination the natural fluorescence of enamel is compromised in areas of reduced mineral content such as in dental caries, artificial demineralization or developmental defects. In a fluorescent background, dental caries appears as a dark spot.

Quantitative light-induced fluorescence [14]

Quantitative light induced fluorescence (QLF) advances early detection of dental caries including the white spots of smooth surface caries. QLF makes use of the intrinsic fluorescence of the teeth within the yellow-green spectrum of visible light. Illumination of the teeth is done by a blue light which is emitted from the handpiece. It causes the tooth structure to fluoresce and the image is produced with a color microvideo charge-coupled device camera.

Image analysis computer software is used to save and analyze the collected data. The tooth is visible as fluorescent green on the computer monitor and dark areas visualized are indicative of loss of mineral content. With the aid of a computer software, the image can be stored and visualized over the course of time to keep track of any demineralization or remineralization of carious lesions. QLF is an enhanced imaging technique for dental biofilm which are invisible clinically under ordinary lights. Furthermore, it acts as an evaluation tool to assess the outcome of preventive self-care plans.

Endoscope/Videoscope

This technique includes the illumination of tooth with blue light in the range of 400 - 500 nm. The light source is connected to an endoscope by a fiber optic cable so that teeth are visible without a filter. The technique is referred to as white light endoscopy and is quite similar to that of QLF. Moreover, the capturing and storage of images was done with the help of a camera and this combination of the camera with the endoscope is called a videoscope. A custom made metal mirror holder is used to mount a miniature color video camera. The entire setup is constructed in such a way that the image of the enamel surface can be directly visualized over a computer or television screen.

Ultrasonic imaging

Ultrasonic imaging was introduced for detecting early carious lesions in smooth surfaces. This non-quantitative technique was found to be more sensitive than visual-tactile method. Ultrasound used in USG is a sound wave with a frequency range of 1.6 to about 10 MHz. The diagnostic purpose of an USG is to localize, visualize and measure internal organs and tissues of the body. When the sound waves are targeted at the organs, images are produced and transmitted back to scanner and measured consequently.

In dentistry, ultrasound has been used to imaging the tooth and thereby detecting dental caries on smooth surface regions. However, studies have concluded that detection of small lesions could be possible, this method was not yet applicable to patients. Moreover, it is impossible to distinguish shallow caries of the teeth [11].

Dye penetration method [15]

A dye can stain and make visible a subject from its normal background or if several objects have an indistinguishable appearance, staining by a dye may help differentiate between them and allow for the identification and diagnosis of dental caries.

Dyes for detection of carious enamel

- 'Procion' dyes: It helps in staining enamel lesions but the process is irreversible as the dye reacts with nitrogen and hydroxyl groups of enamel and acts as a fixative.
- 'Calcein' dye: This dye makes complex with calcium and remains bound to the lesion.
- 'Fluorescent' dye: One of the Fluorescent' dye Zyglo ZL-22 can be used *in vitro* but not suitable for *in vivo* use. Ultraviolet illumination is used to make the dye visible.
- 'Brilliant blue' dye: It enhances the diagnostic excellence of FOTI.

The clinical use of dyes for diagnosing enamel lesions is not yet applicable. When it will become applicable for clinical use, it will thus allow for remineralization as well.

Dyes for detection of carious dentin

Carious dentin is histopathologically alienated into two layers - soft and non-remineralized outer layer of decalcification and the hard and remineralized inner decalcified layer. These two zones of dentinal caries are differentiated with the help of dyes. 0.5% basic fuchsin in propylene glycol is a quite useful dye for this purpose. Thus, it makes it likely to entirely remove the outer carious zone in the dentin as it comprises denatured collagen. Due to the cario-

Figure 3: *Dye penetration method.*

genic property of Basic fuchsin dye, it has now been swapped by acid red and methylene blue but Methylene blue is also found to be a little toxic so Acid red is the most favored dye.

A modified dye penetration method

The Iodine penetration for computing enamel porosity of incipient carious lesion was established by Bakhos., *et al.* (1977). In a well-defined area of enamel potassium iodide is applied for a short period of time and then the excess is removed. The remnants of iodine in the micropores are evaluated since this is the indication of the enamel permeability. Thus, the using this technique for the carious diagnosis remains a complex procedure.

Conclusion

Continued researches on caries processes have created a mounting body of knowledge. When coupled with clinical research; this results in changes in the routine procedures used in dental clinical diagnosis. These changes include improved diagnostic capacities, so that more subtle and early stages of the disease process can be detected. Indeed, the diagnostic armamentarium has undergone vast changes towards increasingly refined and detailed methods. By implementing increasingly refined diagnostic techniques, dentists will be able to detect even the earliest stages of carious lesions. Therefore, by deciding to implement more refined diagnostic techniques a dental clinician implicitly changes his/her threshold for caries lesion detection.

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