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Investigations for the Early Detection of Dental Caries - A Review

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***Abstract**: Early detection and diagnosis of dental caries reduces irreversible loss of tooth structure, the treatment costs and the time needed for restoration of the teeth. Examination and evaluation of carious lesions has traditionally been limited to physical criteria such as size depth presence and absence of cavitation which may fail to detect early lesions. There are various caries diagnostic aids for thedetection of dental caries . this brief review will discuss various investigations to detect dental caries early for appropriate clinical treatment decision*

***Key words**: conventional radiographs , digital radiographs, subtraction radiology ,QLF. DIAGNOdent*

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I. Introduction

Dental caries is an irreversible microbial disease of the calcified tissues of the teeth, characterized by demineralization of the inorganic portion and destruction of the organic substance of the tooth, which often leads to cavitation[1].A general anatomical classification of caries penetration into dental tissues includes:
(1) Initial surface caries confined to the enamel,
(2) Penetration of enamel,
(3) Penetration of the dentino-enamel junction,
(4) Early penetration into dentin,
(5) Advanced penetration into the dentin, and
(6) Penetration to or into the pulp of the tooth.[1]

The loss of mineral content, or demineralization is the major change seen in the carious lesion during its early developmental stage. For much of the last century, the diagnosis of dental caries entailed detecting only cavitation. Over the last decade, however, the caries process became recognized as a biofilm disease characterized by prolonged periods of low pH in the mouth leading to dissolution and net mineral loss of the teeth[2]. The demineralization of the teeth is now understood as a physiological variety, and the understanding of caries shifted from a discrete episode of cavitation to an understanding of demineralization as a spectrum

that ranges from micro porosity to cavitation.Because the emphasis in dealing with caries is shifting from surgical repair to strategies that prevent decay, the challenge now to professionals is to provide better criteria for establishing the true state of a given tooth. Therefore, the primary purpose of caries diagnosis is to identify the disease process and also early signs of tooth demineralization in order to halt itsprogression for appropriate treatment decision.[2]

Conventional Diagnostic Methods:
The most conventional methods used by dentists to diagnose all types of caries are:
Visual and tactile methods
Conventional Radiographs
There are shortcomings and inaccuracies associated with each of these methods whentrying to detect incipient caries.[2]

Visual and tactile methods -

Visual means using direct vision of the oral cavity, and tactile means perception or feelby using an explorer.Visual and tactile methods typically go hand in hand, becausemost dentists use dental probes and other tools to examine teeth during the clinicalexamination. The first visual indication of caries in enamel is generally small whitelesion where demineralization has occurred under the dental plaque[2].The traditional method of detecting caries signs is by visual inspection of dentalsurfaces, with the aid of a bright light and dental mirror if necessary to see teeth from all angles. Reflecting light onto the mouth mirror also can be done to search for darkshadows that could indicate dentin lesions. Visual inspection of the mouth may be inaccurate and miss finding incipient lesions due to their disappearing nature when in the presence of moisture and by operator error. Being that incipient lesions appear as white, chalky, opaque spots, they may blend in well with the natural color of the teeth and be easily overlooked without proper lighting and careful observation.[2]

Conventional Radiographs

Although radiographs still play an important role in caries detection their ability toidentify earlier or hidden caries is questionable.[3] Radiographs may not show caries untilthe lesion has progressed to an irreversible stage of caries. At least 40-60% of toothdemineralization is required before it appears in the radiograph.[1] Intraoral radiographsare better than extra oral radiographs due to their high resolution and greater imagedetails . Incipient caries are usually not displayed on radiographs. A small, faintradiolucency may be observed indicating incipient lesions, but these lesions are difficultto detect and easily overlooked.[1] Accuracy when reading radiographs not only dependsupon the operator's experience and care, but is also related to the exposure parameters,the film and its processing, and the viewing conditions[1]. Bitewing radiographs may beinaccurate for detecting small carious lesions because it is a specific, rather than asensitive, method . They show lower sensitivity and specificity values for enamel caries than for dentinal lesions indicating intraoral radiographs are better for the detection ofdentinal caries and have less value for detecting enamel lesions.[3]

Digital radiographs:

The turning point from film based to digital radiography dates back to 1972 whenG.N.Hounsfield introduced his new invention called computerized transverse axialscanning. A digital radiograph (or a traditionalradiograph that has been digitized) iscomprised of a number of pixels. Each pixel carries a value between 0 and 255, with 0being black and 255 being white. The values in between represent shades of grey, andit can be quickly appreciated that a digital radiograph, with a potential of 256 grey levelshas significantly lower resolution than a conventional radiograph that contain millionsof grey levels.[4]

Dental digital images are acquired by several means including: indirect imaging from conventional radiographs using a flatbed scanner; semi direct imaging using a PSP detector;direct imaging based on solid state electric detector, such as charge couple device -based sensor (CCD), complementary metal oxide semiconductors (CMOS), and photostimulable. Sensitivity to caries detection was higher in digitizedfilm images than in film radiographs. The advantages of digital imaging over conventional radiographs are lower radiation doses, shorter working time, and absence of darkroom processing, digital enhancement and image processing, easy imaging storage, digital subtraction ability. All these improve the quality and diagnostic accuracy of caries detection, especially for incipient and hidden carious lesions.[3]

Subtraction radiology:

Using digital radiographs offers a number of opportunities for image enhancement,processing and manipulation. One of the most promising technologies in this regard isthat of radiographic subtraction which has been extensively evaluated for both thedetection of caries .[4]The basic premise of subtraction radiology is that two radiographs of the same object can be compared using their pixel values. If the imageshave been taken using either a geometry stabilizing system (i.e. a bitewing holder) orsoftware has been employed to register the images together, then any differences in thepixel values must be due to change in the object. The value of the pixels from the firstobject are subtracted from the second image.[4] If there is no change, the resultant pixelwill be scored 0; any value that is not 0 must be attributable to either the onset orprogression of demineralization, or regression. The radiographs must be perfectly, oras close to perfect as possibly aligned. Any discrepancies in alignment would result inpixels being incorrectly represented as change.[4]

II. Methods Based on Light

Optical transillumination:

In high intensity fiber optic-based transillumination (FOTI) system, by Friedman andMarcus (1970), the detection of a carious lesion occurs because of the changes in thesubstraction radiography - The proximal lesion has become more radiolucent and hence has progressed,scattering and absorption of light photons resulting from a local decrease oftransillumination, owing to the characteristics of the carious lesion . [7]When atooth isilluminated by a light, the carious tissue, because of porosity, scatters light morestrongly and the enamel shows as a whiter opaque area. In case dentine is carious, ashadow is observed in the underlying dentine. When it is used for the detection ofinterproximal caries, a high intensity light is placed on the buccal surface, and theinterproximal surface is observed by transillumination through the occlusal surface.Enamel lesions appear as gray shadows, and dentinal lesions appear as orange-brownor bluish shadows.[3]However, the accuracy of the FOTI method in detecting enamelcaries is questionable**.** This leads to the conclusion that the system should not be usedalone, but rather as an adjunct to other diagnostic methods. It has been demonstratedthat the combined use of FOTI and visual inspection is better at differentiating lesionsin enamel from those in dentin.[1]

Digital imaging fiber-optic transillumination (DIFOTI): which are qualitativediagnostic methods by which teeth are transilluminated to detect shadows, which was developed combining FOTI with a charge-coupled device digital intraoral camera.[2]With this system, the images are captured, stored and displayed on a computer screen,which can be compared with the clinical presentation; however, as with FOTI, thedetection is based on a subjective interpretation of the appearance of the lesion. It has high specificity but low sensitivity for both occlusal and proximal surfaces .[3]

III. Fluorescence

Benedict first described enamel fluorescence and it was proposed to detect dentalcaries. Fluorescence results from change in the characteristics of light caused by achange in the wavelength of the incident light rays following reflection from the surfaceof a material.[9]The intensity of the emitted fluorescent can be measured by using a filter systemthrough which only the fluorescent rays pass. The inherent fluorescence of a materialis often referred to as auto fluorescence. Wavelength of the incident light affects thefluorescence: near ultraviolet light emits blue fluorescence, blue and green emits yellowand orange fluorescence, red and infrared light emits red fluorescence.It is suggested that fluorescence is caused by the presence of chromophoresendogenous within the enamel, and the differences in the fluorescence between soundand carious enamel, when illuminated with UV or near visible light are due to loss ofchromophores in the lesion. While others are of the view that this could be explainedby the altered amounts of light scattering in the lesion which is much greater than in

sound enamel, and the resultant absorption per unit volume is less in a lesion with lessobserved fluorescence. As in the lesion, the path length is short and an excitingphoton has only a small chance of being absorbed.[3]

QLF (Quantitative Light Fluorescence):

QLFis an optical method for early detection andquantification of caries lesions. Using a computer program, a line is marked around aselected lesion. The line must be placed entirely in enamel judged visually sound. Ablue green laser light (488nm) is used to illuminate a tooth. As it passes through theenamel, the enamel fluoresces in the yellow region of the light spectrum.[9] Thisfluorescence is observed through a yellow high-pass filter that excludes the toothscattered blue light. Demineralized enamel becomes porous, allowing saliva topermeate. This causes a decrease in the light path in the enamel. Therefore, a cariouslesion has significantly lighter scattering and less absorption of light per unit of volumethan does sound enamel. This results in the carious lesion to fluoresce less and appeardarker than sound tooth structure The QLF method also includes image analysis software which measures the differencein fluorescence between sound and demineralized enamelFor smooth surfaces,the mean sensitivity and specificity of QLF is 0.7 and 0.85. For occlusal surfaces, the values are 0.61 and 0.59**.**

DIAGNOdent:

DIAGNOdent uses infrared light of 655-nm wavelength to excite porphyrinfluorescence from bacteria byproducts trapped in the pores of demineralized tissue forthe detection of "hidden" occlusal caries lesions [8]A numerical value is assigned to the degree of fluorescence, which is used to indicatethe extent of caries. To use, a special laser probe is zeroed in on a non-carious, unstainedportion of tooth, then tracked across the entire occlusal surface. The unit gives a readingcorrelating to the degree of demineralization:

0-14: sound/early enamel lesions

15-20: preventative care is advised

18-99: preventative or operative care advised, depending on patient’s caries risk, therecall interval, etc.[8]

Caries detection dyes:

Dyes are used for carious detection in occlusal surfaces and assessment of caries statusduring cavity preparation. In 1972, a technique using a basic fuchsin red stain wassuggested (and subsequently developed) to aid in the differentiation of two layers ofcarious dentin. Because of potential carcinogenicity, the basic fuchsia endogenousfluorophores within enamel and the differences in the fluorescence protein dyes havebeen marketed as caries-detection agents. [5]Intended to enhance complete removal ofinfected carious dentin without over-reduction of sound dentin, stain was subsequentlyreplaced by another dye, acid red solution. Since then, various the dye was purportedto stain only infected tissue and was advocated for a “painless” caries removal

technique without local anesthetic.Dyes uptake by enamel lesions would be veryadvantageous since it would allow lesions to be visualized at an early stage.[6]

Dyes used for caries detection are:

0.5% Basic Fuchsin

1% Acid red

0.5% Basic Fuchsin has carcinogenic potential and stains the unaffected coronal dentin, so it is replaced by 1% Acid red.[5]

Newer advancements:

Multi-photon technique :

In multi-photon imaging, two infrared photons (with halfthe energy of the blue photon) are absorbed simultaneously. The probability of thishappening is normally low, but by exposing the tooth to many more photons, it ispossible to increase greatly the chances of two-photon absorption. With this technique,sound tooth tissue fluoresces strongly, whereas carious tooth tissue fluoresces to a muchlesser extent. Caries will appear as a dark form within a brightly fluorescing tooth.Multi-photon imaging is able to collect information from caries lesions up to 500microns in depth.[3]

Photon Undulatory Non- linear Conversion (PNC)

The fluorescence emissionspectroscopy system tested (helium-neon [He-Ne], lambda = 633 nm) has a fiber opticdevice that delivers radiation to the teeth and a spectrophotometer device that detects bacterial porphyrins fluorescence, allowing detection of caries, fillings, and calculus bysimultaneous measurement of backscattering and fluorescence intensity. It exceeds xraysin sensitivity, without any ionizing radiation.[3]

Infrared Thermography– Thermal radiation energy travels in the form of waves. Itis possible to measure changes in thermal energy when fluid is lost from a lesion byevaporation. The thermal energy emitted by sound tooth structure is compared with thatemitted by carious tooth structure.[3]

Polarized Raman Spectroscopy– It is a form of vibrational spectroscopy thatfurnishes biochemical information about the tooth's composition, mineral content andcrystallinity. Polarized Raman spectra of caries lesions exhibited a lower degree ofRaman polarization anisotropy than those of sound enamel. The depolarization ratioderived from the dominant phosphate peak of hydroxyapatite in sound teeth isconsistently lower than that from incipient caries. This difference is attributed to thestructural changes in enamel crystallite morphology or orientation that occurs with aciddemineralization and/or increased photon scattering resulting from the larger poreswithin the caries lesions.[3]

Confocal microscopy- Confocal microscopy enables high-resolution imaging to beachieved below semitransparent surfaces in intact living specimens. It uses a tandemscanning microscope, with images recorded via a SIT video camera. It can be used tocollect light from different depths but only within the outer 100 microns of the tooth.Using this system internal tooth structure (e.g. enamel prisms/adhesive restorationinterfaces) and the lining cells of the gingival crevice through to the junctionalepithelium may be examined. Access is limited to the anterior regions as far back as thepremolar teeth.[3]

Ultrasound- Ultrasound waves have a frequency of > 20,000 Hz. Ultrasound imagingwas introduced by Ng et al. (1998) as a method for detecting early caries in smoothsurfaces. They showed that artificial enamel lesions with less than 57% of the soundenamel mineral content in the body of the lesion could be differentiated acousticallyfrom intact enamel on the basis of amplitude changes of the enamel surface echo andthe amelo-dentinal junction echo. Thus, it can measure the mineral loss from a lesionbody. The use of longitudinal waves to measure demineralization in relation to thedentino-enamel junction is very useful, as is the potential for surface sound waves todetect cavitations. Ultrasound may be a quick and reliable tool for the detection ofdental caries in enamel.[3]

Terahertz pulse imaging– This method of imaging uses waves with terahertzfrequency (= 1012 Hz or a wavelength of approximately 30 cm). For an image to beobtained by terahertz irradiation the object is placed in the path of the terahertz beamor the terahertz beam can be scanned over the surface of an object. It is also possible torecord terahertz images using a CCD detector. Higher attenuation of terahertz radiationwas observed in carious enamel as compared with healthy enamel.[3]

Photothermal Radiometry / Luminescence- Nonintrusive, non-contactingFrequency-Doma in Photothermal Radiometry (FD-PTR or PTR) and Frequency -Domain Luminescence (FD-LUM or LUM) have been used with laser sources (650-850 nm) to detect artificial and natural subsurface defects in human teeth. Longerwavelength has shown better ability to detect deep subsurface lesions as compared toshorter wavelength. FD-PTR may also be used as a dynamic quantitative dentalinspection tool complementary to modulated luminescence (LUM) to quantify soundenamel or dentin. PTR is sensitive to very deep (>5 mm) defects at low modulationfrequencies (5 Hz).[3]

IV. Conclusion

Early diagnosis of initial enamel lesions is very important in order to be able to create at an optimum time, an appropriate treatment allowing the re-mineralization of these lesions. Many methods are available to the clinician however, it is imperative that methods with suitable levels of sensitivity and specificity are used in conjunction to obtain a valid diagnosis which will inform the correct and appropriate treatment for the patient.

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