REVIEW ARTICLE

EARLY ENAMEL LESION
PART I. CLASSIFICATION AND DETECTION

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***Summary*:** There has been a paradigm shift from Black's 'extension for prevention' to a minimal intervention approach in the recent time. The most important aspect in diagnosis of earliest stages of enamel demineralization involves accurate and reliable detection of such lesions. The newer diagnostic aids would enable the dentist to detect and diagnose early enamel lesions and direct appropriate preventive measures to promote remineralization and conservation of the tooth substance. A high level of caries experience necessitates preventive strategies which are more cost effective than surgical intervention and restorative procedures.

***Key words**: Early enamel lesion; Demineralization; Remineralization*

Introduction

This paper reviews and discusses the dynamics of early enamel lesions and recent diagnostic methods for their accurate detection. There has been a shift from the earlier concept of "drilling and filling" for caries elimination towards less invasive and preventive methods of caries management (99). The early lesions can be effectively prevented and reversed by chemical treatments while conservative restorative procedures are performed only in surgical intervention of caries. There has been a greater focus on diagnostic methods, particularly in the assessment of early caries lesions. The visual, optical, radiographic and some emerging technologies are discussed. The novel technologies in early enamel lesion detection includes auto-fluorescence (such as QLF) of teeth, electrical resistance (such as ECM), imaging techniques, transillumination, DIAGNOdent and DIFOTI devices, fibre-optics-based confocal imaging system, OCT (optical coherence tomography) imaging, polarization-sensitive optical coherence tomography (PSOCT) system, frequency-domain photothermal radiometry (FD-PTR or PTR) and modulated luminescence.

An emerging concept in dental caries prevention involves caries management by risk assessment where the risk predictors are used to identify the high and low risk patients and plan preventive strategies which are aimed at improving health. In true sense, preventive dentistry involves early diagnosis of early enamel lesion and minimally invasive dentistry.

Definition

The initial carious lesions are the so-called "white spot" lesions, which implies that there is a subsurface area with most of the mineral loss beneath a relatively intact enamel surface (24).

Classification

Clinically, early caries lesion in enamel is initially detected as a white opaque spot and is characterized by being softer than the adjacent sound enamel and is increasingly whiter when dried with air. A cross-section of the white opaque spot reveals the characteristics of carious enamel and this means that dental caries is essentially an enamel defect with a relatively intact surface layer and some subsurface damage due to acid formed from plaque on tooth surface (4).

Downer's criteria for detection of caries include:

Enamel caries – if there is destruction of the enamel surface or a white area in enamel extending up to, but not including the ADJ, and there is no cavity or discoloured area beneath the ADJ.

Dentinal caries – if there is destruction of the enamel extending up to and including the ADJ, or a cavity or discoloured area beneath the ADJ extending into dentine (11).

The main types of enamel demineralization include incipient lesions and "surface-softened defect" (52, 75) which are also some of the various terms that have been used to

describe early caries lesions. It is important to differentiate incipient lesion from arrested lesions. Incipient lesions are active lesions which continue to progress under acid attack whereas an arrested lesions does not progress. In vivo ultrastructural studies by Thylstrup and Fredebo (89) led them to conclude that there were wide variations between active and arrested lesions. "Micro-scars" were seen on active lesions while micro-cavitation was usually seen on arrested lesions (4).

Dental caries – dynamic disease process

Dental caries is now being increasingly regarded as a dynamic disease process wherein an equilibrium exists between pathological factors causing demineralization and protective factors causing remineralization. The major pathological factors involve frequent ingestion of fermentable carbohydrates, inhibition of salivary function and acidogenic bacteria while the protective factors include antibacterial agents which are both natural and applied, composition and rate of salivary flow, fluoride from extrinsic sources and diet. Caries intervention can be natural, or by some mode of treatment or procedure. The disease process is regarded as a continuum beginning with the first atomic level of demineralization, then the early lesions of enamel is followed by dentinal involvement and finally cavitation. However the early lesion is known to remineralise and is therefore regarded as reversible (33).

Detection of early enamel lesion

The prevalence and pattern of dental caries has shown a drastic change over the past two decades with a decrease in smooth surfaces caries and with more lesions being detected on the occlusal surfaces of tooth. It is in this context that early identification and prompt institution of preventive measures for the control of caries assumes significance. The traditional methods of detecting early lesions involves visual inspection and radiography. In visual observation reflected light is used to detect changes in color, texture, and translucency of the tooth substance. However diagnosis of early enamel caries using the traditional methods have been found to be inaccurate and insensitive. Unfortunately, radiographs have the added risk of exposure of ionizing radiation to the patient (11). As the present-day caries lesion progresses slowly, it is better to have a method which misses some of the shallow lesions but yet has a high-positive predictive value for deeper lesions (4). It is difficult to diagnose occlusal caries in teeth without a macroscopic breakdown of the outer enamel surface (95). Enamel approximal caries lesions are poorly detected by radiography since demineralization in excess of 40 % must occur for the radiographic detection to be possible (37) although dentinal lesions in occlusal surfaces may be detected with some accuracy (46).

In a study by Yassin (98) on *in vitro* mechanical damage of early carious lesion (enamel lesion) in artificial U-shaped grooves caused by a sharp dental explorer it was seen that when a force of 500 g was used there was no damage to the sound enamel grooves. However the probing by a sharp dental explorer in demineralized enamel grooves resulted in cavitation of white spot lesion with apparently a sound surface layer. The dentist should therefore be cautious while using a sharp dental explorer to examine early carious lesions in pits and fissures (98).

The newer available methods for caries detection include auto-fluorescence (such as QLF) of teeth, electrical resistance (such as ECM), and imaging techniques like conventional and digital bitewing radiography (71). Transillumination, DIAGNOdent and DIFOTI devices comprise the other supplemental methods to aid in diagnosis (97). Quantitative light-induced fluorescence, (QLF) which measures enamel autofluorescence can detect differences in remineralization of early enamel caries (36). A new fiber-optic diagnostic tool enabling dentists to identify early caries lesions with greater sensitivity and specificity is the fibre-optics-based confocal imaging system which can record axial profiles through caries lesions using single-mode optical fibres (72). A novel technology involving OCT (optical coherence tomography) imaging of tooth which shows greater light backscattering intensity at sites of carious lesions than the sound enamel could be used for screening carious sites and determining lesion depth, in combination with Raman spectroscopy for biochemical confirmation of caries (51). Polarization-sensitive optical coherence tomography (PSOCT) system has also been used to study the spatially resolved scattering and polarization phenomena of teeth which are known to have strong polarization effect. Polarization-sensitive optical coherence tomography (PS-OCT) is another tool that has been used for in vitro dental caries assessment of remineralised lesions (49).

Digital Imaging Fiber-Optic Transillumination (DIFOTI-TM) uses images of teeth obtained with a digital CCD camera, which are sent to a computer for analysis with dedicated algorithms for location and diagnosis of carious lesions by the operator in real time, thereby providing a quantitative characterization for monitoring of approximal, occlusal and smooth-surface caries (74). Frequency-domain photothermal radiometry (FD-PTR or PTR) and modulated luminescence have also been used to detect early interproximal demineralized lesions. However PTR provides more accurate diagnosis than modulated luminescence (48). Laser fluorescence device DIAGNOdent has been used to detect occlusal caries and has more sensitivity and specificity than radiographic examination (2). In a study on Digital Imaging Fiber-Optic Trans-Illumination (DIFOTI), F-speed radiographic film and depth of approximal lesions it was observed that the histologic lesion depth determined by F-speed radiographic film was identi-

cal to that evaluated by polarized light microscopy (PLM) while DIFOTI did not measure the depth. However DIFOTI could detect surface changes associated with early demineralization as early as two weeks. The investigators of this study suggested that surgical or chemical treatment strategies should take into account cavitation rather than histologic lesion depth (100).

Pincus was the first who proposed the principle of electrical impedance system (11). Caries diagnosis, using electrical impedance measurements reveals higher sensitivity, specificity, and positive and negative predictive values than the traditional methods. The high inorganic content of sound enamel makes it a good electrical insulator. However the permeability to oral fluids increases during demineralization resulting in decreased resistance to the flow of electrical charge. The ease in measurement of impedance variation is greater when there is demineralisation up to the amelo-dentinal junction. Electronic Caries Monitor (type IIb, P. Borsboom, Sensortechnology and Consultancy BV, Westeremden, The Netherlands) and Vanguard system (Massachusetts Manufacturing Corporation, Cambridge, MA, USA) developed in the 1980s are examples of electrical impedance system. The detection of caries involves placement of the probe tip at a single point on the tooth surface. Although the entire occlusal surface can be screened for caries by using a conducting medium on the entire tooth surface and then placing the probe tip, these methods have not been validated with research studies (11).

Another study by Ashley (10) for detecting occlusal caries in primary teeth showed that the sensitivities and specificities of the ECM diagnoses were similar for visual method and ECM.

In an *in vitro* comparison of the ability of fibre-optic transillumination, visual inspection and radiographs to detect occlusal caries and evaluate lesion depth it was concluded that radiography was inaccurate in detecting lesions confined to enamel. However FOTI, visual inspection and radiographs correlated well histologically. Accurate detection of deep enamel lesions and those in outer third of dentine was not possible using these methods. Occlusal caries could be diagnosed adequately using visual inspection and FOTI (22). The advantages of the FOTI method over radiographs for caries detection are the absence of ionizing radiation and no requirement for heavy and expensive equipment for a diagnosis to be attained (95).

Data evaluating the accuracy of enamel demineralization detection using conventional, digital, and digitized radiographs, and evaluation of radiographs and logarithmically contrast-enhanced subtraction images show that DenOptix® system represent the advances in the development of photostimulable phosphor plates and is a plausible alternative to conventional radiographs. It was observed that radiographs taken with InSight® film were cheap and accurate and that digital subtraction enhanced approximal enamel caries lesion detection (37).

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Submitted June 2008.
Accepted September 2008.

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