Review Article

Received : 01-09-15
Review completed : 18-11-15
Accepted : 29-11-15

RESIDUAL CARIES DETECTION IN CHILDREN: A SYSTEMATIC REVIEW

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ABSTRACT

Dental caries is an infectious microbiologic disease of the teeth that results in localized dissolution and destruction of calcified tissues. Residual caries detection is as important to restore the teeth to mantain it in a healthy state as the clinician is not sure about complete removal of residual caries. So a comprehensive protocol of early detection, continued assessment and differential diagnostic interventions are useful in detection of residual caries. Several new technologies have emerged that show promising results for the clinical diagnosis of caries and early prediction of caries which are enumerated below.

KEYWORDS: Early detection; secondary caries; diagnostic methods

INTRODUCTION

Dental caries is one of the most prevalent diseases of mankind. If the disease process can be interrupted in its early stages, the cosmetic burden and pain of caries and cost involved in treatment can be avoided.[1,2] Conventional examination for caries detection is based primarily on subjective interpretation of visual examination and tactile sensation aided by radiographs. The clinician makes a dichotomous decision (absence or presence of a lesion) based on subjective interpretation of colour, surface texture and location using rather crude instruments such as a dental explorer and bitewing radiographs.[3] Current state of the art caries management requires proactive intervention, a comprehensive protocol of early detection, continued assessment and differential diagnostic intervention. Several new technologies have emerged that show promising results for the clinical diagnosis of caries and early prediction of caries. For most clinicians the remaining caries after cavity preparation continues to be a great concern, as the success of restorative treatment is largely dependent on removing unhealthy tooth tissues. Insignificant caries detection and removal can result in further loss of tooth structure. [4] The discussion as to how much tissue must be removed in order to arrest the caries process is not new. In 1859, Tomes wrote “it is better that a layer of discolored dentine should be allowed to remain for the protection of the pulp rather than run the risk of sacrificing the tooth”. However in 1908, Black disagreed claiming “... it is better that it is removed of all decayed dentine overlaying”.[5,6] Even now, there is still no better clinical criterion to define the caries excavation limit than the “normal hardness” feeling of sound dentin when probed by hand instruments.[7] Research showed that cariogenic bacteria were never found beyond the softening front of dentin.[8] Further identification of a superficial infected dentin layer and a subjacent affected dentin layer has laid the foundation for a more rational approach for caries removal. Elimination of the heavily infected dentin and preservation of the residual affected dentin were thus defined as prerequisites for effectively arresting the carious process without harming the long-term survival of the pulp and the restoration.[9,10] Thus the different diagnostic methods are important for the objective identification of residual caries after carious dentin removal. Also assessing the accuracy, sensitivity, specificity of these diagnostic methods in detecting of residual caries in cavity preparation becomes all the more important.

Dental Caries

Dental caries is defined as an infectious microbiologic disease of the teeth that results in localized dissolution and destruction of calcified tissues.[11] Dental caries is a dynamic process-taking place in the microbial deposits in dental plaque on the tooth surface which results in a disturbance of balance between tooth substance and surrounding plaque fluid so that over time the net result is a loss of mineral from tooth.[12]

Diagnosis Of Dental Caries In Children

Diagnosis of caries was until recently concerned with the macroscopic detection of caries. This was due to a higher prevalence of manifest caries worldwide and the lack of treatment options other than surgical removal of affected tooth-substance. In modern dentistry non invasive treatments of early caries lesions exist, thus making the diagnosis of such lesions important (Table 1).

Residual Caries

It is the caries that remains in the prepared cavity even after the restoration is completed. This may be left behind either by accident, neglect or intention. Residual caries left behind due to operator's negligence is not acceptable especially if it is at the DEJ or enamel. But sometimes during indirect pulp capping procedures a small amount of soft caries close to the pulp maybe intentionally retained to prevent pulp exposure.[13]

Histopathology Of Dentin Caries

Dentin is a mineralized tissue permeated by cellular extensions from odontoblasts which are located at the peripheral zone of the pulp adjacent to the pre-dentin.[14] For this reason dentin as a vital tissue is perfectly able to respond to any stimuli even when invoked at the enamel surface such as an acid challenge produced by an organized acid-producing biofilm.[15] The first detectable change in dentin in response to a cariogenic biofilm at the outer enamel surface is an area of sclerotic dentin subjacent to the demineralized enamel site. The predominant feature of this reactive dentin is its increased translucency, which can be ascribed to intratubular mineral deposition.[16] The translucent dentinal tubules will be those localized precisely beneath the demineralized enamel surface and appear even before the enamel demineralization has reached the dentin-enamel junction (DEJ). Only when the caries lesion has progressed to a considerable length along the DEJ will the subjacent dentin be demineralized[17] and become recognizable by a yellow to dark-brown discoloration (Fig. 1). Carious dentin consists of two layers: the infected dentin which is irreversibly denatured, physiologically un-remineralizable, infected and non-vital; the inner residual dentin is intermediately demineralized , remineralizable and sensitive. The demineralized and thus unprotected organic dentin matrix (collagen) will be directly degraded through bacterial and host-mediated enzymes.[18,19] Dentin is hardest at the top of the normal dentin layer and gradually becomes softer toward the surface. Affected dentinal caries shows fine plate-shaped crystals of apatite to deposit inside the peritubular dentin walls subjacent to the carious lesion. This is considered to be a vital reaction because hardness peaks, beyond the normal hardness, often observed in the normal dentin immediately under caries invasion of vital teeth. The apatite deposition continues in the sub transparent and transparent layers almost filling up the tubule lumens. The hardness and to a lesser extent the color of dentin are presently the main parameters used by dental practitioners to differentiate between infected and affected dentin during caries excavation.

RESIDUAL CARIES DETECTION

Visual tactile examination

This is based on the use of a dental mirror, a sharp probe and a 3-in-1 syringe and requires good lighting and a clean/dry tooth surface. The examination is based primarily on subjective interpretation of surface characteristics such as integrity, texture, translucency/opacity, location and colour.[19] However, tactile examination of dental caries has been criticized because of the possibility of transferring cariogenic microorganisms from one site to another, leading to the fear of further spread of the disease

Caries Assessment Tools:

Nyvad's system

Nyvad's system is a reliable method for activity assessment of noncavitated and cavitated caries lesions. According to this system, the examination is based only on clinical features of the surface (color, opacity and presence of discontinuities or cavitations) classifying the lesion as inactive or active (Table 2).[20]

International Caries Detection & Assessment System (ICDAS)

International Consensus Workshop on Caries Clinical Trials held in Scotland, concluded that the reliability and reproducibility of currently available caries detection / diagnostic systems, including visual and visual-tactile criteria were not strong thus introduced the International Caries Detection & Assessment System (ICDAS). ICDAS is a two-digit identification system. Initially the status of the surface is described as unrestored, sealed, restored or crowned. After that, a second code is attributed to identify six stages of caries extension, varying from initial changes visible in enamel to frank cavitations in dentin (Table 3).[21] Despite being the most widely used method in clinical practice, many studies have shown that visual-tactile examination should be associated with other caries detection methods such as bitewing radiographs, especially for early caries lesions detection in approximal surfaces and for lesion depth evaluation on occlusal surfaces.

Lesion Activity Assessment (LAA)

The Lesion Activity Assessment (LAA) scoring system has also been developed for use in conjunction with ICDAS-II. LAA is based on the combined knowledge of a number of factors: the ICDAS score of the lesion; whether or not the lesion is in a plaque stagnation area, and the tactile sensation when a ball-ended probe is gently drawn across the surface of the lesion. By using ICDAS-II in combination with LAA, it is possible to detect a lesion, estimate its depth or severity and assess its activity, which are all fundamental prerequisites for the management of the individual lesion (Table 4).[22]

Radiographic Based Methods

Conventional radiography

IOPA

Radiographic examination is useful in monitoring caries lesion development, in view of the fact that non-cavitated lesions can be reversed by non-invasive intervention, providing changes in mineral content of dental tissues. However, there are limits to the radiographic examination which should be considered, particularly since lesion behavior has changed with cavitation occurring much later than previously. Thus, it is worth remembering that radiography is not able to differentiate between an active and an arrested caries lesion (Fig. 2).[23]

Bitewing Radiography

It has been used for the detection and evaluation of caries lesions depth, which are invisible or poorly visible for inspection. Thus, radiography is mainly used for the detection of carious lesions in approximal surfaces, but is also recommended as a supplement for occlusal caries detection. However, experiments have shown that once an occlusal carious lesion is clearly visible on radiographs, histological examination shows that demineralization has extended to or beyond the middle third of the dentin. Therefore, radiographic examination may underestimate the extent of caries lesions (Fig. 3).[24]

Digital Subtraction Radiography

Digital subtraction radiography (DSR) is a more advanced image analysis tools. This method allows professionals to distinguish small differences between subsequent radiographs that otherwise would have remained unobserved because of over projection of anatomical structures or differences in density that are too small to be recognized by the human eye. The procedure is based on the principle that two digital radiographic images obtained under different time intervals, with the same projection geometry, are spatially and densitometrically aligned using specific software. When the two images are registered and intensities of corresponding pixels are subtracted of the gray scale values, a uniform difference image is produced resulting in a new image representing the differences between the two called the subtraction image.[25]

Digital Radiography

Digital radiography is a complementary method that has been available in dentistry for more than 25 years, but digital imaging has not replaced conventional film-based radiography completely. Studies have shown many advantages of digital radiography compared with conventional radiography. These include image acquisition process in real time, since the image is displayed immediately after exposure and no processing had to be performed. Other benefits include reductions in radiation dose (between 5% to 50% of the dose needed for conventional radiography). On the other hand, a professional who is starting his/her career will not find huge differences in

Table 1: Showing caries diagnostic methods

Caries diagnostic methods include	
Visual-tactile examination	Mouth mirror and sharp explorer Nyvad system ICDAS – International caries detection and Assessment system LAA – Lesion activity assessment
X-rays	Conventional radiography Digital subtraction radiography Digital image enhancement
Caries detecting dyes	Caries finder CDK dyes Reveal
Visible light	Fibre optic transillumination (FOTI) Quantitative light-induced fluorescence (QLF) Digital image fibre optic transillumination (DiFOT)
Infrared light	Midwest caries I.D
Laser light	Laser fluorescence measurement(DiagnoDent) Flouorescence camera(vista proof) Sprolife (ACTEON)
Electrical current	Electrical conductance measurement
Electrical impedance	Electronic caries monitor
Ultrasound	Ultrasonic detector

Table 2: Showing description of the scores in the Nyvad system

Description of the scores in the Nyvad system

Score	Category	Criteria
0	Sound	Normal enamel translucency and texture (slight staining allowed in other wise sound fissure)
1	Active caries (cavity)	Surface of enamel is whitish/yellowish, opaque with is moved gently across the surface; generally covered with plaque . No clinically detectable loss of substance intact fissure morphology; lesion extending along the walls of the fissure
2	Active caries (Surface discontinuity).	Same criteria as score 1. Localized surface defect (microcavity) in enamel only. No undermined enamel or softened floor detectable with the explorer
3	Active caries (Cavity)	Enamel/dentine cavity easily visible with the naked eye; surface of the cavity feels soft or leathery on gentle probing. There may or may not be pulpal involvement.
4	Inactive caries (Intact surface)	Surface of enamel is whitish, brownish, or black. Enamel may be shiny and feel hard and smooth with the tip of the probe is moved gently across the surface. No clinically detectable loss of substance. Intact fissure morphology; lesion extending along the walls of the fissure.
6	Intact caries (cavity)	Enamel/dentine easily visible with the naked eye; surface of the cavity feels shiny and feels hard on gentle probing. No pulpal involvement
7	Filling (Sound Surface)	Sound surface
8	Filling + active caries	Caries lesion may be Cavitated or non-cavitated
9	Filling + inactive caries	Caries lesion may be Cavitated or non-cavitated

costs to acquire a conventional or a digital radiography system. Practitioners should remember that conventional radiography also involves costs for items such as radiographic films, film mounts, processing solutions and time needed for cleaning the film processor (Fig. 4).[26]

Caries Detection Dyes

The use of caries indicator dyes has also been suggested as an alternative diagnostic aid for dentinal caries. Histologic dyes are colored markers that have an affinity to the material to which it is being applied. When the staining substance is spilled out onto the surface of tissue

Table 3: Showing ICDAS II codes and criteria

CODE	DESCRIPTION
0	Sound tooth surface: No evidence of caries after 5 sec air drying
1	First visual change in enamel : opacity or discoloration (white or brown) is visible at the entrance to the pit or fissure seen after prolonged air drying
2	Distinct visual change in enamel visible when wet, lesion must be visible when dry
3	Localized enamel breakdown (without clinical visual signs of dentinal involvement) seen wet and after prolonged drying
4	Underlying dark shadow from dentine
5	Distinct cavity with visible dentine
6	Extensive (more than half the surface) distinct cavity with visible dentine

Table 4. Showing Lesion Activity Assessment

Lesion Activity Assessment	
Visual	**Tactile**
Enamel Active the lesion is whitish yellowish; the lesion is chalky (lack of luster) the lesion can be Cavitated or not Arrested the lesion is more yellowish brownish than whitish; the lesion is more shiny, the lesion can be cavitated or not	The lesion feels rough to probing; probing might or might not find a cavity The lesion feels more smooth than rough; probing might or might not find a cavity
Coronal dentine Active the lesion may manifest itself but demineralized enamel: if a cavity extends into the dentine, the dentine appears yellowish brownish Arrested the lesion may manifest itself as a shadow below the intact but demineralized enamel if a cavity extends into the dentine, the dentine appears brownish	Dentine soft to probing Harder than at the active lesion but not as hard as sound dentine
Root dentine Active yellowish brownish Arrested brownish black	Soft/leathery Harder but not as hard as sound root dentine

Table 5: Caries Detection Dyes

Product (code)	Manufacturer	Color	Ingredients
CAM	Voco GmbH, Cuxhaven	Bright	Propylene glycol resin mixture with coloring agents (acid red)
CAD	Kurary Co Ltd	Red	Propane-1,2-diol(propylene glycol)dyes
SEE	Ultradent products Inc. Utla, USA	Red	Glycol base drug and cosmetic dyes
SES	Ultradent products Inc. Ultah, USA	Greenish Black	Food, drug and cosmetic dyes in an aqueous glycol base

or material it will be trapped in the fibers, pores, indentations, or other structures. These dyes are also used to identify caries in difficult to see places, for finding obliterated root-canals and even for finding micro-cracks in fillings and margins (Table 5; Fig. 5).[27] However, during the applications these fluent liquid dyes could spread to the surroundings or proximal restorations. Until date, there is no scientific data available about the

Electronic Caries Monitors

The electronic caries monitor (Electronic caries monitor) device uses alternating current and measures the bulk resistance of tooth tissue. Electronic caries monitor dates back to 1878 introduced by Magitot. The method presents a probe that is directly applied in an occlusal site, and the device shows a number that translates the electrical resistance of the site. Higher numbers

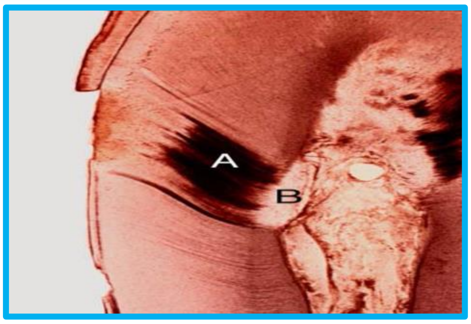

Fig. 1: Dentinal caries

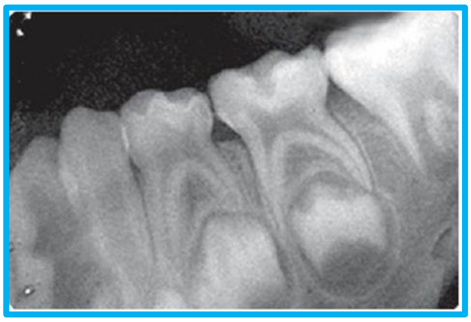
Fig. 2: IOPA radiograph


Fig. 3: Bitewing radiograph


Fig. 4: RVG

Fig. 5: Caries detecting dyes


Fig. 6: Electronic caries monitor


Fig. 7: DiagnoDent

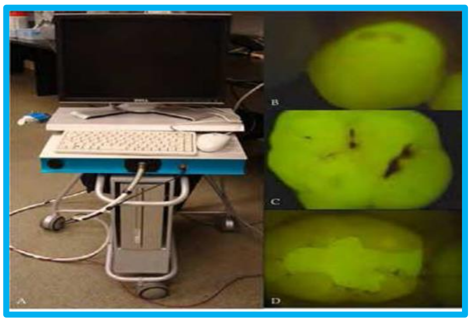
Fig. 8: Quantitative laser florescence device


Fig. 9: Sprolife (ACTEON)

indicate deeper caries lesions. As the method is quantitative, high-reproducibility values would be expected. Nevertheless only fair reliability has been reported, probably due to technical problems (Fig. 6).[28]

Light emitting devices

In this method caries detection is based on optical properties from sound and carious dental tissues. Fluorescence is a phenomenon where the light is absorbed in a specific wavelength and then emitted in a higher wavelength. It is well known that as the enamel as the dentin shows an auto-fluorescence. The caries lesion, dental plaque and microorganisms also show fluorescent component.

Laser fluorescence devices (DIAGNOdent and DIAGNOdent pen)

Laser fluorescence device is a non-invasive and quantitative method based on the laser induced fluorescence. The first laser fluorescence device, DIAGNOdent 2095 (KaVo, Biberach, Germany), was developed in 1998. It is based on the quantification of emitted fluorescence from organic components of dental tissues when excited by a 655nm laser diode (aluminum, gallium, indium and phosphorus - AlGaInP) located on the red range from the visible spectrum. The clinician who intends to use this method as a auxiliary in the caries detection process should be aware of the correct device functioning and remember that several factors might interfere the results such as staining, calculus or powder/paste remnants, calibration procedures and cut-off points variation for enamel and dentin caries (Fig. 7).[29]

Quantitative light-induced fluorescence (Qlf)

Quantitative light-induced fluorescence (QLF) (Quantitative Laser florescence Clin, Inspektor Research Systems BV, Amsterdam, Netherlands) was developed for use in caries detection and it is available commercially for clinical use. This device consists of a handheld intraoral color microvideo CCD camera, interfaced with a personal computer and custom software the use of Quantitative laser florescence consists of three main steps. The first is lesion detection by the examiner and subsequent capturing of an image of the lesion. Second, quantitative analysis is done of the image. Finally, the third step involves the long-term monitoring of the caries lesions, which enjoys the benefit of an innovative video repositioning part of the software, setting the initial image and the live image based on the geometry of similar fluorescence intensities the use of Quantitative laser florescence consists of three main steps (Fig. 8).[30] The first is lesion detection by the examiner and subsequent capturing of an image of the lesion. Second quantitative analysis is done of the image. Finally the third step involves the long-term monitoring of the caries lesions, which enjoys the benefit of an innovative video repositioning part of the software, setting the initial image and the live image based on the geometry of similar fluorescence intensities.

Fiber-optic transillumination (FOTI) and digital imaging fiber-optic trans-illumination (DIFOTI)

Fiber-optic trans-illumination (FOTI) and digital imaging fiber-optic transillumination (DIFOTI) have been introduced to improve early detection of carious surfaces and have been accepted by clinicians as a supplementary tool during clinical examinations. FOTI device is a practical, easy, fast and inexpensive method of imaging teeth in the presence of multiple scattering. It is based on the changes in the scattering and absorption phenomenon of light photons that increases the contrast between sound and enamel caries.[31-32]

Soprolife

The newest modality, SOPROLIFE from ACTEON, seems to hold the most promise. It is highly accurate and solves many of the earlier problems with other techniques and modalities. SOPROLIFE uses blue LED light at a wavelength of 450 nm. This wavelength excites dentin and its reaction produces a light signal called fluorescence. SOPROLIFE can quickly and accurately help the practitioner determine whether or not to perform a restoration. The initial exam clearly reveals the need to excavate the lesion. Upon confirming with caries detection dyes, we see the dye is not as accurate. The SOPROLIFE image clearly shows an area of decay but the dye shows little penetration with mostly staining (Fig. 9).[33]

ADHESIVE / CLINICAL IMPLICATIONS

Lower bond strengths

The presence of carious dentin results in thicker hybrid layer and lower bond strengths. The bond strength of adhesives to carious dentin has been reported to be inversely proportional to the degree of caries progression; with caries infected dentin presenting thicker hybrid layers followed by caries affected and sound dentin.

Low cohesive strength

The lower bonding effectiveness to caries infected dentin is related to its extremely low cohesive strength. Due to its low degree of mineralization and the collagen-matrix disorganization results in lowered cohesive strength. This type of dentin allows only superficial monomer penetration, keeping many dentin tubules completely free from tag formation.

Lower hardness and modulus of elasticity

Firstly reduction in mineral content and loss of crystallinity of the remaining mineral phase, coupled to the changes in the secondary structure of collagen, result in a dentin substrate with a lower hardness and modulus of elasticity than those of sound dentin. Secondly the deposition of mineral casts, namely of β-tricalcium phosphates (whitlockites), in the dentin tubules during caries progression also alters the etch pattern and thus the penetration capacity of resin monomers into the tubules.

CONCLUSION

Identification of a superficial infected dentin layer and a subjacent affected dentin layer has laid the foundation for a more rational approach for caries removal. Elimination of the heavily infected dentin and preservation of the residual affected dentin were thus defined as prerequisites for effectively arresting the carious process without harming the long-term survival of the pulp and the restoration. This has currently raised some discussion about moving toward more objective and hopefully more conservative approaches to selectively remove carious dentin. Thus making residual caries detection all the more important in children.

CONFLICT OF INTEREST & SOURCE OF FUNDING

The author declares that there is no source of funding and there is no conflict of interest among all authors.

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