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Diagnosis of the early carious lesion

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ABSTRACT

In recent decades a desire has driven the uptake of the minimum intervention dentistry (MID) philosophy to end the destructive 'drill and fill' mentality prevalent amongst dental training programmes since the establishment of formalized dental training courses more than 100 years ago. This change in attitude has been concomitant with the decrease in caries prevalence in large sectors of the community and a better understanding of the caries process. One of the pivotal arms of MID is caries risk assessment, and early and accurate caries detection is a major part of this procedure. There is great variation between the diagnostic decisions between individual clinicians, and the development of valid detection aids may decrease this variation and improve the clinical decision making process as it relates to dental caries.

Keywords: Dental caries, dental caries detection, dental caries diagnosis, radiography, caries index.

Abbreviations and acronyms: CAST = Caries Assessment and Treatment Instrument; DIFOTI = digital imaging fibre optic transillumination; FOTI = fibre optic transillumination; ICDAS = International Caries Detection and Assessment System; MID = minimum intervention dentistry; OCT = optical coherence tomography; PUFA Index = Pulpal, Ulceration, Fistula, Abscess Index; UNIVISS = Universal Visual Scoring System; WSL = white spot lesion.

INTRODUCTION

The last three decades have seen a significant reduction in the prevalence, incidence and severity of caries in much of the developed world, although certain sections of these communities, such as those from lower socio-economic groups, are still at high risk of developing dental caries.[1] As a result of this decline, the sensitivity of caries diagnosis has been reduced. Early diagnosis is vital, as it allows intervention to remineralize or 'heal' the carious lesion, whilst also addressing the caries risk factors involved in the lesion development, or directing appropriate sealing or restorative measures. There is great variation between the diagnostic decisions between individual clinicians, and the development of valid detection aids may decrease this variation and improve the clinical decision making process as it relates to dental caries.[2] This variation has often been accepted as a consequence of the 'art of dentistry'; however, valid and reliable diagnosis of dental caries is important to ensure both under- and over-provision of dental care is minimized.[2] The notion of appropriate dental care can be used, defined as the care 'that maximizes the gap between the expected health benefits and the expected negative consequences of the procedures we intend'.[3]

The description of the characteristics of detection methods requires some definition of terms:[4,5]

Sensitivity is the ability to detect disease when it is present – in other words, the proportion of individuals with the disease who test positive.

Specificity is the ability to detect the absence of disease when it is absent, so the proportion of individuals without the disease who test negative.

Positive predictive value is the proportion of individuals with a positive result who actually have the disease.

Negative predictive value is the proportion of individuals who test negative who actually do not have the disease.

In descriptive terms (modified after Attia)[4]:

True diagnosis

Disease present	Disease absent
A True positive	B False positive
C False negative	D True negative

A+B equates to the positive test results
C+D equates to the negative test results

Sensitivity = A/(A+C)
Specificity = D/(B+D)
Positive predictive value = A/(A+B)
Negative predictive value = D/(C+D)

Diagnosis versus detection versus measurement

A distinction should be made between three considerations: the diagnosis of dental caries, the detection of the carious lesion, and the measurement or quantification of that lesion.[6] Diagnosis can be defined as 'the art or act of identifying a disease from its signs and symptoms',[7] which in caries apart from lesion detection also involves the assessment of the individual *in toto*, considering all caries risk factors, such as personal factors, oral environmental factors and daily factors directly contributing to the caries risk of the individual and of the specific tooth surface. Caries detection involves the use of an objective instrument to detect the presence of disease or not, basically with a dichotomous outcome – yes or no, the so-called 'diagnostic threshold'.[6,8] Measurement or quantification of the lesion characterizes and quantifies the extent and status of disease. This may then lead to a threshold decision – whether to undertake a specific clinical procedure such as placement of a sealant or restoration. This can be considered in the context of Pitts' diagnostic threshold model with stages ranging from D1 to D4, where D1 represents initial enamel caries (white spot lesion) and D4 an advanced dentinal carious lesion.[6] At which stage clinicians undertake restorative care varies greatly.

Visual detection

To undertake accurate visual assessment the tooth must be clean, dry and there must be adequate lighting.[5] The initial stages of caries present as a white spot lesion (WSL) due to the changed visual characteristics of the enamel due to less mineral being present. In the early stages of demineralization, WSL may only be visible to the naked eye after drying.

Visual occlusal caries detection is complicated clinically by surface morphology, past fluoride exposure, anatomical fissure topography and the presence of plaque and stain.[9] Radiography can improve the detection of occlusal lesions when they have progressed into the dentine.[10,11] The visualization of interproximal caries in posterior teeth is complicated by the overlying tooth structure at the marginal ridge, especially in the early stages of the carious lesion. However, in primary teeth it is still a reliable method of early detection.[12] The detection of interproximal caries can be improved by the use of transillumination with radiography.[12–14]

Tactile detection

The use of tactile detection has been a mainstay of clinical dentistry for more than 100 years, and using a sharp probe or explorer as a caries detection method persists in both clinical practice and undergraduate dental education.[15] It has been recommended for at least two decades that this technique be limited or replaced for detection of fissural or smooth surface caries.[9,15,16] This is due to the limited amount of extra information tactile examination provides in addition to what can be gained by using other detection techniques, and also the possible damage that may be done to demineralized enamel during the 'probing' procedure.[9,15,17,18] It is recommended that only a ball-ended probe is used, especially to check enamel surface integrity/roughness.[18]

Caries indices

Many indices have been developed to record clinical caries data, with the WHO method being used widely since the late 1970s. This used a simple dichotomous ruling – carious or not – at the D3/cavitated lesion threshold – basically representing whether the tooth needed clinical intervention or not. Since then, especially as no reliable detection device had been established, and as the caries prevalence in many communities changed the need for detection at an earlier stage than frank cavitation was realized. The International Caries Detection and Assessment System (ICDAS) was developed 10 years ago to allow assessment of lesions at early stages, especially useful in epidemiological studies and also in remineralizing product trials.[19] The codes range from measurement of the first visible carious change in enamel after drying (code 1) to extensive cavitation (code 6).[20]

There are other indices such as Nyvad, the Pulpal, Ulceration, Fistula, Abscess Index (PUFA), the Universal Visual Scoring System (UNIVISS), the Caries Assessment and Treatment Instrument (CAST), and the FDI caries matrix which still require validation.[21–25] One advantage of the Nyvad system is that lesion activity can be measured with accuracy, and ICDAS and Nyvad activity has been used together in clinical trials.[21,26,27] The CAST system records non-cavitated and cavitated carious lesions, teeth with lesions large enough to have pulpal involvement, abscessed teeth as well as treatments already present.[23] The FDI caries matrix is an amalgam of ICDAS and PUFA.[22]

Radiography

Radiography has been a mainstay of clinical dental practice for nearly 100 years. The limitations of radiography are in the detection of occlusal carious lesions, especially in their early stages.[28,29] 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.[9,11,30] 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.[11]

The use of digital radiography has become common place amongst many practitioners. 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.[29] The use of subtraction radiographic methods have been reported to increase the accuracy and reproducibility compared to visual assessment of the images.[10] Computer assisted detection using bitewing radiography can improve accuracy, especially when lesions are deeper than half way through the enamel.[31] The sensitivity of detecting cavitated and non-cavitated lesions in posterior teeth increased from 0.34 to 0.63 after tactile detection was included with radiography; the specificity decreased from 0.99 to 0.93 after tactile detection was added to radiographic detection.[13]

Transillumination

Transillumination relates to the positioning of a light source against the side of the tooth (usually buccal or lingual), and mostly a fibre optic source of light is used (fibre optic transillumination; FOTI).[30] The method of FOTI is based on the principle that a sound tooth structure has a higher index of light transmission than carious tooth. In other words, the photons are scattered when the tooth is demineralized.[32] Primarily it is used for detection of proximal carious lesions, aiding visual inspection and supplementing radiographic methods, although studies have indicated it can also improve visual detection of occlusal lesions.[9,14,30] Carious lesions limited to the enamel appear as grey shadows, and those in the dentine appear as orange-brown or bluish shadows.

The use of transillumination has been limited, despite it being promoted for more than 30 years and reported as similar in validity to visual inspection and more sensitive than radiography for the detection of occlusal lesions.[30,33] One limitation of FOTI is the lack of a visual record, so the development of digital imaging FOTI (DIFOTI) has overcome this problem.[34] To date commercially available systems have not provided software to allow quantification of lesion changes, despite a new DIFOTI system being released recently (DIAGNOcam™, KaVo Dental Gmbh, Biberach, Germany).

Laser fluorescence

Laser fluorescence, namely the DIAGNOdent™ (KaVo Dental Gmbh, Biberach, Germany), can be used for both occlusal and interproximal detection, with the technology based on the fluorescence of porphyrins excited by laser light. The sensitivity and specificity of laser fluorescence in detecting intradentinal lesions varies greatly with false positives the major limiting factor of the technology.[35] To achieve best results the angulation of the tip should be consistent, and the results should be seen in conjunction with other detection methods, not as a stand-alone gold standard as the sensitivity and specificity of results vary.[12]

Light-induced fluorescence

Quantitative light-induced fluorescence systems (including QLF™, Inspektor BV, The Netherlands; Vistaproof™, Durr Dental AG, Germany; and Sopralife™, Acteon, Le Ciotat, France) utilize differences in autofluorescence between sound and demineralized enamel and also dentine. Demineralized enamel appears darker than the adjacent sound tooth structure, and the carious dentine fluoresces red depending on the filters used. In the QLF™ and Vistaproof™ systems, software allows the quantification of fluorescent changes, and longitudinal recording of images and analytical results.

The use of QLF enables the early detection of enamel demineralization and also there is the possibility that it may be used to discriminate between affected and infected dentine. Like the DIAGNOdent™, QLF technology is reliant on standardized technique, especially control of ambient light, and the results must be interpreted in conjunction with other detection methods in the context of the caries risk of the individual.

Electrical characteristics

The electrical characteristics of dental structure change as the mineral content changes. A current is applied across a tooth and the instrument, such as the Cariescan™ (Cariescan Ltd, Dundee, UK) can quantify the changes in the impedance of the tissue and potentially quantify mineral content. Some factors can influence the accuracy and reliability of the measurements such as hydration of the tooth surface, thickness of the tissue and temperature.[32]

Photothermal radiometry

A new system released recently uses laser-based photothermal radiometry/modulated luminescence (PTR-LUM; Canary, Quantum Dental Technologies Inc., Toronto, Canada), detecting luminescence differences and also change in temperature to quantify mineralization changes. Images are captured and stored in the associated software, a 'Canary' number is generated putatively indicating the lesion characteristics.[36]

Further research is required into all of the discussed new technologies, and further details are provided in the following Tassery *et al.*[37] paper.

Assessment of lesion activity

The assessment of caries activity at the surface level provides information that can be used in conjunction with other risk measures to assess the current caries risk and also be used as a baseline measure for future assessment of caries risk changes.[26] The most commonly used system is the visual and tactile index developed by Nyvad *et al.*[21] This index discriminates activity using surface appearance and surface integrity – e.g. Score 1 – Active caries (intact surface) – surface is white/yellow opaque with loss of lustre; feels rough when the probe is moved gently across the surface.[21]

Reproducibility

Obtaining reproducibility between examiners is difficult, as practitioners tend to develop individual concepts based on experience regarding caries detection and the subsequent preventive or restorative treatment options.[38] Length of experience also contributes, with experienced examiners having higher sensitivity, higher specificity and greater reproducibility than those less experienced.[39]

Due to the lack of a single detection method that provides both high sensitivity and high specificity, combining a number of methods is recommended to increase the accuracy of detection. For example, this may mean combining DIAGNOdent™ findings with visual and radiographic images, or FOTI.[39] Several factors, such as fluorescent lighting, can upset the results of fluorescent based detection methods, so care in control of ambient lighting and standardization of methodology is imperative when using these new detection methods.

Several other methods of detection include Raman spectroscopy, optical coherence tomography (OCT) and ultrasound; however, none of these technologies has had commercial release with scientific validation.[32,40]

CONCLUSIONS

The early and accurate detection and diagnosis of dental caries is an important component of the overall management of the dental patient. 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.

DISCLOSURE

The author has no conflicts of interest to declare.

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