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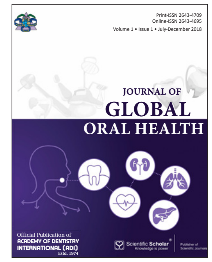

Review Article

Conventional diagnostic aids in dental caries

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ABSTRACT

Dentistry is rapidly evolving from a surgical and reparative profession into a healing profession focused on overall patient wellness. The oral systematic connection has been well established, with the condition and status of the oral cavity being a great indicator of the patient's overall health. In today's scenario, most of the focus is towards prevention, early diagnosis, and intervention to minimize treatment, to enable the most desirable outcomes. Thus, the dental practitioner's should have efficient cognitive skills to be a diagnostician and for case management. Furthermore, the diagnostic modalities available have been expanded greatly on the foundation of a comprehensive visual assessment, with a ultimate goal of improving both the sensitivity and specificity level for any caries detecting diagnostic tool.

Keywords: Dental caries, Diagnosis, Radiography, Sensitivity, Specificity

INTRODUCTION

Caries process is dynamic with demineralization and remineralization occurring over time such that the net balance of these events determines the caries activity and severity.[1] The need for the identification and clinical staging of the presence, activity, and severity of dental caries is of paramount importance in the deployment of treatment strategies. The dilemma in clinical detection arises not with the advanced lesion, but primarily with the early, non-cavitated lesion of dentin, recurrent caries, and sublingual root caries.[1]

According to Pitts,[2] the ideal tool for diagnosis of the carious lesion would be noninvasive, reliable, valid, sensitive, specific and provide a robust measurement of lesion size and activity and would be based on the biological process directly related to the carious process. Unfortunately, currently used diagnostic methods are subjective in nature, detect lesions only at an advanced level, cannot quantify the mineral loss, and cannot measure the small changes in mineral loss (gain) on demineralization.[3] However, a variety of innovative technologies have been developed and introduced in the last few years to aid the clinician not only in early caries diagnosis but also to make a firm diagnosis and treat cases conservatively.[4]

While awaiting further technologic development, dentist and researchers have to select the combination of methods that are most appropriate for the particular diagnostic task at hand. This paper reviews certain conventional caries detection methods available.

CONVENTIONAL METHODS

Visual method

This is the oldest diagnostic method wherein the teeth are air dried and illuminated under adequate light source to look for the presence of cavitations, opacification and discoloration. Visual examination has been shown to have high specificity but low sensitivity and reproducibility.[5] The low sensitivity of this method to detect signs of early disease often leads to many decayed teeth to be left untreated,[6] underestimation of caries prevalence and over-treatment with fissure sealants.[7]

The first move towards increasing the sensitivity of visual caries detection by 50% was made by the evolution of magnifying devices such as head-worn prism loupe. Ekstrand index was introduced for visual standardization and improved detection of dental caries. The Ekstrand index scores resemble the clinical situations and are based on signs found on the enamel surface such as opacities, white spots, brown spots, presence of cavities or micro-cavities, and a combination of these conditions. This system is expected to increase the sensitivity and reliability of the visual examination.[8]

Lussi[9] based on the results of different diagnostic methods used by 26 dentists under standard dental operatory conditions concluded that fissure morphology and discoloration are unreliable for definitive diagnosis of caries as at least 55% of sound teeth would be misclassified. Other studies have also found that the presence of stain is not necessarily indicative of caries.[9,10] Ricketts *et al*[11] observed that visual examination alone was not helpful for deciding the treatment or preventive option for lesions as no significant correlation between the visual appearance of the site and the level of infection in the dentine was noted. Furthermore, non-cavitated occlusal fissures, diagnosed as carious and requiring restoration, exhibited a range of visual appearances of which no particular feature was indicative of its condition.[11] On the other hand, Ekstrand concluded that the external signs of caries were a good indicator of the degree of caries within the tooth[12] and caries activity[13] under optimal clinical conditions.

Cleaton-Jones *et al.*[14] reported that visual examination on its own is comparable with the traditional visual-tactile method and to the fiber-optic transillumination (FOTI) method. Further, the new data collected by visual diagnosis alone may, reasonably, be compared with historical data diagnosed with visual-tactile examination. Costa *et al.*[15] and Bahrololoumi *et al.*[16] reported that the specificity of radiography and visual methods for the diagnosis of enamel caries was greater than that of DIAGNOdent. As the visual method has a lower cost, is faster and has acceptable sensitivity; therefore, it can still be used as an appropriate method for clinical caries detection.[16] Furthermore, Reis *et al.*[17] concluded that in a low prevalence sample, the visual inspection provided the highest proportion of true disease identified correctly.

Temporary elective tooth separation can be used as a method of visual examination of approximal surfaces. Studies[18,19] have shown that tooth separation has detected more noncavitated enamel lesions than visual-tactile examination without tooth separation or bitewing examination. Abogazalah and Ando[20] reported that tooth separation may not always result in improved accessibility for direct examination of the approximal lesions and may also create patient discomfort. Moreover, it also requires an additional visit from the patient. Temporary elective tooth separation in conjunction with a localized impression allows a more sensitive diagnosis of cavitation and an advantage of providing a replica as a reference for visual monitoring of changes.[1]

Visual-tactile method

The visual-tactile method has been a mainstay of clinical dentistry for more than 100 years and is based on the use of a dental mirror, sharp probe, and a 3-in-1 syringe and clean and dry tooth surface. The examination is primarily based on subjective interpretation of surface characteristics such as integrity, texture, translucency or opacity, location, and color.[8] Use of dental floss for tactile evidence of proximal caries has been shown to be effective, wherein shredding of dental floss indicates a proximal cavity.

Tactile examination using a sharp probe has been criticized because of the possibility of transporting cariogenic bacteria, may cause irreversible traumatic defects in potentially remineralizable enamel and may not be able to add any information to the visual examination.[21] *In vitro* studies by Beltrami *et al.*[22] and scanning electronic microscopic study by Kuhnisch *et al.*[23] confirmed that using a sharp probe for caries detection can cause mechanical damage to the enamel. Ekstrand *et al.*[24] showed that dentists were not able to reliably and reproducibly determine the subtle visual and tactile differences between active and inactive enamel lesions.

Histological studies showed that only a small section of occlusal carious lesions can be detected by visual-tactile method[25,26] and conventional radiography is not sensitive in detecting early carious lesions involving enamel.[10] Thus, conventional radiography in conjunction with visual-tactile examination has been shown to significantly improve the accuracy of occlusal caries diagnosis and is commonly employed in clinical practice.

Caries indices

For several decades, dental researchers have followed the decayed, missing and filled (DMF) index developed by Klein, Palmer, and Knutson in 1938 for assessing dental caries. The World Health Organization has adopted this index in oral health assessment form for conducting national oral health surveys. From the public health point of view, the major disadvantage of using DMF index is that it records only cavitated lesions using visual-tactile criteria.

Today, various indices of decay describe the entire spectrum of the disease from early demineralization of the enamel to an extensive cavity with pulp involvement. As SiC index is an expansion of DMF index and follows the same criteria as that of DMF index, it may have a limitation in determining dental carious among population subgroup in the same manner as that of DMF index.[27] Nyvad's system has predictive and constructs validity (the different conditions of carious lesions project different outcomes) related to caries lesion activity status, but it requires a careful visual examination on a clean/dry surface.[28] ICDAS was devised based on the principle that visual examination can be carried out on clean, plaque-free teeth with careful drying of the lesion and to avoid traumatic and iatrogenic defects on incipient lesions by replacing the traditional explorer with a ball end periodontal probe.[29] Although ICDAS has good validity and reliability, it has major shortcomings such as recording of non-primary carious lesion related conditions, does not correlate well with various types of restorations, and may lead to an overestimation of dental caries experience.[30] Further, an *in vitro* study found no significant difference between Nyvad system and ICDAS in assessing caries activity.[31]

The major drawback of the DMF index is that it cannot assess the clinical consequences of untreated dental caries, such as pulpal abscess, which has significant impact on health than the carious lesions themselves, and is the basis for the development of PUFA index.[32] This index records the advanced stages of untreated caries lesions so that caries data collected should have an impact on health decision-makers, which is not possible with DMF index. However, the reliability and validity of this index requires further discussion.

CAST index was developed based on the strengths of PUFA and ICDAS indices and provide a link to the widely used DMF index (M and F component). It covers the total dental caries spectrum – from no carious lesion, through caries protection (sealant), and caries cure (restoration) to carious lesions in enamel and dentine, and the advanced stages of caries lesion progression in pulpal and tooth surrounding tissue.[33] The major limitations of the index is that it does not record active and inactive carious lesions, has not been validated, nor has its reliability been tested.[32]

Reliable, reproducible, and realistic detection and estimation of lesions that result from dental caries has been a challenge for a long time. There are many promising newer dental caries indices, which will help in identifying caries at early or pre-cavitated stage and accurate diagnosis of dental caries. It must be assumed that these newly developed tools of epidemiological caries assessment will evolve further.

CONVENTIONAL RADIOGRAPHIC METHOD

Radiography is the most common carious lesion detection aid and is based on the fact that as the caries progresses, the mineral content of enamel and dentin decreases resulting in a decrease in the attenuation of the X-ray beam as it passes through the teeth. This feature is recorded on the image receptor as an increase in the radiographic density.

Bitewing radiographs show high sensitivity (50–70%) to detect caries lesions in the dentin of both approximal and occlusal surfaces, compared to clinical visual detection. However, the validity of detecting enamel lesions is limited on the approximal surfaces and low for the occlusal surfaces.[34] Radiographs are of lesser use in detecting the initial dentinal lesions and occlusal enamel lesions due to the superimposition of buccal and lingual enamel. 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.[11] Therefore, the radiographic examination may underestimate the extent of caries lesions.[35] In addition, adding radiographs to a visual-tactile exam have been shown to not significantly increase decayed, missing, and filled surfaces (DMFS) scores in a clinical epidemiological study.[36]

In vitro bitewing radiography alone results in a sensitivity of 58%, higher than that of visual inspection and a specificity of 87% according to histological validation.[37] Systematic review evidenced that radiographs have high specificity and low sensitivity in detecting occlusal caries, as there were greater chances of false-negative diagnosis in the presence of caries than false positive diagnosis in the absence of disease.[35] It is important to stress that many different factors can affect the ability of bitewing radiography such as overlapping of approximal contacts, technique, image processing, type of image receptor, exposure parameters, vertical and horizontal angulations of the X-ray beam, positioning of the film, display system, and viewing conditions, possible distortions caused by the structures attached to the dental tissues and incorrect diagnosis due to misinterpretation.

Meta-analyses[38,39] have observed that visual and radiographic examination for detection of early approximal caries has noticeably high specificity (Sp) but low sensitivity (Sn). Dental practitioners traditionally use a combination of the two methods. Several studies reported increased Sn for detection of approximal caries when bitewing radiographs were used in conjunction with the visual-tactile examination.[19,40] However, approximal carious lesions were detected much earlier when tooth separation was performed compared to visual-tactile or bitewing radiographic examination without tooth separation.[18,19]

Besides visual-tactile screening for dental caries, radiographic caries detection is the most frequently used diagnostic tool in general dental practice. Given that radiography is associated with potentially harmful ionizing radiation and considering that an increasing number of alternative techniques are available for detecting both initial and advanced occlusal or proximal lesions, the accuracy of radiographic caries detection needs to be critically appraised to inform both clinicians and researchers.

XERORADIOGRAPHY

Xeroradiography was invented by a physicist Chester F. Carlson, in 1937. He based his invention on the principle of photoconductivity, i.e., some materials which are nominal insulators become conductors when they are exposed to light or ionizing radiation. Using selenium as a photoconductor, he was able to reproduce a number of graphic articles, and with the aid of another physicist, Otto Kornei, successful images were made.[41] The main characteristics of the xeroradiographic technique are the ability to have both positive and negative prints together. When positive current is applied to the film, negative particles are attracted, and when negative current is applied, positive particles are attracted.

Greater diagnostic accuracy, easier and rapid interpretation, good quality images, shorter exposure times and a relatively low radiation dose, i.e., 1–1.5 rads per exposure, economic benefit evaluation of different tissues on one xeroradiograph are some of the advantages of xeroradiography. However, the electric charge over the film, many a time, and cause discomfort to the patient since the oral cavity has a humid environment, which acts as a medium for the flow of current, technical difficulties and slower imaging speed were the disadvantages.[42]

Receiver operating characteristic analysis (whereby one measures the performance of observers in solving specific diagnostic tasks using competing imaging systems), it has been found that there is no essential difference in diagnostic value between xeroradiographs and conventional radiographs, it has been proved that xeroradiography is more useful in detecting carious lesions.[43,44] With several features of convenience, xeroradiography is a valuable alternative to conventional radiography for the detection of carious lesions, calculus deposits interpreting periapical structures, and periodontal disease.

DYES

With the advent of minimally invasive dentistry as a potential growth market for various products and procedures, there has been a renewed emphasis on the use of caries detector dyes. Apparently the use of these agents makes the task of detecting early enamel caries and assessing the depth of dentine caries more “scientific.”

In 1972, a technique using a basic fuchsin red stain was developed to aid in the differentiation of the two layers of carious dentin.[45] Because of potential carcinogenicity, the basic fuchsin stain was subsequently replaced by another dye and acid red solution.[46] Since then, various protein dyes have been marketed as caries-detection agents. Intended to enhance complete removal of infected carious dentin without over-reduction of sound dentin, the dye was purported to stain only infected tissue and was advocated for a “painless” caries removal technique without local anesthesia.

Kidd *et al.*[47] measured the level of infection of dye-stained and unstained dentin at the dentino-enamel junction at the completion of cavity preparation; it was discovered that not all dye- stainable dentin was infected. The lack of specificity of caries-detector dyes was confirmed by Yip *et al.*[48] where they observed that sound circumpulpal dentin and sound dentin at the dentinoenamel junction took up the stain because of the higher proportion of organic matrix. Thus it confirms that dyes stain the collagen associated with less mineralized organic matrix rather than the bacteria.

Dye staining and bacterial penetration are independent phenomena,[49] which significantly limits the usefulness of these dyes for diagnostic purposes. Quantification of the intensity of staining measures the severity of diseased tissue, and the contrast helps to identify carious dentin if tactile discrimination is unavailable. Ideally, a caries-detector dye would differentiate between infected and non-infected dentine. However, a caries detector dye does not stain bacteria and so cannot tell where infected dentine finishes and non-infected dentine starts.

Dyes for detection of carious enamel:[50] Procion dyes stain enamel, but the staining becomes irreversible because the dye reacts with nitrogen and hydroxyl groups of enamel and acts as a fixative. Calcein dye makes a complex with calcium and remains bound to the lesion. Fluorescent dye like Zyglo ZL-22 has been used *in vitro*, which is not suitable *in vivo*. The dye is made visible by ultraviolet illumination. Brilliant blue has also been used to enhance the diagnostic quality of FOTI, but use of dyes for diagnosing enamel lesions cannot be used clinically as yet. If possible, it will allow lesions to be visualized at an early stage and thus allow remineralization procedures to be carried out early in the treatment plan.

Dyes for detection of carious dentin: [50] Histopathologically, carious dentin is divided into two layers – the outer layer of decalcification, which is soft and cannot be remineralized, and the inner decalcified layer, which is hard and can be remineralized. Dyes have been tried to differentiate between these two zones of dentin caries. 0.5% basic fuchsin in propylene glycol has proved to be successful for the purpose. Demineralized dentin in which the collagen has been denatured is stained while the inner one remains unstained. This method is recommended as a clinical guide for complete removal of the outer carious zone in dentin caries as it contains denatured collagen.

A modified dye penetration method: The iodine penetration method for measuring enamel porosity of the incipient carious lesion was developed by Bakhos *et al.* (1977).[51] Potassium iodide is applied for a specific period of time to a well-defined area of the enamel thereafter the excess is removed, the iodine, which remains in the micropores, is estimated and that indicates the permeability of enamel.

Al-Sehaibany *et al.*[52] evaluated the use of caries detector dye in the diagnosis of occlusal carious lesions. Histological cross sections showed that the accuracy of caries detection dye in diagnosing occlusal caries was 100% in comparison to traditional explorer examination, which was only reliable up to 25%. Javaheri *et al.*[34] evaluated the efficacy of two caries detector dyes in the diagnosis of dental caries and concluded that they may not be reliable when used as the one and only diagnostic technique for revealing carious lesions in posterior teeth.

As reported by Mc Coomb D,[53] Caries-detector dyes should, therefore, stain only in a manner that permits proper discrimination between healthy and diseased tooth structures. As none of the available caries-detection dyes are caries specific, their routine use can lead to over-treatment and pulp exposure. A considerable body of evidence shows that careful and thorough use of tactile and visual criteria provides an acceptable assessment of the caries status of dentin during cavity preparation.

CONCLUSION

The ultimate goal of any caries detecting diagnostic tool is to improve both the sensitivity and specificity level. If the disease can be detected before cavitations occur, preventive therapy may avoid the need for any unnecessary operatory intervention. This would be stepping stone toward a more conservative and minimally invasive treatment approach.

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Conflicts of interest

There are no conflicts of interest.

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