RECENT ADVANCES IN DIAGNOSIS OF DENTAL CARIES

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Abstract

Dental caries is one of the most prevalent diseases throughout the world accounting for more than 70% of the population. Early diagnosis of caries is as important as its treatment. A small dental decay can lead to periapical infection if left untreated. The main aim of this review is to list various methods of caries diagnosis with main emphasis on recent methods.

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INTRODUCTION:

Dental caries also known as tooth decay is defined as an irreversible microbial disease of the calcified tissues of teeth characterized by demineralization of inorganic matter and demineralization of organic substance of tooth leading to cavitation. It is one of the most prevalent diseases throughout the world. Caries lesions start to form when there is an imbalance in the continuum coupled with a net demineralization over time [1] It is now widely acknowledged that the development of new technologies for the early detection and quantitative monitoring of dental decay at an early stage of formation could offer health and economic benefits ranging from prompt preventive interventions to a reduction in the time required for clinical trials of anticaries agents [2]. Many researches and trials have been carried out from times unknown in order to diagnose dental caries at an early stage and to prevent its deterioration. Conventionally used methods for caries diagnosis include- tactile sensation, visual evaluation and radiographic evaluation, Although these techniques successfully detect cavitated lesions, they are insufficient for early detection[3]. Other non-invasive methods, including Quantitative Light-induced Fluorescence (QLF), DIAGNOdent (DD), Fibre-optic Transillumination (FOTI), and Electrical Conductance, have been created and studied for the purpose of detecting early caries (EC)[4]. The sensitivity and specificity of each method determines its utility and results. Various newer and more recent methods for diagnosis of dental caries include expression of mRNA, LDH gene expression, ac impedance spectroscopy, etc. These more modern methods might be used in conjunction with older ones to help detect cavities earlier. Despite all the available methods of diagnosis, a narrative review of the same can help provide a generalized idea of which intervention or method proves to be the most useful and successful as well as holds a promise to the future.

METHOD	YEAR
RADIOGRAPHY	1896
ELECTRIC CARIES MONITOR	1950
CBCT	1967
FIBRE OPTIC TRANSILLUMINATION	1970
POLARISATION SENSITIVE OPTICAL COHERENCE TOMOGRAPHY	1991
ACIST	1991
QUANTITATIVE LIGHT INDUCED FLUORESCENCE	1995
DIGITAL IMAGING FIBER OPTIC TRANSILLUMINATION	1998
LASER INDUCED FLUORESCENCE	1998
CAMBRA	2002
mRNA	**2010**
LDH	**2018**

CONVENTIONAL METHODS FOR CARIES DIAGNOSIS VISUAL METHODS FOR CARIES DIAGNOSIS

For use in clinical practise, clinical research, education, and epidemiology, the international caries detection and assessment system (ICDAS) was created as a manual for standardised visual caries assessment. [5]

The ICDAS uses a two-stage process to record the status of the caries lesion. The first is a code for the severity of the caries lesion and the second is for the restorative status of the tooth. [6,7]

The status of the **caries severity** is determined visually on a scale of 0–6:

- 0 = sound tooth structure
- 1 = first visual change in enamel
- 2 = distinct visual change in enamel
- 3 = enamel breakdown, no dentine visible
- 4 = dentinal shadow (not cavitated into dentine)
- 5 = distinct cavity with visible dentine
- 6 = extensive distinct cavity with visible dentine

This severity code is paired with a **restorative/sealant** code 0–8:

- 0 = not sealed or restored
- 2 = sealant, partial
- 3 = sealant, full; tooth-coloured restoration
- 4 = amalgam restoration
- 5 = stainless steel restoration
- 6 = ceramic, gold, porcelain-fused-to-metal (PFM) crown
or veneer
- 7 = lost or broken restoration
- 8 = temporary restoration

A study conducted recently showed that visual-tactile methods provide high specificity but poor sensitivity, it was also indicated that diagnodent demonstrated greater sensitivity but lower specificity compared to visual caries diagnosis [8]

DENTAL EXPLORER FOR DIAGNOSIS OF DENTAL CARIES

The recommended instrument for assessment of surface roughness is the Community Periodontal Index of Treatment Needs (CPITN) probe having a 0.5 mm sphere at the tip.[9]

• Sharp explorers previously have been used to evaluate fissures and pits in an attempt to diagnose fissure/pit caries. However, numerous studies have found that the use of a sharp explorer for this purpose did not increase diagnostic validity compared with visual inspection alone. [10,11,12]

• The use of the sharp dental explorer for this purpose was found to fracture enamel and serve as a source for transferring pathogenic bacteria among various teeth. [13,14]

Forcing an explorer into pits and fissures also theoretically risks cross-contamination from one probing site to another. In contrast, for assessment of root caries, an explorer is valuable for detecting root surface softness.

RADIOGRAPHS

The diagnostic toolkit of the modern dentist is indispensible without radiographs. If at all possible, information from radiographs should be confirmed or enhanced by findings from a clinical examination before making a diagnosis and choosing a course of treatment [15]

LIMITATIONS OF RADIOGRAPHS

Always proceed with caution while interpreting dental radiographs. A three-dimensional mass is depicted in two dimensions on a dental radiograph.

• To radiographically imitate a proximal caries lesion, a facial or lingual lesion (or radiolucent tooth-col- oured restoration) may be superimposed over the proximal area (false positive).

• A caries lesion may exist and be undetected due to the common observation that about 25% mineral loss must occur before a radiolucency starts to emerge on a radiograph (false negative).

Even though a caries lesion may be more extensive clinically than it looks radiographically, it is still possible for a misdiagnosis to occur when cervical burnout (the radiographic picture of the normal structure and shape of the cervical third of the crown) resembles a caries lesion.

Sensitivity of radiographs for occlusal dentinal caries is 50% whereas the specificity for the same is 80%.[16]

ELECTRIC CARIES MONITOR

The high electrical conduction resistance of the hard tooth tissues is the foundation of electronic caries monitorization (ECM). Even though caried enamel exhibits greater conductivity compared to unbroken enamel, enamel is a poor electrical conductor.[17] Enamel that has been demineralized becomes more porous, fills up with minerals from saliva and ion-containing fluid, and as a result, has enhanced electrical conductivity.[18] Two instruments with tips made to be applied to the occlusal surface and measure electrical conductance in pits or fissures have been created.[19] Similar to its predecessor (Vanguard, Electronic Caries Detector, Massachusetts Manufacturing Cooperation Cambridge, MA, USA), the Electronic Caries Monitor (LODE, Groningen, the Netherlands) was created for the diagnosis of occlusal surface caries and allows the identification of early-stage demineralization lesions. The table displays the sensitivity and specificity results from in vitro and in vivo research using ECM to treat occlusal caries.

Author	Level	Study	Sensitivity	Specificity
Ashley et al [20]	Enamel	In vitro	0.65	0.73
Ekstrand 1997 [21]	Enamel	In vivo	0.63	0.73
Lussi 1999[22]	Dentin	In vitro	0.87-0.92	0.64-0.78

CBCT

Hounsfield developed computed tomography (CT) [23], which is regarded as a technological advance. It is a well-known medical procedure for the non-destructive inspection of internal structures, and its use to dentistry has been innovative in that it can produce real 3-dimensional images.[24] Cone beam computed tomography (CBCT) is a new use for CT that produces 3D images at a lower cost and radiation than traditional "fan beam" CT used in clinical practise.[25] In comparison to traditional CT systems, data from the craniofacial region are frequently gathered at higher resolutions in the axial plane.[26] Additionally, these systems are relatively space-efficient and can easily fit into the majority of dental clinics in use today. The table given below shows the sensitivity and specificity values.[27]

Young et al[58,*]	146	8	CCD (#2 CCD)	0.18±0.15 (E) 0.33±0.06 (D)	0.96±0.08 (E) 0.96±0.02 (D)
			3DX accuitomo FOV (4 cm)	0.24±0.08 (E) 0.61±0.05 (D)	0.95±0.05 (E) 0.94±0.05 (D)
Haiter-Neto et al[25,*]	100	6	PSP (Diagora-fmx)	0.17	0.91
			Film (Kodak Insight)	0.18	0.92
			NewTom FOV (12 inch)	0.13	0.88
			NewTom FOV (9 inch)	0.14	0.85
			NewTom FOV (6 inch)	0.18	0.84
			Accuitomo FOV (4 cm)	0.21	0.89

FOTI

The qualitative method known as fiber-optic transillumination (FOTI) was first used in the 1970s. It is a straightforward, non-invasive, painless operation that the patient is not at risk from repeating. It is effective at finding proximal lesions and can be utilised to identify caries on all surfaces. About occlusal dentine lesions, a recent review found a mean sensitivity of just 14 and a specificity of 95, while for proximal lesions, a sensitivity and specificity of 4 and 100%. The FOTI approach has some drawbacks; it is subjective rather than objective. No continuous data output is made. It is impossible to capture what is viewed as an image. [28]

POLARISATION SENSITIVE OPTICAL COHERANCE TOMOGRAPHY

A well-known technique for high-resolution cross-sectional and three-dimensional imaging of transparent and translucent objects and tissues is optical coherence tomography (OCT). However, conventional, intensity-based OCT lacks a tissue-specific contrast, which might make it difficult to interpret images in some situations. The ability of various materials and tissues to alter the polarisation state of the light makes polarisation sensitive (PS) OCT advantageous since it adds a second contrast channel and provides quantitative data. In this article, we examine PS-fundamental OCT's and sophisticated approaches and illustrate how they might be used in particular biomedical contexts [29]. According to research done by Lee et al [30] to assess the remineralization of artificial enamel lesions with PS-OCT, the sensitivity and specificity values were 0.92 and 0.97, respectively.

ALTERNATING CURRENT IMPEDANCE SPECTROSCOPY

This instrument uses an insensitive amount of electrical current to pass through the tooth in order to detect the presence and location of the decay. It is based on the well-established technology of alternating current impedance spectroscopy [31]. A sinusoidal signal with known amplitude and frequency is applied to a sample to create the frequency domain. Next, the applied voltage perturbation and obtained response current are used to determine the impedance using the response waveform as input. It is the first dental diagnostic instrument to quantify dental cavities using ac impedance spectroscopy at an early enough stage to improve preventative care. The Carie Scan provides a qualitative value based on the disease state rather than the optical properties of the tooth, the creators claim. It is unaffected by optical factors like staining or tooth discoloration. Primary coronal dental caries (occlusal and accessible smooth surfaces), which are not readily visible to the naked eye, are advised for detection, diagnosis, and monitoring with the device. It cannot be used to evaluate dental root caries, secondary caries, the integrity of a restoration, or the extent of an excavation during cavity preparation [32]. The CarieScan-Plus is a wirelessly linked control system that works in tandem with the Carie Scan and is intended to be used as a patient management system. It enables data to be automatically captured, filed, and recalled electronically on a basis of by-tooth, by-surface, and by-date for dental health monitoring. This improves communication with the patient to encourage preventive behaviour and control of dental decay[1]. According to a comprehensive analysis comparing the Carie Scan with bitewing radiograph, clinical visual examination, and DIAGNOdent, it has higher sensitivity and specificity (both 92.5%) than other techniques [33].

QUANTITAIVE LIGHT INDUCED IMMUNOFLUORESCENCE

This is a well-known dental diagnostic method. When the quantitative light-induced fluorescence (QLF) technology was first introduced in 1995, it was immediately put to use tracking the progression of caries lesions [34]. Since then, numerous studies have shown that the QLFTM system can identify and track caries in both children and adults in real time. [35,36] To distinguish between caries and surrounding sound enamel, QLF uses the natural fluorescence of the teeth, which is determined by the light absorption and scattering characteristics of the teeth. With demineralization, the auto fluorescence of tooth tissue decreases. QLF quantifies the percentage fluorescence change in demineralized enamel relative to surrounding sound enamel and correlates it with the amount of mineral lost during demineralization. When viewing caries lesions with QLF, they appear dark. This is based on the idea that a demineralized tissue limits light penetration due to excessive photon scattering that occurs as photons enter the lesion, limiting the possibility of a photon being absorbed and fluorescence emitted [37,38,39]. A study stated that the sensitivity and specificity of this method are 64% and 80% [40].

DIFOTI

Developed by Schneidermann et al. from the New Jersey Dental School, University of Medicine and Dentistry of New Jersey's Department of Oral Pathology, Radiology, and Diagnostic Sciences. Using fibre optic transillumination, visible light is used to create images of teeth. Since a digital electronic CCD camera was used to capture the images, DIFOTI may eliminate or significantly minimise both intra- and inter-observer variation. From the optical fibre, light propagates through the tooth to an unlit surface (usually the opposite surface). By keeping a number of imaging control parameters adjusted, DIFOTI pictures can be acquired in a reproducible manner. The information is then transferred to a computer where it is processed by specialised algorithms to create digital images that may be viewed by the dentist and patient in real time or saved for later assessment. Additionally, this technology has the ability to measure the characteristics of early, frank, and secondary caries lesions on occlusal, approximate, and smooth surfaces as well as improve contrast between healthy and carious tissues. Additionally, it can be utilised to spot fluorosis and other alterations to the coronal architecture of teeth. When compared to a radiographic examination, DIFOTI is more sensitive in detecting early lesions and has the potential to quantitatively track some lesions over time [41][42]. However, only with careful angulation can approximal lesions be detected by DIFOTI. Since the generated image is of a surface or anything close to it, it does not measure the depth of the lesion. Although photos can be compared over time, the course of the lesion cannot be quantified. There is a significant risk of overdiagnosis due to the higher sensitivity and somewhat poorer specificity.[28] According to research done by Menero et al [43] to analyse the validity of DIFOTI for the diagnosis of proximal caries, the sensitivity and specificity values were 0.69 and 0.89, respectively.

LASER INDUCED IMMUNOFLUORESCE-NCE (DIAGNOdent)

The purpose of the DIAGNOdent gadget (KaVo Dental Corporation, Charlotte, NC, USA) is to identify and measure bacterial products and changes in tooth structure in a caries lesion using laser fluorescence technology [44]. This small, portable instrument generates a numerical score between 0-99 and requires a dry, clean occlusal surface. Threshold scores that indicate the presence and size of a lesion have been recommended by the manufacturer. The gadget is definitely more sensitive than conventional diagnostic methods, but the higher risk of false-positive diagnoses restricts its usefulness as a primary diagnostic approach, according to a systematic study [45]. According to a study, the sensitivity and specificity of this method is 0.86 and 0.80 respectively. [46]

CAMBRA

Non-destructive risk-based caries management solutions are the current trend in the treatment of dental caries, as opposed to focusing primarily on restorative therapy. Numerous changes in understanding are currently being made in relation to the diverse nature of the caries process and its management. The Caries Management by Risk Assessment (CAMBRA) evidence-based technique focuses on identifying the various factors that lead to illness manifestation and implementing the necessary interventions. The doctors can identify the behaviours that are increasing a patient's risk for disease and disease progression by evaluating the patient's current caries risk. A innovative treatment plan can be devised to stop dental caries and reduce the risk of cavitation with the help of this modern CAMBRA procedure. Once it was realised that caries, including the biofilm, are multifactorial, the primary goal of current therapy was to control the locally imbalanced oral biofilm and stop the progression of the disease. The initial caries lesions can be located with the aid of modern diagnostic technologies, and CAMBRA can assist in restoring the integrity of the tooth surface at an early stage of the caries process, which will considerably benefit patients.[47] in research done in preschool children by gao et al [48], CAMBRA showed a sensitivity of 83.7% and a specificity of 62.9%.

EXPRESSION OF mRNA FOR CARIES DIAGNOSIS

Dental caries is a complex illness that is clearly influenced by environmental factors like as food, oral hygiene, mouth bacteria, and fluoride exposure. However, there is also substantial evidence that hereditary factors play a role in the disease's aetiology[49]. According to the factors affecting caries, these genes can be divided into enamel-forming genes, immune response genes, saliva-related genes, taste-related genes and others [50]. In the recent years, a number of GWASs have discovered some genes that are linked to dental caries, including interleukin 32 (IL32), galactokinase 2 (GALK2), CUGBP, Elav-like family member 4 (CELF4), BCL6 corepressor (BCOR), BCL6 corepressor like 1 (BCORL1), inhibin subunit beta A (INHBA), C-X-C motif chemokine receptor (BMP7) [51]. According to a study conducted in 2019, Dental caries was included in a genome-wide association study (GWAS) dataset that was collected from the UK Biobank. Using the FUSION technology and the gene expression reference weights of the musculoskeletal, whole blood, and peripheral blood genes, a TWAS of dental caries was performed. Gene ontology (GO) and pathway enrichment analyses were further used to the TWAS-identified dental caries-associated genes to further investigate dental caries-related gene sets. Finally, to identify shared genes and gene sets, the TWAS results of dental caries were compared with genome-wide mRNA expression profiling of dental caries. Furthermore, the study's discovery of a collection of genes and GO keywords linked to dental caries offers fresh insights into the genetic causes of dental caries [52]

EXPRESSION OF LDH GENE FOR CARIES DIAGNOSIS

Walther et al (2021) [53] researched about the analysis of relative bacterial activity and *lactate dehydrogenase* gene expression of caries-associated bacteria in a site-specific natural biofilm. The study aimed at investigating both the relative bacterial activity and the lactate dehydrogenase (*ldh*) gene expression of caries-associated bacteria in a site-specific natural biofilm. Caries-free subjects (CF) or caries-active subjects (CA) were the two groups of sixty subjects. (CA). One sound surface was provided by CF (CFS, n = 30). A cavitated caries lesion (CAC, n = 30) and a sound reference surface (CAS, n = 30) were provided as the two donor sites in CA. Targeting the 16S gene, the 16S rRNA, the ldh gene, and the ldh mRNA, real-time quantitative PCR (q-PCR) was carried out on species or genus level and total bacteria (increasing 16S ribosomal RNA copy numbers can function as an indicator of increased energy metabolism). The ratio of the relative abundances serves as a measure for the relative bacterial activity (%) because the abundance of the 16S rRNA indicates the number of ribosomes and the abundance of the 16S gene represents the number of genomes. The relative bacterial activity of lactobacilli and S. mutans was highest in CAC and lowest for both sound reference surfaces. For both lactobacilli and S. mutans, there were significant differences between CAC and CAS as well as between CAC and CFS (p 0.05). No significant differences were found since the ldh gene expression of lactobacilli and S. mutans only displayed moderate values in CAC and CFS.

CONCLUSION:

Dental caries, if uncontrolled can have catastrophic effects on the oral health of an individual. Thus, it is necessary to diagnose caries at an early stage to prevent the deterioration of the tooth. Many studies have been conducted to estimate the sensitivity and specificity of various diagnostic aids assisting in diagnosis of dental caries. This narrative review was written based on the emerging advances in the diagnosis of dental caries varying from visual and tactile methods to advances such as usage of mRNA in the diagnosis of carious lesions. The following table summarises the specificity and sensitivity along with the year of establishment of various diagnostic aids:

METHOD	YEAR	SENSITIVITY	SPECIFICITY
RADIOGRAPHY	1896	0.50	0.80
ELECTRIC CARIES MONITOR	1950	O.63-0.92	0.64-0.78
CBCT	1967	0.18-0.33	0.96
FIBRE OPTIC TRANSILLUMINATION	1970	0.14	0.95
POLARISATION SENSITIVE OPTICAL COHERENCE TOMOGRAPHY	1991	0.92	0.97
ACIST	1991	0.93	0.93
QUANTITAIVE LIGHT INDUCED FLUORESCENCE	1995	0.64	0.80
DIGITAL IMAGING FIBER OPTIC TRANSILLUMINATION	1998	0.69	0.89
LASER INDUCED FLUORESCENCE	1998	0.86	0.80
CAMBRA	2002	0.83	0.62
mRNA	**2010**	**0.94**	**0.83**
LDH	**2018**	**0.91**	**0.86**

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