Recent Trends in Caries Diagnosis

Priyatama Meshram, Vikas Meshram, Abhishek Soni, Praveen Sundarkar, Aparna Thombre, Vivek Thombre, Savita Ghom

1Reader, Department of Conservative Dentistry, Maitri Dental College and Research Institute, Durg, Chhattisgarh, India
2Reader, Department of Oral Surgery, New Horizon Dental College, Bilaspur, Chhattisgarh, India
3Reader, Department of Periodontia, Maitri Dental College and Research Institute, Durg, Chhattisgarh, India
4Professor, Department of Prosthodontia, Triveni Dental College, Bilaspur, Chhattisgarh, India
5Reader, Department of Pathology, VSPM Dental College, Nagpur, Maharashtra, India
6Lecturer, Department of Periodontia, Chhattisgarh Dental College, Rajnandgaon, Chhattisgarh, India
7Postgraduate Student, Department of Oral Medicine, Chhattisgarh Dental College, Rajnandgaon, Chhattisgarh, India

Correspondence: Priyatama Meshram, Reader, Department of Conservative Dentistry, Nirman Heritage, Onkar Nagar, Nagpur, Maharashtra, India, e-mail-drpriyatama_p@yahoo.co.in

ABSTRACT
To create opportunity for a preventive approach to the management of caries, it is important to keep abreast of developments in diagnostic systems. It is apparent that conventional methods for the detection of dental caries do not fulfill the criteria for an ideal caries detection method. These methods rely on subjective interpretation and are insensitive to early caries detection. To overcome these shortcomings, researchers are developing advanced techniques. These not only detect mineral loss but also quantify it.

Keywords: Digital radiography, Electrical resistance measurement, Diagnodent, Quantitative light-induced fluorescence (QLF).

INTRODUCTION
Dental caries is one of the most common diseases of the oral cavity affecting both child and adult. Management of caries and its complication is the crux of dentistry. Every year thousands of rupees are being spent on restorations. With advent of fluorides there has been a reduction in the prevalence and a change in the pattern of caries. A small initial lesion often progresses under an intact layer of surface enamel. Early carious lesions are reversible and can be arrested. Noninvasive intervention can convert a lesion from an active to an inactive state. Such small lesions are getting difficult to diagnose, precise diagnostic methods are the need of the hour.¹ ²

Caries diagnostic methods have been broadly divided into conventional methods and advanced techniques. The conventional methods include a visual method, sharp instrument (explorer, probe), separation of teeth and radiographs are not without their inherent shortcomings. To overcome these shortcomings, researchers are developing advanced techniques. These not only detect mineral loss but also quantify it.¹ This article focuses light on advance techniques for caries detection.

DIRECT DIGITAL RADIOGRAPHY
Radiovisiography (RVG) was developed by Dr Francis Mouyen in the year 1980. It has become common place in dentistry. It reduces the radiographic dose to the patient. Exchange of information is possible. It can be used for patient education. The images can be manipulated hence cannot be considered as legal proof. The sensor may deteriorate overtime. It is a costly instrument.³

ELECTRICAL CONDUCTANCE DETECTION METHOD (ECM)
The ECM monitors the electrical resistance behavior of a suspected carious spot. Although the idea of tooth as an electrical conductor was given by Magitot in as early as 1878, its application for caries diagnosis is credited to Pincus P. The principle is that the sound enamel is a poor conductor of electricity. It has very small pore size, in the order of 2 to 6 nm radii. Demineralization due to caries brings about large increase in the size of these pores. These join together to form conductive pathways when filled with the ions and minerals from saliva. Thus carious enamel has a higher conductivity than sound enamel.⁴

Detection of early carious lesion can be done which may respond to preventive interventions. It can aid in the detection of fissure caries in recently erupted molar teeth. It can predict the probability that a sealant restoration will be required within 18 to 24 months after eruption of the tooth. They have the potential to monitor lesion progression or arrest. It has low specificity. It is not a substitute for conventional and radiographic methods which are better predictors of invasive treatment needs.⁴

LASER LIGHT
The laser-based systems are in the forefront of the commercial systems being manufactured for the detection of caries.
Light emitted by the laser can have four different interactions with the target tissue depending on the optical properties of that tissue and wavelength used: Reflection, absorption, transmission and scattering. The primary and beneficial effect of the laser energy is the absorption of the laser light by the biologic tissue. Fluorescence occurs when light at one wavelength is absorbed by the tissue (excitation wavelength) and emitted at a second longer wavelength (emission wavelength).\(^5\)

**Laser-induced Fluorescence: Diagnodent**

The Diagnodent (KaVo America, Lake Zurich, Ill.) is a portable, diode laser-based system developed from research by Hibst and Gall, 1998. The Diagnodent clearly is more sensitive than traditional diagnostic methods. It uses red light of wavelength 655 nm. When tooth is illuminated with this light, it fluoresces in the infrared range. A demineralized area appears to fluorescence brightly. A photodiode measures the amount of fluorescent light passing through the filter. A control unit displays the digital representation of the wavelength detected. The signal comes out as a number on the instrument on a scale of 0 to 99. Higher the number, more the caries below dentin.\(^5,^7\)

The device performs best on smooth surfaces and in occlusal pits and fissures. It eliminates potential operator bias as a value for caries severity is displayed on a LCD panel without requiring further input from the operator. It has excellent reproducibility and accuracy. It is simple to use and a time-saving device.\(^6\)

Occlusal and interproximal surfaces need to be clean and dry as they may give false diagnosis. It fails to distinguish clearly between superficial and deep dentinal caries. It can only be used as a second opinion or diagnostic adjunct because of the increased likelihood of false-positive diagnoses compared with that visual methods. It is unable to detect failures around the margins of fissure sealants, caries below translucent fissure sealants and different patterns of caries progression.\(^7\)

**VISIBLE LIGHT**

The caries lesion can be examined by shining white light through the tooth. The wavelengths are in the visible range of the electromagnetic spectra (400-700 nm).\(^8\)

**Quantitative Light-induced Fluorescence**

The quantitative light-induced fluorescence (QLF) is based on the principle that the autofluorescence of the tooth alters as the mineral content of the dental hard tissue changes. Increased porosity due to a subsurface enamel lesion scatters the light either as it enters the tooth or as the fluorescence is emitted, resulting in a loss of its natural fluorescence.\(^8\) The changes in enamel fluorescence can be detected and measured when the tooth is illuminated by violet-blue light (wavelengths 290-450 nm, average 380 nm) from a camera hand piece, followed by image capturing using a camera fitted with a yellow 520 nm high pass filter. The image is captured, saved and processed; it is first converted to black and white, so that thereafter the lesion site can be reconstructed by interpolating the grey level values in the sound enamel around the lesion. These can be stored measured and quantified in terms of shape and area. To enable calculation of fluorescence radiance in carious lesion, the fluorescence radiance of sound tissue at the lesion site is reconstructed by interpolation from the fluorescence radiance of the sound tissue surrounding the lesion and the difference between the actual values and the reconstructed ones give the resulting fluorescence loss.\(^9\)

It is a sensitive and reproducible method for quantification of enamel lesion to a depth of about 400 nm. It is appropriate for *in vivo* monitoring of mineral changes in incipient enamel lesions. It is useful for evaluation of preventive measures in caries-susceptible individuals, such as orthodontic patients.\(^9\)

It is limited to enamel lesions. It cannot differentiate between decay, hypoplasia or unusual anatomic lesions. It has the potential for operator bias as it relies upon a subjective analysis of a stored tooth image.\(^9\)

**Digital Fiberoptic Transillumination (DIFOTI) System**

The digital fiberoptic transillumination technique is an improvement over the FOTI. It was developed by Schneiderman et al, 1997. It utilises the principle of scattering of light. The tooth is illuminated by a fiberoptic handpiece. Images of the tooth are acquired by a digital CCD camera and sent to a computer for analysis. *In vitro* studies by Schneiderman et al, 1997 suggested superior sensitivity for detection of approximal, occlusal and smooth surface caries vis-à-vis radiological imaging. Decrease intraobserver and interobserver variation. It can indicate the presence of incipient and recurring caries even when radiological images fail to show their presence. It may be used to monitor lesions over time. It provides lesion location but not depth. It cannot be used to detect caries in the subgingival area. It cannot image teeth completely covered by restoration.\(^10\)

**NEAR INFRARED LIGHT SYSTEMS**

This is a promising technique for detecting the presence of caries and measuring its severity. It uses longer wavelengths (780-1550 nm) of the electromagnetic spectra. Identification of caries by transillumination is based on the fact that increased mineral loss in an enamel lesion leads to a twofold increase in scattering coefficient at a wavelength of 1.3 nm. The decreased light transmission associated with the lesion can be detected when compared to that of the surrounding sound tissue. Following systems used near infrared light.\(^1\)

**Multiphoton Imaging**

For multiphoton imaging of teeth infrared light (\(\lambda = 850\) nm) has been used. It is able to collect information from carious lesions up to 500 microns in depth. In the multiphoton technique, two infrared photons are absorbed simultaneously. The choice of a longer wavelength of light for imaging reduces the
scattering, allowing the light to penetrate more deeply within the tooth. This may make any image of the tooth clearer and reduces the levels of phototoxicity. The probability of this happening is normally low, but by exposing the tooth to many more photons, it is possible to increase greatly the chances of two-photon absorption (the probability of two-photon absorption is proportional to the square of the light intensity). Generally, this means increasing the intensity of the light beam, which is also likely to generate heat within the tooth. To protect the pulp, high-intensity light is used for ultra-short pulses, measured in femto seconds (fs), (~100 fs = 100 × 10⁻¹⁵ s) of laser light. This produces adequate peak laser power but low average power, to increase the chances of a two-photon event. Even with such high peak powers, the fluorescence is generated only in the focal plane, and hence one has a method of optically sectioning entire samples. With this technique, sound tooth tissue fluoresces strongly, whereas carious tooth tissue fluoresces to a much lesser extent.1,11

It is a noninvasive method of acquisition of a quantifiable measurement of mineral loss, as function of fluorescence loss, from a caries lesion in three dimensions. There is low risk of phototoxicity to the pulp, and the longer incident wavelength results in enhanced depth penetration. The technique has been performed only on extracted teeth. The large and complex laser equipment required to produce such an image will require many years to develop into a clinically usable form.11

Optical Coherence Tomography

Optical coherence tomography (OCT) is a method of imaging transparent and semitransparent structures. Teeth fall into the latter category. It is based upon the interference of light. When a light beam is split into two and then recombined, interference produces a pattern, the intensity of which is determined by the level of light in each beam. Most OCT techniques described for imaging dental tissues have used wavelengths of 840 to 1310 nm. This has resulted in imaging depths of 0.6 to 2.0 mm. It can detect morphological changes of the tooth surface structure during tooth demineralization. It can determine lesion depth. It can be used for noninvasive diagnosis of secondary caries. As with all optical methods, it is likely that uptake of any stain will confound the technique. No in vivo data have been reported.12

Raman Spectroscopy

Raman spectroscopy is a form of vibrational spectroscopy. It provides biochemical characterization of hydroxypatite [Ca₁₀(PO₄)₆(OH)₂], the major mineral component of tooth enamel, i.e. biochemical confirmation of caries. It quantifies caries severity. Differences in the morphology of sound and carious enamel rod causes shift of Raman peaks of PO vibrations. This is due to loss of enamel crystalline orientation, i.e. induced structural changes during the caries formation process. Recent technological improvements in NIR laser sources and the detector response in the NIR wavelength region also helped the advancement of biomedical Raman spectroscopy. By simply directing an optical fiber at a tooth, a trained professional can analyze how the light responds and determine if cavity-causing bacteria are present. Bacteria respond to light in a particular manner, so scientists see exactly where they are destroying a tooth. At this stage, demineralization, preventive measures could stop a cavity from forming and eliminate the need for a dental filling.13,14

Raman spectroscopic studies have been limited to enamel which contains only a few percents of organic material. Furthermore, the complexity and cumbersomeness of most Raman spectrometers are responsible for their unpopularity. The potential of the Raman technique, including the micro-Raman technique, has not been fully explored.13,14

Infrared Thermography

Technique of infrared thermograph has been described by Kaneko in 1999. It determines lesion activity rather than determining the presence or absence of a lesion. Thermal radiation energy travels in the form of waves. It is possible to measure changes in thermal energy when fluid is lost from a lesion by evaporation. The thermal energy emitted by sound tooth structure is compared with that emitted by carious tooth structure.15

There is variation in the temperature of the oral cavity with respiration or fluid evaporation from other oral surface. Staining of the lesion also affect the heat transfer between the sound and carious tooth structure. This technique has not been used intraorally.15

ULTRASOUND

This method utilizes a sonar device in which a beam of ultrasound wave is directed against the tooth surface and if reflected is picked up by an appropriate receiver. It is more sensitive than visual-tactile method. It can be used readily for easily accessible area. It cannot be use for interproximal surfaces and in vivo cases.16

TERAHERTZ IMAGING

This method of imaging uses waves with terahertz frequency (10¹² Hz or a wavelength of approximately 30 μm). Low powers (>1 μW) are used for imaging because of the relative transparency of human tissue to terahertz rays. It uses non-ionizing radiation. Terahertz waves are strongly absorbed by water so a potential complication in the mouth can occur. The instruments are costly and it requires precise specimen management. Dental applications for this technique have been limited but promising.17

MAGNETIC RESONANCE MICROIMAGING (MRM)

MRM is noninvasive and nondestructive technique. Teeth examined with MRM do not suffer the sectioning artefacts that can occur during conventional histologic examination. It is a refinement of the whole body MRI and a development of nuclear magnetic resonance (NMR). This technique uses a moderate
magnetic field in much the same way as MRI. It has the capability for producing high resolution three-dimensional images of internal and external tooth morphologies of teeth. Carious lesion appears as intense three-dimensional features with internal structure when both spin echo and gradient echo pulse sequences are used to acquire images. The extent of carious lesion and its relation to other tooth structures can be seen. MRM will provide information not available through other methods of investigation, on the site, extent, structure of carious lesion. This technology is not available for clinical application.18

CONCLUSION
The shortcomings of conventional caries detection methods and the need for supplementary methods have long been acknowledged. Complementing traditional diagnostic methods with advanced, more sensitive methods will improve caries diagnostic routines and hence the dental care and treatment of patients. Few of these systems are in their infancy and many are based solely in laboratories. However, such technologies may prove useful in the future.

REFERENCES