Review Article

NOVEL DENTAL CARIES DIAGNOSTICS: AN OVERVIEW

Manu Batra,[1] Pradeep Tangade, [2] Himanshu Punia, [3] Vipul Gupta [4]
Senior Lecturer, [1]Professor & Head,[2] Senior Lecturer, [3] Senior Lecturer, [4]
1,3,4. Department of Public Health Dentistry, Teerthanker Mahaveer Dental College & Research Center, Moradabad.
2. Department of Public Health Dentistry, Kothiwal Dental College & Research Center, Moradabad.

Abstract

Recent years have seen an increase in research activity surrounding diagnostic methods, particularly in the assessment of early caries lesions. The drive for this has come from two disparate directions. The first is from the dentifrice industry that are keen to develop techniques that would permit caries clinical trials (CCTs) to be reduced in duration and subject numbers to permit the investigation of novel new anti-caries actives. The second is from clinicians who, armed with the therapies to remineralise early lesions are now seeking methods to reliably detect such demineralised areas and implement true preventative dentistry. This review examines novel technologies and the research supporting their use. Techniques based on photo thermal radiometry, thermography, terahertz imaging and some emerging technologies are discussed.

Key Words: - Dental Caries, Diagnosis

Introduction

Dental caries is an irreversible microbial disease of calcified tissues, of the teeth, characterized by demineralization of the inorganic portion and destruction of organic substance of tooth, which often leads to cavitation. It is complex and dynamic process where a multiple of factors influence and initiate the progress of disease.[1]

The word diagnosis (plural, diagnoses) is derived from the Greek ‘‘dia’’ meaning ‘‘through’’ and ‘‘gnosis’’ meaning ‘‘knowledge’’. Thus, ‘‘to diagnose’’ implies that it is only through knowledge about the disease that a diagnosis can be established. Diagnosis can be a complicated process.[2]
In dentistry the terms caries diagnosis and caries detection are very often used incorrectly and interchangeably. This usage is possibly due to the fact that the earlier stages of the disease process are virtually symptom-free, giving the perception by many, in the restorative dominated strategies of the past that a diagnostic step is not needed.

Caries diagnosis has changed from an exercise in detection of manifest caries, to be treated restoratively, towards identification of the early lesion and staging of the lesion, as a part of caries assessment and diagnosis for the individual patient.[3]

Caries diagnostic methods have transformed from the conventional techniques i.e. the visual, tactile, combination of the two and radiography. Several methods have been evolved for better caries diagnosis. Some of the newer methods have been discussed here.

Frequency-Domain Laser Infrared Photo-thermal Radiometry (PTR)

The approach consists of a combined dynamic (i.e. non-static, steady-state signal level) dental depth profilometric inspection technique, which can provide simultaneous measurements of intensity-modulated frequency-domain PTR (FD-PTR) and luminescence (FD-LUM) signals from defects in teeth.

FD-PTR is an evolving technology and has been applied, among other areas, to the non-destructive evaluation of subsurface features in opaque materials. It has shown promise in the study of excited-state dynamics in optically active solid-state (laser) materials.

The technique is based on the modulated thermal infrared (black-body or Planck radiation) response of a medium, resulting from radiation absorption and non-radiative energy conversion followed by temperature rise (in the case of dental interrogation, less than 1 ° C). The generated signals carry subsurface information in the form of a temperature depth integral. Thus, PTR has the ability to penetrate, and yield information about, an opaque medium well beyond the range of optical imaging. Specifically, the frequency dependence of the penetration depth of thermal waves makes it possible to perform depth profiling of materials.

In PTR applications to turbid media, such as hard dental tissue, depth information is obtained following optical-to-thermal energy conversion and transport of the incident laser power in two distinct modes: conductively, from a near-surface distance controlled by the thermal diffusivity of enamel (50–500 Ì m); and radiatively, through blackbody emissions from considerably deeper regions commensurate with the optical penetration of the diffusely scattered laser-induced optical field (several millimetres).

Under 488-nm laser excitation and frequencies in the range of 10 Hz to 10 kHz, it was found that PTR images are complementary to LUM images as a direct result of the complementary nature of non-radiative and radiative de-excitation processes, which are responsible for the PTR and LUM signal generation, respectively, at that wavelength.

It was also concluded qualitatively that radiometric images are depth profilometric (meaning they yield depth-dependent information as a function of the laser-beam modulation frequency), but no definitive conclusions regarding the depth profilometric character of LUM were reached. Finally, LUM frequency responses from enamel and hydroxyapatite were found to exhibit two relaxation lifetimes, the longer of which (ms) is a benchmark hydroxyapatite relaxation lifetime common to all teeth and is not sensitive to the defect state or the overall quality of the enamel. A degree of sensitivity to enamel quality was established for the shorter (µs) lifetime.[4]

Infrared Thermography

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.

The method uses indium/antimony thermal sensors, which can detect temperature changes in the order of 0.025°C. With a constant flow of air over the surface of the tooth, the change in temperature of the lesion is compared with that of the surrounding sound tooth structure.

The source-to-sensor distance is 20 cm, and the time taken to capture the data for a lesion is up to 2 min.

The technique has not been used intra-orally. Problems will exist in relation to variations in the temperature of the mouth with respiration or fluid evaporation from other oral surfaces. The source-to-specimen distance is presently unsuitable for posterior teeth. Accessible smooth surface lesions have been used in vitro, but there are no data on lesions which cannot be directly accessed. Additionally, the issue of lesion staining may also affect the heat transfer between the sound and carious tooth structure. To the authors' knowledge, there is no evidence that the rate, or pattern, of fluid loss from a lesion is directly related to the subsequent reactivity of a lesion in vivo or in vitro.[5]

Tera-Hertz Imaging

This method of imaging uses waves with terahertz frequency (= 1012 Hz or a wavelength of approximately 30 µm). This wave-form is short enough to provide reasonable resolution but long enough to prevent serious loss of signal due to scattering.

In the early 1980s, it was discovered that photoconductive emitters or certain crystals (e.g., zinc-telluride) exposed to short pulses (< 10-12 s) of visible or infrared light would emit electromagnetic waves with a frequency in the terahertz range. To detect terahertz irradiation, photoconductive detectors can be used in addition to a technique called "free-space electro-optical sampling" (EOS).

For an image to be obtained by tetrahertz irradiation, the object is placed in the path of tetrahertz beam. Alternatively, tetrahertz beam can be scanned over the surface of an object. It is also possible to record tetra-hertz images using CCD detector.
Dental applications for this technique have been limited but promising. A longitudinally hemi sectioned sound human premolar tooth has been imaged from the intact surface. Images have demonstrated the outline of the enamel-dentin junction as well as the dentin-pulp interface. Longitudinal sections through 3 teeth have demonstrated increased terahertz absorption by early occlusal caries and, intriguingly, an apparent ability to discriminate dental caries from idiopathic enamel hypomineralization. Work is in progress to image intact teeth with early caries lesions.[5]

Trans-illumination with Near-Infrared Light

The caries lesion may also be examined by shining white light through the tooth. Wavelengths in the visible range (400–700 nm) are limited by strong light scattering, making it difficult to image through more than 1mm or 2mm of tooth structure.

Method that use longer wavelengths, such as in the NIR spectra (780 to 1550 nm), can penetrate the tissue more deeply. This deeper penetration is crucial for the trans illumination (TI) method. Research has shown that enamel is highly transparent in the NIR range (750nm to 1500 nm) due to the weak scattering and absorption in dental hard tissue at these wavelengths.

Therefore, this region of the electromagnetic spectrum is ideally suited to the development of new optical diagnostic tools based on TI. Figure illustrates the typical experimental set-up of a TI system with an NIR light source, an imaging camera such as a charge-coupled device (CCD), and software for computer controlled acquisition. The image can be captured, saved, and stored in digital format.

This is a promising imaging technique for detecting the presence of caries and measuring its severity. The TI image is presented as a visually recognizable image, which is preferred by the average clinician. The method is non-destructive, non-ionizing and more sensitive to detect early demineralisation than dental X-rays.

Identification of dental caries by TI 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 µm. Caries thus appear as dark regions, since less light reaches the detector. Most research to date has used this wavelength, where low-cost light sources are available. When light illuminates the tooth the strong scattering effect in the enamel caries lesion results in less transparency. The decreased light transmission associated with the lesion can be detected when compared to that of the surrounding sound tissue.[6]

Thermal Imaging

Continuous evaporation of water accumulated inside the pores produces a thermodynamic transient on the tooth surface that will last until a new thermal equilibrium is reached when the tooth dries. The temporal profile of the temperature will depend on the amount of water stored inside the lesion as well as the shape of the lesion and can therefore contain information related to its degree of porosity and severity. Thermal imaging for caries' detection has been little explored in the past.

Their method relies on sensing the temperature time-decay due to water evaporation from the tooth surface as it is dried by an air-jet. The technique appears promising for the detection of pit and fissure caries up to 5 mm below the surface. It is less appropriate for imaging. Although thermography has shown to be useful in the evaluation of smooth surface caries, no evidence is found of such evaluation at occlusal surfaces.[7]

Polarized Micro-Raman Confocal Spectroscopy

Based on changes in Raman spectra were observed in $PO4^{-3}$ vibrations arising from hydroxyapatite of mineralized tooth tissue. Examination of various intensities of the $PO4^{-3}$ vibrations (431 cm, 590 cm, 1043 cm) showed consistent increase intensities spectra of carious lesions compared to sound enamel.

The spectral changes are attributed to demineralization-induced alterations of enamel crystallite morphology and/or orientation. This hypothesis is supported by reduced Raman polarization anisotropy derived from polarized Raman spectra of carious lesions. Earlier polarized Raman spectroscopy was used to study the orientation of tooth enamel rods. The majority of enamel rods have one orientation in a tooth and this orientation could be changed in the carried regions.

Examining tooth surfaces under polarized Raman microscopy, the carious lesion appears like a weak yellow region deep in the enamel. The carious lesion is deep subsurface at enamel-dentin interface and not easily observed.[8]

Cone Beam Computed Tomography (Cbct)

CBCT offers an alternative to conventional intraoral and panoramic imaging that circumvents he superimposition and distortion problems. At a significantly lower cost compared to conventional medical CT and utilizing a radiation exposure comparable with other dental radiographic modalities, CBCT provides a true 3-D imaging of the orofacial structures.

Although its utilization in dentistry focuses mostly on implant, orthodontic and TMJ evaluation, CBCT technology has potential advantages in common dental disease diagnosis. During the last decade, an increasing number of CBCT systems have become available. CBCT units can be classified according to the imaged volume or field of view, FOV, as large FOV (6 inch to 12 inch or 15 to 30.5 cm) or limited FOV systems (1.6 inch to 3.1 inch or 4 to 8 cm). In general, the greater the FOV the more extensive the anatomic area imaged, the higher the radiation exposure to the patient, and the lower the resolution of the resultant images.

CBCT is reported to more accurately assess proximal caries depth compared to film or storage phosphor periapical radiographs. Although these and similar reports outline the potential benefit of CBCT technology in caries detection, they are performed in well-controlled experimental settings that do not reflect the reality of everyday dental practice. Beam hardening artifacts are frequent in the imaging of dental structures and particularly tooth crowns. Such artifacts originate from metallic restorations, implants, endodontic restorative material, or other dense objects and create distortion of structures, streaks of bright and dark bands and noisy projection reconstructions that project over adjacent teeth and render diagnosis difficult or unfeasible.[9]

Optical Coherence Tomography (Oct)

OCT is an imaging technology that is capable of providing high-resolution (10–30µm) morphologic depth images. It is similar in operation to ultrasound imaging, but uses light waves rather than sound waves. This technique provides image resolution that is an order of magnitude higher than that obtained by ultrasound imaging. However, where ultrasound is well suited for imaging deep-tissue structures, such as a fetus within a pregnant mother, OCT can only image the first several millimeters of tissues (2–4 mm, depending on the wavelength of light used). Thus, OCT is better suited for imaging near surface structures.

The technique is based on coherent back-scattered light. Briefly, an OCT system contains a Michelson interferometer that splits a light beam into 2 paths, bouncing the beams off 2 mirrors (1 fixed, 1 moving) then recombining the beams. The interference pattern created by the reflected beams generates a depth profile at a single point along the laser trajectory. This point is known as an A-scan. As the laser is moved across the surface laterally, adjacent A-scans are assembled to produce a 2-dimensional depth image, also known as a B-scan.[10]

Multimodal Imaging System

In order to detect dental decay with high sensitivity and specificity, there is a multimodal imaging system with the combination of reflectance, fluorescence, and OCT imaging. Fluorescence and OCT images are distinct and complementary, with fluorescence providing information about biochemical composition and OCT information about tooth structural information.

With the help of reflectance imaging, calculus, stain, and amalgam can be clearly shown. Thus, the combination of reflectance, fluorescence, and OCT imaging modalities may enable higher sensitivity and specificity for dental caries detection than any single modality alone.

In order to remove specular reflection, the polarized illumination method is applied in this system. A polarization beam splitter (PBS) is used as a polarizer to condition the illumination light so that linearly polarized light illuminates the tooth surface. After the light reflects and scatters back from the tooth, the polarization beam splitter works as an analyser to block the light with the same polarization state as the illumination beam, but transmits the light with the orthogonal polarization state to the sensor. Also, in order to block the blue excitation light, a long pass filter (LP) is placed in the optical path before the sensor. This filter should have a sharp cut-off edge and very good extinction to block the blue excitation light while transmitting visible light, so that the system can capture visible reflectance images without having to move the LP filter out of the optical path.

In order to integrate with an OCT imaging system, another dichroic mirror is used to direct the light from the OCT subsystem to the tooth surface. As shown in Figure 1, the dichroic mirror reflects the infrared light from the OCT subsystem and transmits visible light from the area imaging subsystem. The OCT subsystem can be a time-domain or Fourier-domain system.

This multimodal imaging system has the advantage that the user can screen the tooth with visible illumination light to obtain a visible reflectance image, just as a conventional intra-oral camera, or screen the tooth with blue excitation light to view the fluorescence image. With the white light reflectance image and the fluorescence image, and possibly with further image processing, the user can identify the healthy, carious, and suspicious regions. Once the carious and suspicious regions are located, OCT imaging can then be used to scan those regions. For carious regions, OCT images can provide more detailed information, such as decay depth, size, and boundary. For suspicious regions, OCT images can verify whether the regions are indeed carious lesions, and if so, how deep the lesions are. All three images, reflectance, fluorescence, and OCT, can be saved for progression monitoring.[11]

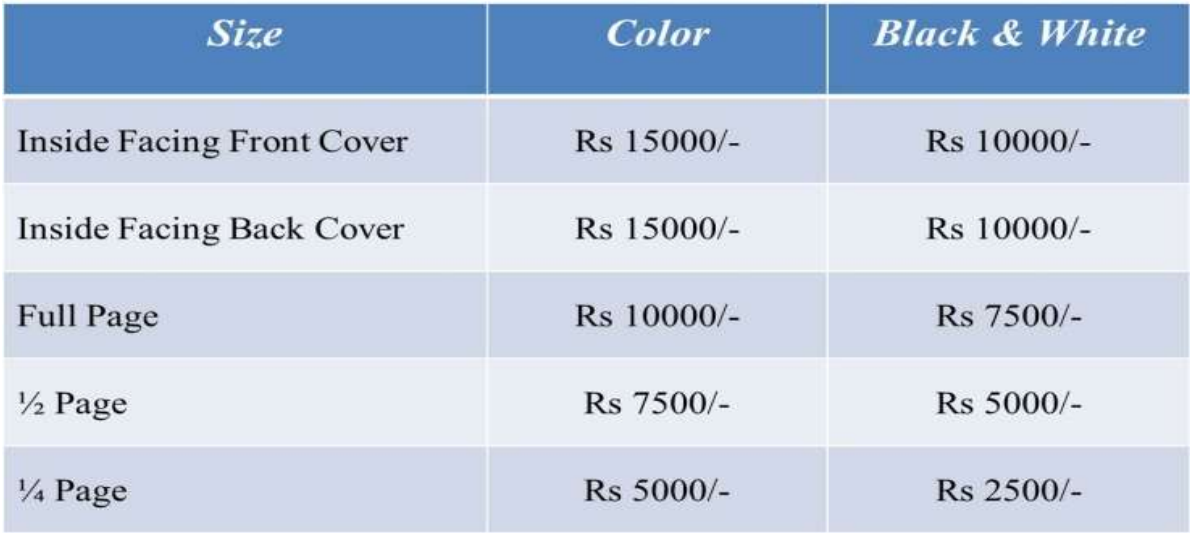
References

1. Sivapathasundharam B, Gururaj N. Shafer's textbook of Oral Pathology 5th edition.
2. Fejerskov O, Kidd EA. Dental Caries: The Disease and Its Clinical Management.Blackwell Munksgaard publication 1st edition.
3. Baelum V, Heidmann J, Nyvad B. Dental caries paradigms in diagnosis and diagnostic research. Eur J Oral Sci. 2006; 114: 263–277.
4. Jeon RJ, Han C, Mandelis A, Sanchez V, Abrams SH. Diagnosis of pit and fissure caries using frequency-domain infrared photothermal radiometry and modulated laser luminescence. Caries Res. 2004; 38(6):497-513.
5. Hall A, Girkin JM. A Review of Potential New Diagnostic Modalities for Caries Lesions. J Dent Res. 2004; 83 Spec No C: C89-94.
6. Karlsson L. Caries Detection Methods Based on Changes in Optical Properties between Healthy and Carious Tissue. Int J Dent. 2010; 2010: 270729. Doi:10.1155/2010/270729
7. Zakian CM, Taylor AM, Ellwood RP, Pretty IA. Occlusal caries detection by using thermal imaging. J Dent. 2010;38(10):788-95.
8. Ionita I. Diagnosis of tooth decay using polarized micro-raman confocal spectroscopy. Romanian Reports in Physics 2009;61(3):567–574.
9. Tetradis S, Anstey P, Graff-Radford S. Cone Beam Computed Tomography in the Diagnosis of Dental Disease. J Calif Dent Assoc 2010;38(1):27-32.
10. Choo-Smith LP, Dong CCS, Cleghorn B, Hewko M. Shedding new light on early caries detection. J Can Dent Assoc 2008;74(10):913-918.
11. Liang R, Wong V, Marcus M, Burns P, McLaughlin P. Multimodal imaging system for dental caries detection. Progress in Biomedical optics and Imaging 2007;8(2):1-7.

Corresponding Address: -

Dr.Manu Batra
Senior Lecturer
Department of Public Health Dentistry
Teerthanker Mahaveer Dental College & Research Center,
Moradabad.
Email Id: - drmanubatra@aol.com

Inviting Ads and the expected Tariff is: -



Size	Color	Black & White
Inside Facing Front Cover	Rs 15000/-	Rs 10000/-
Inside Facing Back Cover	Rs 15000/-	Rs 10000/-
Full Page	Rs 10000/-	Rs 7500/-
½ Page	Rs 7500/-	Rs 5000/-
¼ Page	Rs 5000/-	Rs 2500/-