

OPTIC COHERENCE TOMOGRAPHY- A review

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ABSTRACT:

OCT, a type of optical imaging non-invasive technique , reproducing the cross sectional 2D and 3D images of the tissues. It's based on low coherence interferometry, employs near infrared light (long wavelength) which penetrates into the scattering media (e.g.: oral tissues) and capture sub-micrometer resolution. Already an established medical imaging technique, it can be used for a wide range in dentistry for early detection of oral cancer (initial dysplastic changes), periodontal diseases, including dental caries. This paper reviews the understanding of the OCT, its basics, systems & setup, uses, limitations with the focus of it as a diagnostic imaging tool for oral lesions.

KEYWORDS: Optical Coherence Tomography, cross-sectional images, diagnostic, oral tissues.

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INTRODUCTION:

OCT, based on interferometers is essentially a non invasive, non radiative, optical diagnostic method. It was first presented by FUJIMOTO et al in 1991 (1). Since the time of its inception it

has been clinically used in various fields like ophthalmology (2,3,4), dermatology (5,6,7), gastroenterology (8,9,10) and dentistry (11,12). OCT was first applied in retinal imaging as well as atherosclerotic plaque (1,13).

It uses near infrared light source with a low coherence broadband with a superior spatial resolution (~20 μm) , non invasive, sub-surface detection, showing the real time images.(14,15,16). Its uses low coherence or partial coherence source of light along with “time domain gating “ for obtaining the depth of the resolution.(b)

The distinguished advantages are:

- Real time imaging
- Sub surface resolution
- No radiation exposure
- No site preparation before taking image
- Incomparable spatial resolution

Thus OCT can be aptly be called as “OPTICAL BIOPSY” without any excision requirement in comparison to the conventional biopsy.(17)

USES

OCT has become a very well established and new technique in the field of diagnostics with an almost two decade of history and still ongoing accelerated and intensive research and continuous improvement in the modality. (18) At present its more than 50% of its marketing belongs to ophthalmology (19-28)with cardiovascular imaging being on the second place(29-36). Besides these two it holds a value in dermatology,(37-40) dental (41-52) developmental biology and endoscopic imaging (18).

Application of OCT in dental is becoming well known. The main aim of this paper is to review the application in Dentistry.

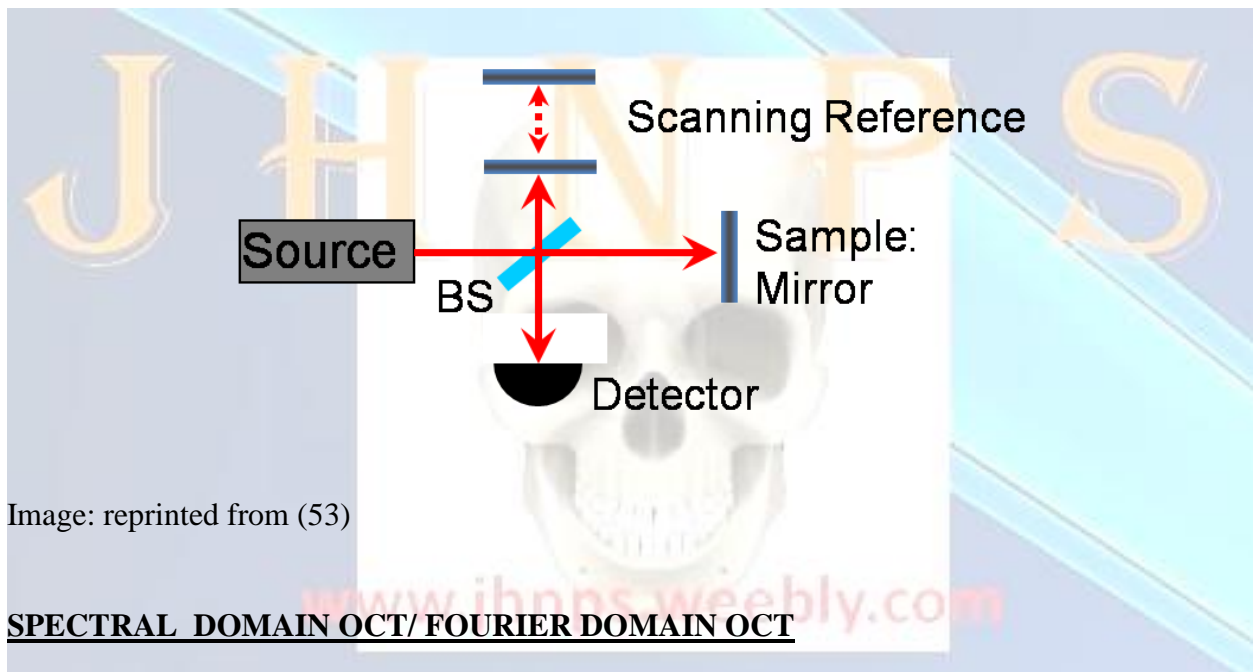
OCT SETUP AND ITS SYSTEMS SPECIFICATIONS

Based on the interferometer system OCT uses a low coherence length broadband light source.(17).The use of light source can range from super luminescent diodes , ultra short pulsed

lasers and super continuum lasers to obtain a sub micrometer resolution. (wikipedia) Light reflects from the reference arms and the sample within the interferometer. These interference signals are taken up by photodiode (PD) or charged coupled device (CCD). The method to acquire the signals differs in the different systems of OCT. (17)

TIME DOMAIN OCT

It moves the reference reflector to acquire various optical path lengths (OPL) (62). It uses Photo diode (PD) to acquire interference signals.



OPL here is determined by various different wavelengths (62) with no requirement of a moving reference arm .It have essentially same components with an added grating and CCD to acquire signals.

Spectral / Fourier Domain OCT

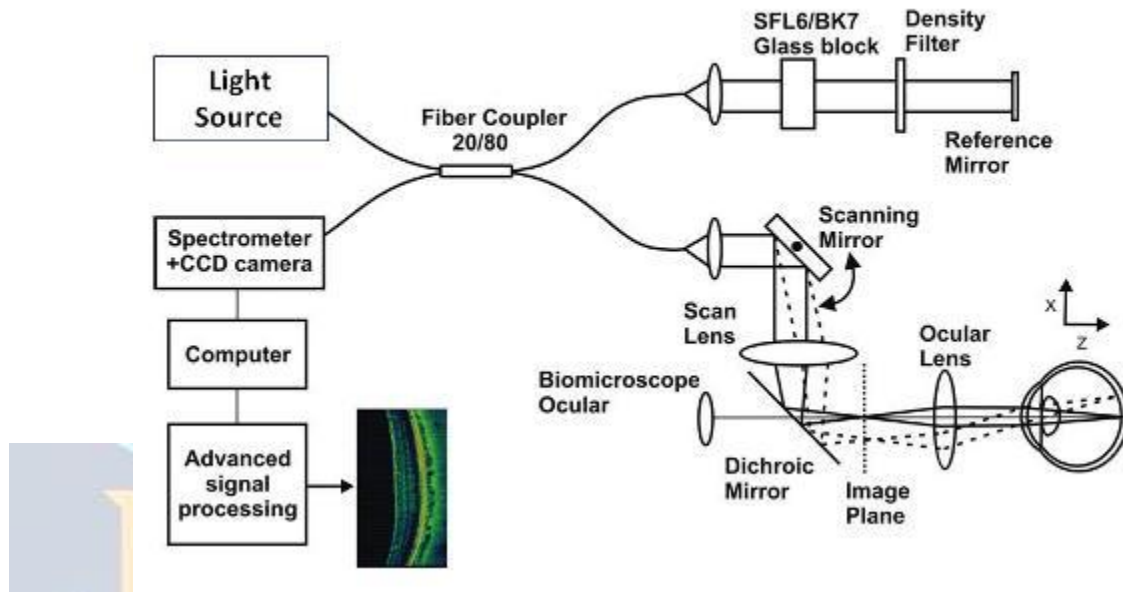


Image : reprinted from (64)

COMPARISION WITH OTHER DIAGNOSTIC SYSTEM IN DENTISTRY :

Oral cavity has three main part

- 1: hard tissue: tooth and bone,
- 2: soft tissue: oral mucosa and gingiva,
- 3: periodontal tissues (65).

Dental diagnosis was primarily restricted to probe exploration and X-rays. Both of the techniques are quite popular even with the drawbacks associated with them.

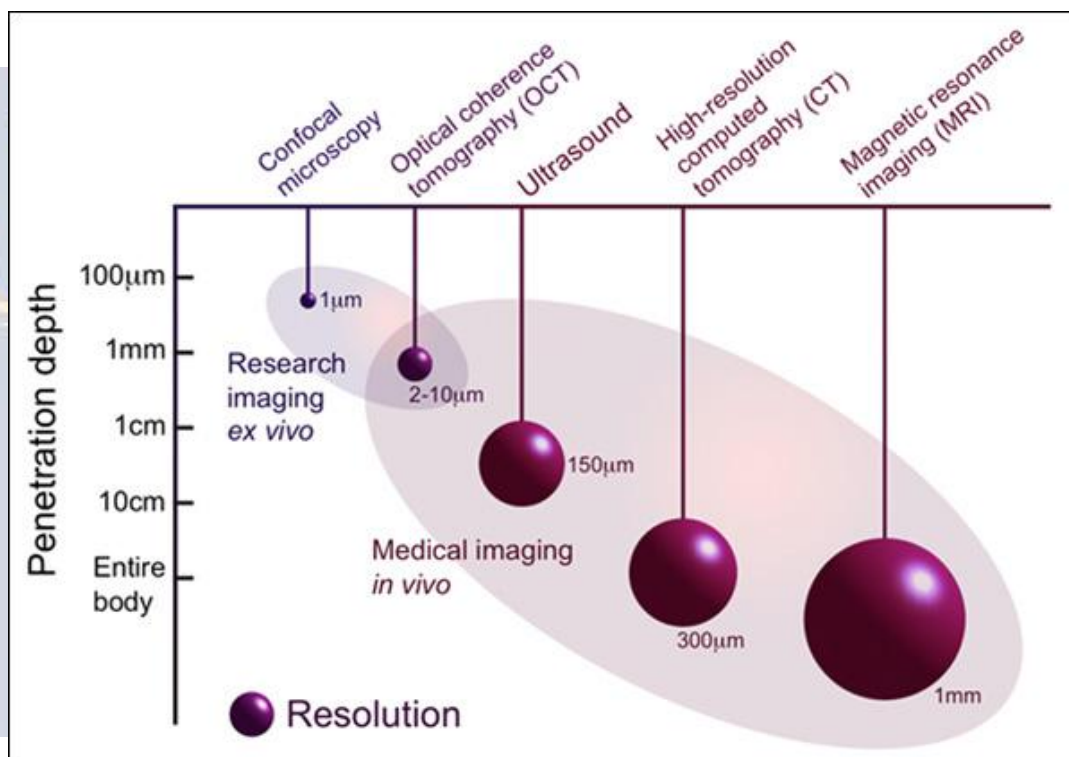
Periodontal probes in dental exploration have low sensitivity and reliability which limits the dentist to reevaluate and monitor progression of the disease progression and treatment prediction outcome.(66).

Though radiography is the “gold standard” in dental diagnostics it has limitations in imaging of resolution and contrast. The various types of hard tissues in the tooth do not show a great difference in the contrast and thus early demineralization is a major hurdle in diagnostics.

Traditional diagnostics is 50% less efficient as compared to the modern diagnostics. X-ray also

fails to aptly diagnose biting surface cavities as the photons attenuates and travels in a different direction and having a high possibility to miss it. As also X-rays are taken from the side of the tooth the orientation is not a highly accurate 2D reproduction of the 3D object.

Modern diagnostics has take the level of diagnosis to another level with the introduction of novel and advanced techniques like smart ultrasonic devices [66,67-69], LED-based dental optical probes [70], and laser fluorescence [71,72]. Raman and laser fluorescence spectrometers are under research for its scope of application in dentistry.



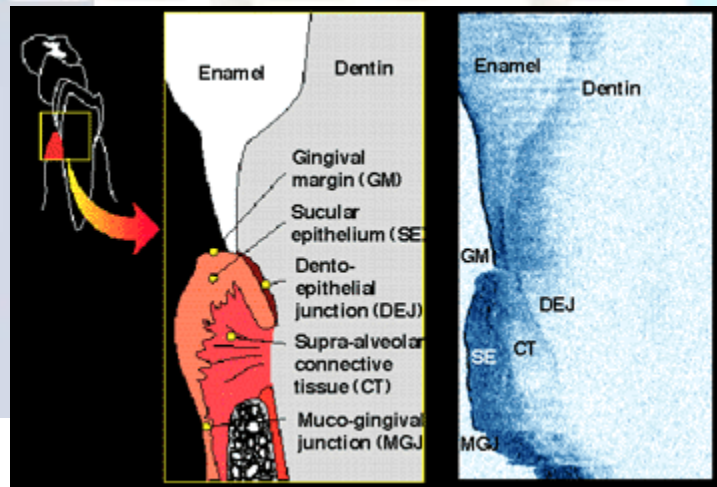
OCT USE IN DENTISTRY AND SCHEMATIC IMAGES

OCT is thus an, optical biopsy imaging tool which is non-invasive for detection of oral disease at an early stage. This paper throws a light on the detection of normal tooth structure, dental cavity, periodontal disease, secondary caries, micro leakage, plaque and calculus and even oral cancer and implant. The use of OCT in dentistry is further simplified with the introduction of handy dental probes where diagnosis can be done on the chair side. For best results in in-vivo imaging dental optical probe, data acquisition time and also the scanning range should be balanced well.



PICTORIAL REPRESENTATION OF OCT THE VARIOUS SECTIONS TAKEN IN ORAL CAVITY

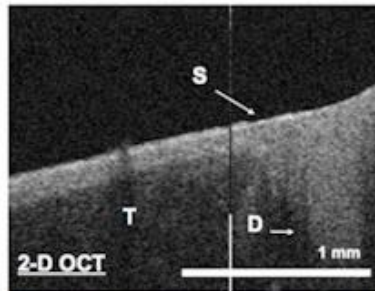
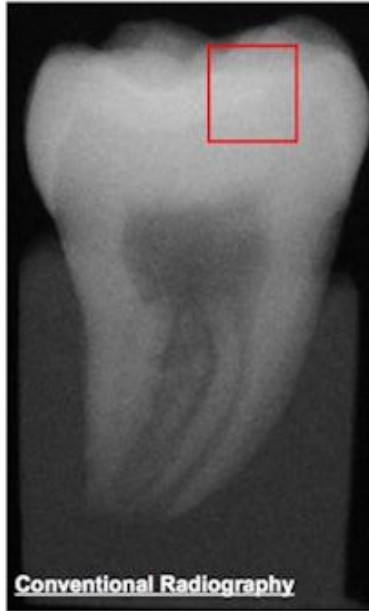
Normal tooth structure :



Reprinted from : Optical Engineering Laboratory, 2001(54)

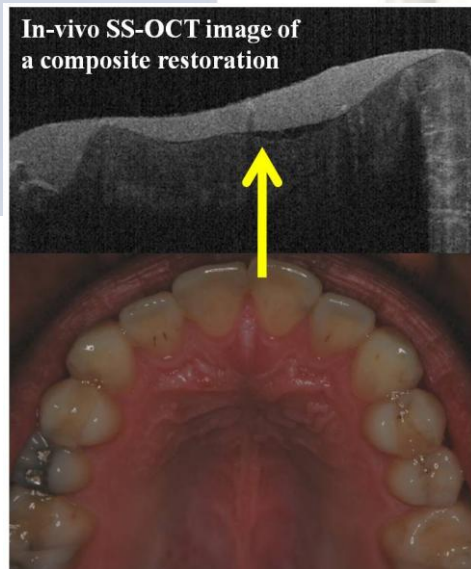
Dental Caries:

Tooth 14 – Lateral View



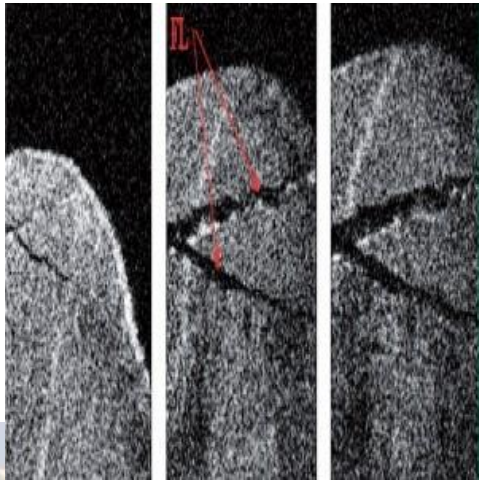
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Composite Restoration:



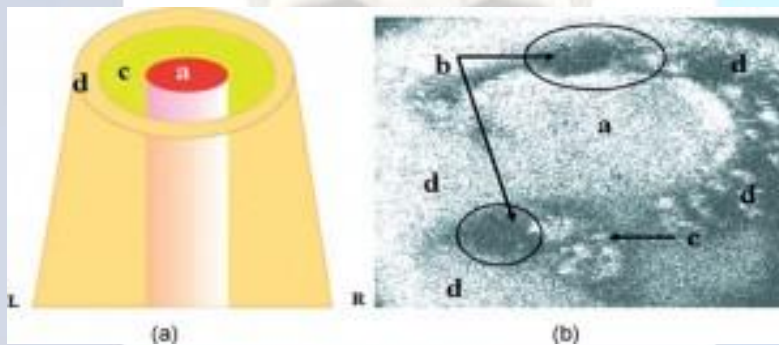
Reprinted from : Yushima, 2010 (56)

Fracture lines in tooth :



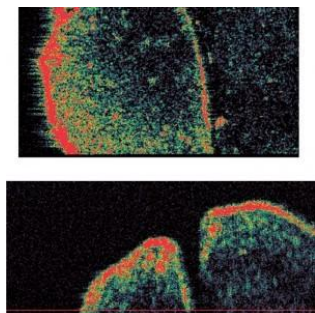
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Endodontics: Root canal fillings



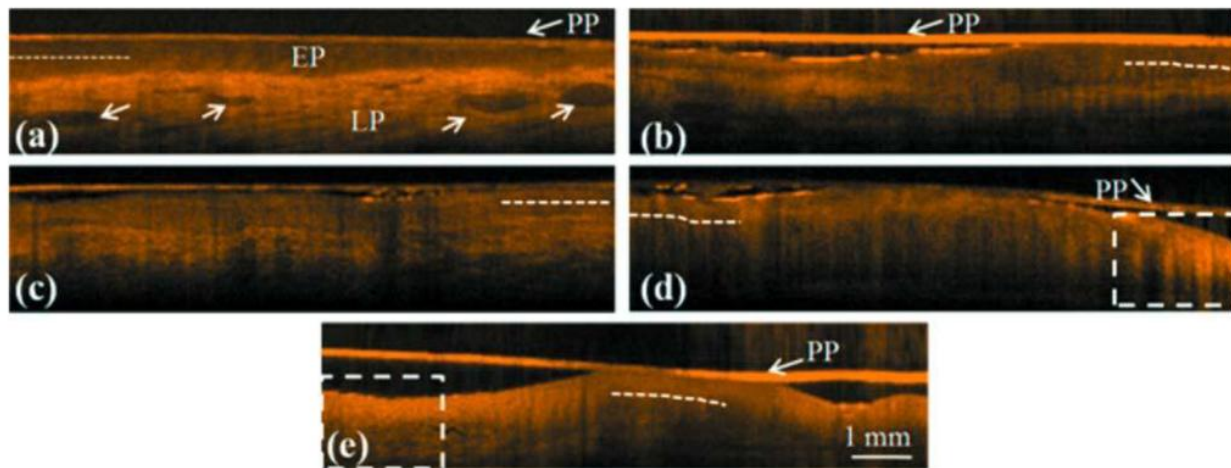
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Prosthodontics: Marginal adaptation of an empress veneer on the proximal area



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Oral Cancer :



SS-OCT scanned images of the (a) normal control and biopsied oral (b) MiD, (c) MoD, (d) ES-SCC, and (e) WD-SCC lesions. Their histological images were shown in Figure 13(a–e) (reprinted from reference (58))

DISCUSSION

The various advantages of OCT includes: Instant, direct imaging of tissues morphology, Live subsurface images at near microscopic resolution, No ionizing radiation used.

OCT is becoming very popular both in research as well as clinical applications. Along with early detection, obtaining real time images of the sample OCT also have the potential to monitor and compare the effect of various treatment modalities (18). Dental OT has also demonstrated a vast application in both the hard tissues and soft tissues non invasive real time imaging. Apart from the direct structural images obtained it can also give orientation of tissues, blood flow and also may be applied in bone related disease (with the use of longer wavelength)(17)

The various disadvantages of the OCT includes

1: “INADEQUATE SCANNING DEPTH” :

A whole lot number of pictures may be required for the whole lesion. This can be somewhat solved bt the use of an efficient dental probe as mentioned before. It can also be solved by use of a high quality light source for imaging.

2:WAVELENGTH CHOICE

It can be one of the most critical criteria in OCT performance in dental applications. Near infra red use of light gives an adequate penetration depth in tissue due to its scattering and absorption (17)

after 1000 nm , absorption effect increases with max at 1400 nm. The various factors like water in the tissue impairs the source energy. So it is highly crucial to employ different wavelength for different source.

3:DATA ACQUISITION TIME

It is another vital determinant. OCT acquisition of image is very fast but it somehow diminishes the image quality. So its crucial to obtain a balance between the two.

ADVANCEMENT

Eventually 3D-OCT have a promising future as the diagnostic tool of dentistry. IT owes this to its polarization sensitivity, resolution contrast and image orientation which favors the drawbacks of X-ray. In due course of time clinical fields will have several assorted techniques for a early and accurate diagnosis.

Recent advancement of lateral scan there can be a 2D and 3D images available. Since the time of its inception it has undergone various modification and the introduction of the Fourier domain (FD-OCT) has brought a big revolution to the industry.(18). Modern OCT uses broadband to be more specific giving a true 3D imaging with high speed data, real time diagnosis which is free from artifacts in the final image which initially resulted from motion (18) With these biomedical research further presented many functional OCT setups: Doppler OCT, (18) acoustic OCT(17), endoscopic OCT , polarization sensitive OCT (17). These have further advantages of producing not only real time image but also specifically can give blood flow velocity and tissue orientation promoting further efficiency in the diagnosis.

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