Optical Coherence Tomography (Oct) – An Insight Into Its Applications In Dentistry

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ABSTRACT

Optical Coherence Tomography (OCT) is an emerging assessment tool for detecting early caries, enamel cracks, defective restorations, oral precancers, gingival and periodontal diseases, and various other dental diseases. OCT is very much similar to ultrasound imaging except that it uses light instead of sound. OCT is a non-invasive, non-contact imaging technique that uses light waves to capture high-resolution, cross-sectional images of biological tissues. OCT can function as a type of optical biopsy and is a powerful imaging technology in medical and dental diagnosis. With its wide range of applications, OCT is worth considering for the future of dentistry. OCT is a promising technology that has the potential to revolutionize the way dentists diagnose and treat dental conditions. Further research can help OCT a part of the daily dental practice.

INTRODUCTION

Optical Coherence Tomography (OCT) is an emerging non-invasive, non-radiative, contactless optical diagnostic aid that uses a low-coherence broadband near-infrared light source to obtain real-time, high-resolutioncross-sectional images of the biological tissues (1). OCT finds its applications in various fields such as in analytical technology where they use in finding the quality and age of ceramics, paintings, and glass (1). OCT was first introduced in 1991 which visualised the internal microstructure of the eye using optical backscattering of the light source (2). OCT provides a digital image with 20 µm resolution and 1 to 3mm of tissue penetration depth. The first use of OCT in dentistry was done in 1998 by researchers from the Laboratory of Medical Technology of Livermore, California in collaboration with researchers from the University of Connecticut (2). The prototype designed by them demonstrated the possibility of visualising the gingival margin, periodontal pockets, and attachments and scanned both hard tissues to a depth of 3mm and soft tissues to a depth of 1.5mm (2).Fig: 1, 2,and 3 show the OCT system setup.

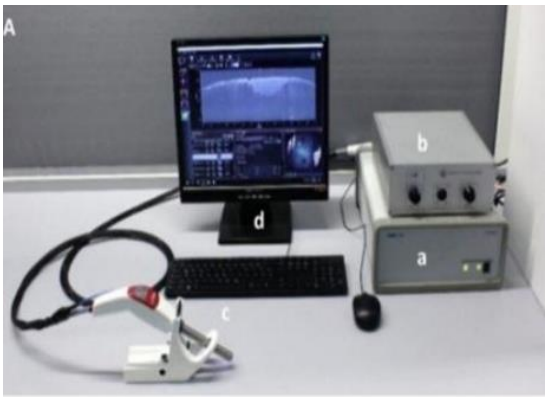


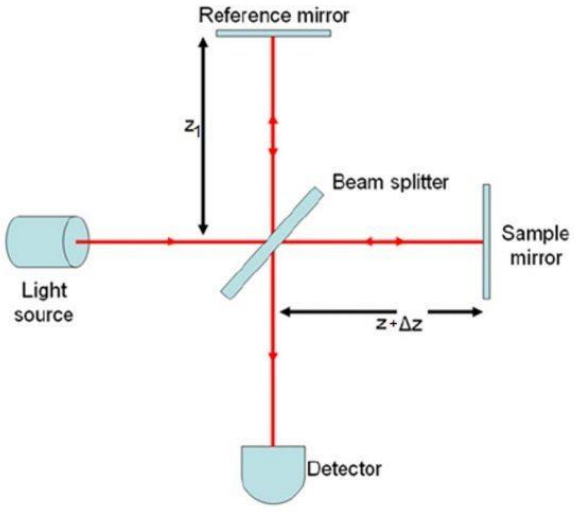
Figure 1: Photograph of an OCT system setup (a) Scanner controller (b) balance detector (c) OCT probe (d) computer

Figure 3: Examination of the oral cavity with OCT

WORKING PRINCIPLES OF OPTICAL COHERENCE TOMOGRAPHY

OCT is a modular device that consists of coupled software and hardware components. It consists of five basic modules which include a partially coherent light source, an imaging apparatus, a measurement head, a module for data processing and image generation along with a computer-controlled system (2).

An interferometersplits the broad spectral bandwidth light source into two,the reference beam and the probe beam, using a beam splitter (BS). The one used here is Michelson's interferometer (2). The reference beam along with a movable mirror (M1) constitutes the reference arm from where the light is reflected to the screen D (Detector). The second beam which is the probe beam along with the fixed mirror (M2) constitutes the sample arm, from where the light is reflectedin a perpendicular direction and falls on the detector (2). The OCT scanner, scans each sample point with the reference arm, thus providing a complete profile depth of the sample reflectivity which is given as an amplitude scan (A-scan). The cross-sectional images are created by using the sagittal scan (B scan) and the lateral scan (C scan). Thus, by the combination of measurements of the probe beam, a two-dimensional image of the sample is formed (2). The focal length of the objective lens which is present within the handheld probe is 50mm. The probe could work either in contact or noncontact mode by adjusting the lens tube to visualize the lingual sides of teeth and buccal sides of the posterior tooth a mirror is mounted at 45 – degrees (2).



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DISCUSSION:

APPLICATIONS IN MEDICINE:

OCT plays a pivotal role in ophthalmology to precisely analyse the choroidal thickness in conditions such as diabetic neuropathy and macular degeneration due to aging (3). In cardiology, it can be used in coronary imaging, guiding percutaneous coronary intervention, and diagnosing myocardial infarction with non-obstructive coronary arteries (3). In otology, it can be used for diagnosing conditions like otitis media and conductive hearing loss (3).OCT can also be used in imaging the skin and its associated structures for diagnosing basal cell carcinoma, observing the treatment response of inflammatory dermatoses,and detecting non-melanoma skin cancers (3).

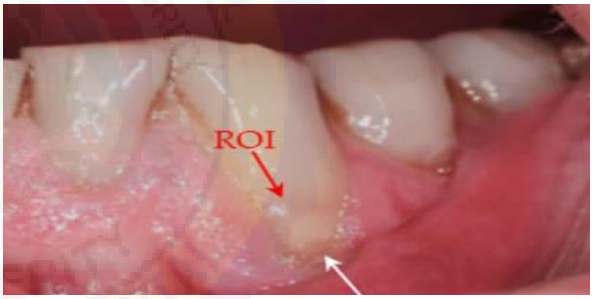
APPLICATIONS IN DENTISTRY:

DENTAL CARIES AND DEMINERALISATION OF TEETH

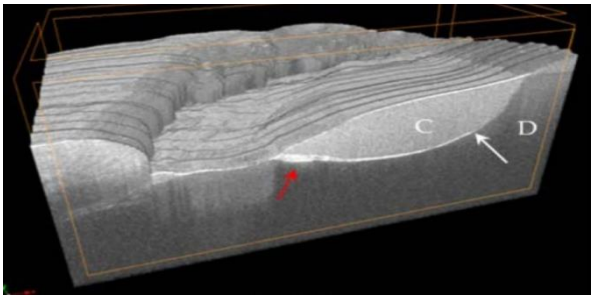
Radiography cannot distinguish properly between active and arrested lesions (3). Tooth demineralization can be differentiated from healthy tooth tissue by increasing light scattering in porous demineralized tooth tissue while performing OCT (3). In enamel caries, the images appear brighter on grayscale OCT, and this could be the result of increased brightness due to the light reflection occurring between two homogenous structures with different refractive indices (3). The demineralized mineral crystals and water in the pores cause increased reflectivity resulting in characteristic brightness in the OCT image. The suggested wavelength for caries detection is 1310nm (3).

DEFECTIVE RESTORATION

Composite restorations are common these days due to their aesthetic appearance. In acid etching, there is the formation of carbon dioxide from the hydrochloric acid thus leading to bubble formation which hinders the resin penetration into the caries-affected areas (4)(5). OCT imaging can detect the air bubbles within the composite restoration and evaluate the bonding interface (4) (5). This assessment becomes easy as poorly sealed polymer composites demonstrate brightly clustered images, whereas tightly fit boundaries do not exhibit too much scattering (4)(5).



(A)



(B)

Figure 6: (a) A cervical composite restoration (b) shows a margin discoloration (white arrow); In OCT images, a margin gap with the ingress of material is detected (red arrows). At dentin (D), an extensive interfacial gap has formed (white arrows) (4)

ORAL PRECANCER

Most common precancerous lesions like leukoplakia, oral lichen planus, OSMF, and frictional keratosis can be detected by OCT with much ease. OCT was used in conditions where incisional or excisional biopsy could cause complications, thereby playing the role of an optical biopsy in such situations. Gambino. A et al. conducted an in vivo study on oral lichen planus. OCT images showed a hyper-reflective, nonhomogeneous area indicating the

lesion occurring within the epithelial layer. Lee CK et al. conducted an in vivo study for the diagnosis of oral submucous fibrosis using OCT (6). OCT imaging showed a decrease in the thickness of the epithelial layer with homogenous contrast of the image indicating the collagen-rich layer which isan effective indicator for the diagnosis of oral submucous fibrosis. The sensitivity and specificity are 100% in oral submucous fibrosis (6).

ORAL CANCER

Various diagnostic aids used in cancer detection such as the biopsy, and Raman spectroscopy are usually time-consuming with poor resolution and difficulty in visualization of high-grade carcinomas. Whereas, OCT has been shown to have a sensitivity of 82% and specificity of 93% (7). OCT helps in locating the boundaries of the tumour which is useful during the resection of the tumour (8). The drawback of OCT imaging is that it cannot detect the cellular aggregations and disorganization of cells. Researchers are underway to help improve their efficiency.

DENTAL PLAQUE AND CALCULUS

The current diagnostic aids used in the detection of dental plaque and gingivitis are visual examination, plaque-disclosing agents, and periodontal probing. These methods are usually confined to the tissue surface and can cause discomfort to the patient. Therefore, several non-invasive have been used in investigations (9). In vivo study conducted by Won J et al. showed OCT imaged soft and hard tissues that included the dental plaque in between the gingiva, the enamel of the facial and lingual/palatal sides of all teeth, and the subgingival and root surface calculus deposits (9). This reveals the versatility and feasibility of OCT in assessing dental plaque and gingiva.

CLINICAL SIGNIFICANCE

ADVANTAGES OF OCT

As discussed earlier, OCT has its hand on medicine and dentistry. [1] Since they use near-infrared light sources for imaging, they have the least side effects proving them non-invasive. [2] OCT provides real-time diagnosis and hence it is less time-consuming.[3] It images the diseased site exactly, thus being site-specific. [4] OCT images are digital. It helps the viewer to zoom in and improve the contrast and quality of the image for better visualisation. [5] Its simple working principle enables any person to directly work on it eliminating the need for trained personnel. [6] The handheld probe provides easy access to any site of the oral cavity. [7] They also act as an alternative to resection or excision as they can be used as an optical biopsy tool (10).

DISADVANTAGES OF OCT

It cannot identify the causative organism responsible for infection. In the detection of malignant and premalignant conditions, the increase in cellular aggregations, disorganization, irregular collagen or elastic fibres, and disorganization of the basement membrane which are the indicative factors of the cancerous process is not detected. Therefore, OCT acts as a supportive diagnostic tool. Cancer staging cannot be done with OCT images. Although the OCT technique is highly effective and user-friendly, they are not commonly used due to its high cost.

CONCLUSION

Optical coherence tomography, a non-invasive, non-radiative diagnostic tool is commonly used in the medical field and is gaining popularity in the dental field. The real-time, digital and site-specific images obtained make it a less time-consuming diagnostic procedure. This technology is still in its infant stage of development and requires more research for the betterment of future diagnostics.

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REFERENCES:

1) Fujimoto JG, Pitris C, Boppart SA, Brezinski ME. Optical coherence tomography: an emerging technology for biomedical imaging and optical biopsy. Neoplasia 2000;2(1-2):9-25.

2) A Balaputri, A Schnyder, VC Divya. "Optical Coherence Tomography (OCT)-Present and Future Applications in Dentistry." Special Education 1.43 (2022).

3) Ali, Saqib, et al. "Optical coherence tomography's current clinical medical and dental applications: a review." F1000Research 10 (2021).

4) Shimada, Yasushi, et al. "Evaluation of dental caries, tooth crack, and age-related changes in tooth structure using optical coherence tomography." Japanese Dental Science Review 56.1 (2020): 109-118.

5) Schneider, Hartmut, et al. "Dental applications of optical coherence tomography (OCT) in cariology." Applied Sciences 7.5 (2017): 472.

6) Lee CK, Tsai MT, Lee HC, Chen HM, Chiang CP, Wang YM, Yang CC. Diagnosis of oral submucous fibrosis with optical coherence tomography. J Biomed Opt 2009;14(5):054008.

7) Tsai MT, Lee HC, Lee CK , Yu CH, Chen HM, Chiang CP, Chang CC, Wang YM, Yang CC. Effective indicators for diagnosis of oral cancer using optical coherence tomography. Opt Express 2008;16:15847-15862

8) Sunny SP, Agarwal S, James BL, Heidari E, Muralidharan A, Yadav V, Pillai V, Shetty V, Chen Z, Hedne N et al. Intra-operative point-of-procedure delineation of oral cancer margins using optical coherence tomography. Oral Oncol 2019;92:12-19.

9) Won J, Huang PC, Spillman DR, Chaney EJ, Adam R, Klukowska M, Barkalifa R, Boppart SA. Handheld optical coherence tomography for clinical assessment of dental plaque and gingiva. J Biomed Opt 2020;25(11):116011

10) Jerjes W, Hamdoon Z, Yousif AA, Al-Rawi NH, Hopper C. Epithelial tissue thickness improves optical coherence tomography's ability in detecting oral cancer. Photodiagnosis Photodyn Ther 2019;28:69-74.