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Is Optical Coherence Tomography A Revolutionary Technology In Periodontics ? – A Review

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Abstract

Periodontitis is a multifactorial disease that may result in significant debilitation. For better diagnosis, early diagnostic in health care is mostly desirable and necessary. Imaging methods are widely used in diagnostic medicine and Optical Coherence Tomography (OCT) is the most innovative imaging technique used in different field of medicine along with dentistry. The oral cavity is ideal for OCT imaging as it has both non-transparent and transparent tissues. It is also easily acceptable for interrogation by the fiberoptic OCT device. OCT is not only an 'image tool' but also are important and non-invasive method for early detection of oral diseases such as tooth decay and periodontal diseases with its well developed component. Studies analyzed on periodontal structures using OCT to periodontal diagnostics are discussed here.

Keywords: OCT-principles of OCT-dental application-periodontal application-advantages.

Introduction

Periodontitis is an endemic infectious disease that may result in significant debilitation. It is one of the two most important oral diseases contributing to the global burden of chronic disease[1].Dental calculus is a type of mineralized plaque from deposited microorganism that promotes more plaque retention which plays a major role in periodontitis[2]. Periodontal probing is a traditional diagnosis of subgingival calculus and has a drawback of being uncomfortable and painful technique from the patient point of view which results in difficulty for the dentist to assess the bone destruction and treatment outcome [3]. Radiography is helpful in identifying subgingival calculus located at the proximal surface, since for the vestibular and buccal surface there is a superposition with the tooth which does not allow proper imaging. Other than radiograph and periodontal probing smart ultrasound devices, LED band optical probe, laser fluorescence spectroscopy and OCT are the different methods used for calculus detection. Radiography can

determine the level of bone related destruction but it underestimates the bone loss by approximately 30% [4].

OCT is certainly a promising tool to be considered since it is non invasive, non destructive, non radioactive and real time monitoring method of imaging diagnostic and also able to give quantitative results. OCT was first developed by Fujimoto's group at MIT in 1991[5]. Colston et.al in 1998 was the first to perform in dental OCT. They developed a prototype OCT and acquired images of procine periodontal tissues. Clinical measurements and radiographs are important to diagnose the periodontal diseases. To get the valuable information and for judging the presence and severity of periodontal diseases frequent monitoring of gingival sulcus is important. Painful sensation results with manual probing due to instrument penetration into the pocket with gingival inflammation. This invasive technique has the risk to promote its active tip penetration into periodontal tissue thus leading to trauma.

Generally periodontal probing constitutes the main diagnostic parameter for periodontal diseases as measured by *Schneider et al* using digital determination. OCT reviews micro structural details of the periodontal soft tissues that help to observe periodontal structures that might be associated with inflammatory process. In healthy condition, the free gingiva is very close to the tooth surface, enlargement of gingival sulcus is an important point to predict the presence and absence of periodontal disease. OCT helps in identifying accurately active periodontitis before significant alveolar bone changes occurs.

Measuring the gingival thickness is very important as it is one of the predictors for the gingival phenotype. There is a strong correlation between gingival phenotype and periodontal therapy and its variation has a direct implication on the result of periodontal therapy. Several method have been used both invasive and non invasive, the main advantage of OCT compared to these technique is its real time and quantitative high resolution patterns. The measurements obtained with the OCT were smaller than the histological measurements but the images showed details that allows the early detection of periodontal diseases. The images can be stored and stored images at the different movement of evaluation will allow comparison with the future periodontal examination. It helps the surgeon to detect the changes or inflammatory response in region of interest.

Online images can also be made available and even in real time evaluation at a distance by experts. The development of low cost OCT system will be of greater importance to push its use in clinical environment. Diagnosis is a pivotal step in the periodontal management. OCT is a useful imaging device that employs a near infrared laser light and this method is free from the risk of radiation exposure[6] It is one of the most important imaging modality for biophotonic application and this modality is capable of creating high resolution, real time cross sectional images at the chair side.

Periodontal health depends on the balance between the dental biofilm and inflammatory response of the host. Periodontal diseases are characterized by the destruction of periodontal tissue and causes 5% to 15% of dental loss in susceptible individuals. The identification of alterations in periodontium is the subclinical phase and monitoring the progression of periodontal diseases is still a greater challenge for the periodontist.In the field of periodontics, OCT application is used for detecting the calculus in extracted tooth, observation of procine gingiva and measurement of gingival sulcus. Study on observation and determination of periodontal tissue profile using OCT by *kakizaki et al* confirmed the use of OCT system as a diagnostic tool for the observation of periodontal tissue

profile. Their study gave a promising result about OCT which can be used for analyzing morphometric analytic device for periodontal tissues including the determination of biological width.

OCT could be the 6th generation [7] of periodontal probes, because it captures bi and three dimensional images, obtaining transverse images with high resolution in micrometer scale in situ without physical contact or excision, it allows analysis in place where biopsy is not feasible. By using OCT modality the profile of gingiva, epithelium and connective tissue thickness and the position of the alveolar bone crest can be determined. OCT helps to identify their anatomical characteristics, such as the extension of pocket, visualization of early biofilm deposits and early tissue changes in subclinical level. Through OCT images we can identify the structures like enamel, dentin, dentinoenamel junction, gingiva, gingival margins, oral epithelium, sulcular epithelium and part of gingival sulcus and periodontal probe, junctional epithelium, connective tissue, calculus deposits, biofilm and plaque depositions. In addition it is still possible to see the dentinoenamel junction in all images obtained by OCT. It was possible to observe the changes and variation in the regression, progression and maintenance of periodontal disease in the period evaluated.

Types

- Time domain OCT –TD-OCT - first OCT that was used in dentistry.
- Fourier domain OCT-FD-OCT
- Parallel OCT
- en-face optical tomography
- Polarization sensitive OCT

Principles

OCT is a new non invasive imaging technique that produces high resolution images of biological tissue and gives a cross-sectional optical imaging of both hard and soft tissue structure with a penetration depth up to a few millimeters in three dimensional manners. It is based on fiber optic Michelson – type interferometer. Output from a low coherence light source is split at the 2x2 fiber optic coupler. This is directed towards the periodontal tissue and reference mirror. Reflection from the mirror and back scattered light from the tissue are recombined at the coupler and propagated to the detector and light source. Coherence between the reference mirror (a scanning mirror is used in the reference arm to impose a change in the optical delay) and sample reflections created a signal at the detector and when the reflections have travelled approximately the same optical group delay. The reference arm group delays must be matched for an interference signals to be detected. The shorter the coherence length of the source the closer is the sample. To get a high accuracy, knowledge of mirror velocity, cross-sectional image is produced by transversely scanning the beam across the sample and collecting the reflectionable profile at each point and recoded digitally on a gray scale image.

OCT works on the principle of Michelson or Mach-Zehnder interferometer. Signal is captured by photodiode or charge coupled device and this mainly depends on the type of OCT used. It was designed using a super luminescent diode centered at 1300nm, with a spectral band width of 45nm with total scan time of each image was approximately 120seconds.Two types of interference are there : non-constructive and constructive. When the Optical Path Length of light is reflected by the reference and the sample is same, non-constructive interference occurs. When OPL between the light reflected by the reference and the sample is multiples of wavelengths, constructive interference occurs. TD-OCT was the first OCT used in the dentistry. In this type, the path length of the reference arm is scanned in time.

Advantages

- Penetrates high depth and transversal solution.
- Contact free and non-invasive operation.
- Function dependent image contrast.
- Diagnostic tool helps in early diagnosis.
- Helps in real time monitoring of both hard and soft tissue.
- Can image the normal and abnormal changes in the oral mucosa.
- Patterns of occlusion can be mapped and recorded.

Disadvantages

- OCT takes longer time to get the images
- Due to tissue birefringence, the artifacts are produced.
- Many pictures are needed to scan the entire lesion.
- Penetration depth is limited in scattering media.

Visualization And Probing

These are the two traditional methods that are used to assess the dental diseases. As sensitivity and specificity are questionable with those methods nowadays, radiograph and dental computed tomography (Dental-CT) has become more popular today. Use of Raman and laser fluorescence spectrometer is still under investigation. OCT is an effective diagnostic tool because it is a real time monitoring method.

Biofilm

OCT wave used to evaluate the salivary pellicle and salivary pellicle islands were visible in the sample incubated in saliva, that grow in to complexes completely covering the enamel surface. OCT may also be treated as fully fledged quantitative measures for bacterial plaque, which can be quickly and relatively visualized around orthodontic hooks. OCT was able to identify the extension of periodontal pocket to the visualization of early biofilm deposits.

Periodontal Applications of Oct

Periodontitis is one of the major multifactorial chronic infectious disease in the oral cavity with prevalence rate of 50% among the population [8,9]. Periodontal disease is a plaque induced disorder that results in loss of connective tissue attachment and resorption of bone which is a major cause for bone loss. Clinical examination, radiographic findings and periodontal examination/probing are the different procedures used for diagnosing the periodontal diseases. Diagnosis of periodontal disease is made by quantifying the degradation noted in mechanical and pressure sensitive probes. Manually operated probes shows an average measuring error of 0±0.5mm. Limitations of periodontal probes includes,(1)variations in insertion force[10], (2)inflammatory status of the tissue[11], (3)diameter of the probing tip[12] and(4)anatomical tooth contours and are often painfully uncomfortable for the patient [13]. It is difficult to assess the hard and soft tissue structures of periodontium through routine imaging modalities. Periodontal fibers measured in X-ray images appeared to be much thinner than in reality

The accuracy of OCT images were evaluated using an animal model [14,15]. OCT is the diagnostic tool with the aid of Computed Tomography, early detection of periodontal disease and monitoring the periodontal treatment could be useful. The OCT can provide excellent images of the periodontal soft tissue attachment, contour, thickness and depth of the periodontal pocket with wavelength of 1310 nm which can produce better images than 850 nm system. The sulcular fluid will enhance the contrast for imaging periodontal tissues in vivo. Variations in the tissue fluid provide differences in contrast for clinical imaging in periodontal diseases. OCT also reveals micro structural details of the periodontal soft tissues which offer the potential for identifying active periodontal diseases before significant alveolar bone loss [16].

Peri-Implantitis

Due to its high predictability and reliability, practicing implant for a missing tooth has become a routine procedure. Maintaining peri-implant health has attracting interest due to the expectation of its high survival rate**.** Verifying bone loss is essential for diagnosing peri-implantitis where the inflammation of soft tissue and concomitant irreversible loss of the supporting bone. For a long term survival, maintaining the stability of the peri-implant crestal bone level is essential. Radiographs are crucial diagnostic tool for confirming bone loss but with this technique estimating bone loss at least 1.0 mm is not possible, so the early detection is impossible [17].

Optical coherence tomography images can be used to visualize the peri-implant bone levels and helps to identify bone defect. OCT may be a candidate for a future diagnostic tool as it can visualize tissues. The potential quantitative non-invasive measures of the amount of bone loss were also confirmed. High predictability and reality dictates the dental implant restoration for a missing tooth as a routine procedure. Maintaining peri-implant crestal bone level is essential for the long term success of an implant.

In clinical situations the imaging tools like intraoral and panoramic radiograph mostly used to identify the peri-implant bone levels, in which the buccal and lingual surfaces are obscured and only bone levels of proximal surfaces can be evaluated.Though it is expensive, involving the high dose of radiation shows metal artifacts which may degrade visibility. CBCT can be a complementary modality of a three dimensional images .OCT is a [better diagnostic tool] utilizing an optical source to obtain a high resolution image non invasive without irradiation. Various thresholds of radiographic bone loss in the range of 0.4-5.0 mm have been used to diagnose peri-implantitis.

Peri-implantitis is more destructive than the periodontal lesion because the inflammation extend to the bone marrow incase of peri-implantitis. To maintain the health of the peri-implant tissue, continuous monitoring of the crestal bone level is essential. This will allow early detection of tissue and its appropriate treatment. Probing pocket depth is the basic parameter for diagnosis and it doesn't give proper quantitative evaluation because of low reproducibility of the insertion position, angle, and force, the presence and contour of the abutment and prosthesis affect the measurements [18]. Probing has the disadvantage of causing discomfort and more pain around the implant than around the teeth to the patient. Generally peri-implant bone defects were assessed by CBCT and intra oral radiography, the accuracy was comparable and clinically acceptable. The sensitivity and specificity was only in the range of 60%.

Mucosal Changes

One can evaluate the mucosal changes with imaging tool as it has potential broad application in mucosal lesions. Generally most of the mucosal lesions can be evaluated by simple visual examinations where as others at the cellular level requires early examination. OCT can be used for those cases for the assessment of tissue injury eg ; Radiation mucositis.

Molecular Imaging

Molecular Imaging is defined as the description and measurement of molecular elements at the cellular and molecular level which evaluates the molecular abnormalities that are basis for disease at an early stage. The properties of OCT and its improved resolution capabilities helps in evaluating the diseases at molecular level near future.

Malignancy

Early diagnosis permits minimally invasive treatment, treatment of oral cancer and the survival rate is related to

the stages of cancer diagnosed [19]. OCT could detect epithelial and sub-epithelial neoplastic related changes that are characteristics of carcinogenesis. It is a good tool for early diagnosis, predictors of malignant changes, risk of recurrence and response to therapy. The sensitivity and specificity are 100% and 96% in differentiating between malignant and non-malignant lesions [20].

Discussion

OCT can produce tissue imaging in micron scale in real time which can be analogous to an optical biopsy. Imaging in real time saves the need of incision, excision, and processing of histological specimen. OCT is a new technology for performing high resolution cross sectional images. It can provide images of tissue insitu and in real time. It can be used where standard excisional biopsy is hazardous or impossible. By using OCT, sampling errors associated with excisional biopsy can be avoided and it can be used to guide interventional procedure.OCT are not yet fully used in dentistry, the reasons are low availability by customized intraoral equipment and insufficient range of OCT rays which penetrates in to the tissue to a depth of only few millimeter depending on the apparatus type and histological conformation was a challenging problem. For conventional histology we need decalcification of dental hard tissue before thin slices are made. To maximize the efficacy, the wavelength of light responsible for generating the image should be subjected to testing and the central wavelength determine the maximum depth of penetration in to the tissue due to scattering and absorption properties.

The important dental issue is caries that has high prevalence and wide distribution among ages. OCT provides capability of early detection of caries and PS - OCT is suitable for detection of secondary caries. Universal OCT should offer the possibility of controlling wavelength depending on the type of tested tissue, hydrated tissues dissipates much more energy than hard tissue containing a small percent of H2O[21]. OCT is comparable to ultrasound imaging but here light in use instead of sound[22] .Cross- sectional images are generated by measuring the echo time delay and intensity of the light that is back scattered from internal structures in tissue.

Conclusion

OCT imaging suggests that it has the potential to have a significant impact on the diagnosis and clinical management of many oral and systemic diseases. Hand held OCT systems like other dental gadgets which can be placed along side the dental chair. The unique feature of OCT makes it ideal for research and clinical practice and for evaluating dental treatment, hence reducing failure rates. The sensitivity and specificity of OCT provide a diagnostic approach which is both comprehensive and quantitative. OCT allows for soft tissue imaging, which is very much important in the treatment of periodontal diseases which will be the method of choice in modern dental diagnosis. The future of diagnosis lies in more clinical studies in various branches of dentistry.

Abbreviations

OCT - Optical Coherence Tomography

OPL - Optical Path Length

TD-OCT - Time Domain

FD-OCT - Fourier Domain

CBCT - Cone Beam Computed Tomography

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