Review article

Optical Coherence Tomography: A new era in dentistry

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Abstract

Dental prostheses are very complex systems, heterogenous in structure, made up from various materials, with different physical properties. They have to satisfy high stress requirements as well as aesthetic challenges. The failures of dental prostheses lead to functional, aesthetic and phonetic disturbances which finally render the prosthetic treatment inefficient. OCT is a tomography imaging technology capable of producing high-resolution cross-sectional images of the internal architecture of materials and tissues. This includes not only the images of normal and abnormal dental hard tissue structures but also teeth after several treatment methods. It can be used for non-invasive investigations for both in-vivo and in-vitro structural imaging within the oral cavity.

Keywords: optical coherence tomography; non-invasive investigation; dentistry

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Introduction:

During the last 20 years, optical coherence tomography (OCT) has evolved into a powerful technique for imaging of transparent and translucent structures[1]. OCT is an attractive noninvasive, nontouch imaging technique for obtaining high-resolution images. The first application in the biomedical optics field was for the measurement of the eye length. Optical Coherence Tomography (OCT) is an optical imaging method with medium penetration and high resolution primarily used in medicine. It has the potential to create live cross-sectional images even of non-transparent tissue at depths of up to 3 millimeters at a resolution of little more than a micrometer[2].

Principles:

One of the light characteristics which is used in the OCT is the phenomenon of interference. Two electromagnetic waves can interfere, add up or subtract each other and create a new one. Interferences could be fully constructive interference or completely destructive, but are usually partially destructive or constructive. (Fig.a)

The light source has low-coherence like an SLD. Light is driven through the fibre to the beam splitter which divide by two (50/50) the beam. The first 50% are driven in direction of the sample (sample arm) to

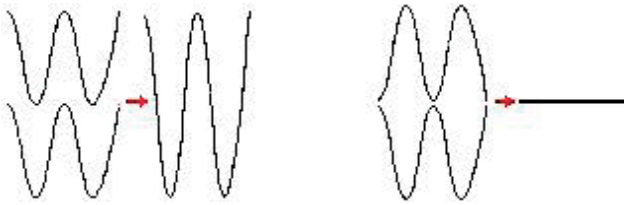

Fig. a: Constructive (left) and Destructive Interferences (right).

be reflected or backscattered by the different sample's tissues. The second 50% go through the reference arm ended by a movable mirror. Both are reflected back to the detection arm which has a detector to convert light intensity into electrical current. That current is converted to a digital signal and analyzed by a computer which generates an image of the sample[3]. (Fig.b)

Uses In Dentistry:

OCT is useful widely in almost all the fields of dentistry as it is capable of imaging both the hard and soft tissues and also can be used both in vitro and in

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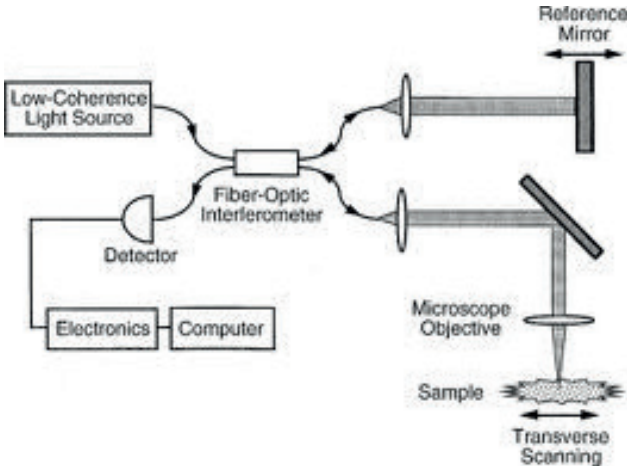

Fig.b: Interference Principle in a Michelson Interferometer.

vivo. The various applications are:

A) To detect the presence or absence of material defects and microleakage at the prosthetic interfaces[4]. The investigations upon fixed partial prosthesis presented many defects that can lead to their deterioration. These defects are usually located inside the material and cannot be depicted visually or by other conventional imagistic method.

B) OCT imaging offers the exciting potential to detect periimplantitis before significant osseous destruction occurs. OCT images of soft tissue surrounding failing implants are characterized by linear signal deficits, low-intensity collagen signals, and pronounced increases in vascular elements[2]. The quality of the implant insertion could be investigated by implant bone interface analysis.

C) Used to view the integrity of temporo-mandibular joint disc.

D) OCT, as a relatively new imaging technique for detection and analysis of early caries, correlated well with an established method of quantifying demineralization. The reflectivity loss in tooth tissue following demineralization, measured using OCT, could be significantly related to the amount of mineral loss during the demineralization process[5].

E) OCT is a promising non-destructive imaging method for the diagnosis of vertical root fractures[6].

F) Optical coherence tomography clearly proves its utility in investigating orthodontic bonding. With this non-invasive method the material defects trapped inside the matrix resin can be localized and 3D reconstructed. Adding confocal microscopy to the OCT investigation leads to a much better evaluation of the communications of these gaps in order to forecast the strength of the orthodontic brackets' bonding[7].

G) Malignant lesions of oral mucosa: Accounting for 96% of all oral cancers, squamous cell carcinoma (SCC) is usually preceded by dysplasia presenting as white epithelial lesions on the oral mucosa (leucoplakia). This high-resolution optical technique permits minimally invasive imaging of near-surface abnormalities in complex tissues, having a penetration depth of 1-2 mm[8,9]. This permits *in vivo* noninvasive imaging of the macroscopic characteristics of epithelial and subepithelial structures, including: depth and thickness, histopathological appearance and peripheral margins.

H) In the Todea C. et al. study[10] the quality of endodontic treatments and root canal fillings were investigated with *eF*OCT/CM technology. Areas of apical microleakage were detected between the gutta-percha cones and the root canal walls and the filling material of the root canal space.

I) OCT is particularly well-suited for periodontal diagnosis, generating ultrahigh resolution crosssectional images of dental tissues. OCT provides rapid, consistent, and reproducible images of the surface topography, pocket morphology, and attachment

Table 1:Applications of OCT

S.No.	Field	Application
1.	Prosthodontics	• Microleakage at prosthetic interface. • Integrity of temporomandibular joint disc
2.	Implantology	• Detect peri-implantitis. • Implant- bone interface analysis.
3.	Dental materials	• Material defects.
4.	Conservative and endodontics	• Detect early caries. • Diagnosis of vertical root fracture. • Apical microleakage.
5.	Orthodontics	• Bracket bonding defects.
6.	Oral pathology	• Detect malignant lesions.
7.	Periodontics	• Surface topography of gingiva. • Attachment level. • Pocket morphology.

level that are digitally recorded. These images pinpoint with great accuracy sites of disease progression. OCT also provides quantitative information regarding the thickness and character of the gingiva, root surface irregularities, and the distribution of subgingival calculus[2].

Conclusion:

OCT represents a valuable method for investigation and assessment of the health status of soft oral tissues and of hard dental structures. OCT can be used for evaluation of dental treatments reducing their failure rate and saving time and resources, by eliminating incorrect restorations before their insertion in the oral cavity.

References:

1. Carmen Todea, Meda Lavinia Negrutiu, Cosmin Balabuc, Cosmin Sinescu, Florin Ionel Topala, Corina Marcauteanu, Silvana Canjau, Gianfranco Semez, Adrian Gh. Podoleanu. Optical coherence tomography applications in dentistry. *TMJ* 2010;**60**(1):5-17.
2. J. Fujimoto and W. Drexler. Optical Coherence Tomography. *Springer Berlin Heidelberg*, 2008.
3. Optical coherence tomography: 3-D dental scanning imaging probe. *Dubosson Fabrice*.2007. page no.7.
4. Cosmin Sinescu, Meda Lavinia Negrutiu, Carmen Todea et al, Quality assessment of dental treatments using en-face optical coherence tomography, *Journal of Biomedical Optics* 2008;**13**(5). http://dx.doi.org/10.1117/1.2992593
5. B. T. Amaechi, A. Gh. Podoleanu, G. N. Komarov, J. A. Rogers, S. M. Higham, and D. A. Jackson. Application of optical coherence tomography for imaging and assessment of early dental caries lesions. *Laser Physics*.2003;**13**(5):703–710.
6. Hagay Shemesh, Gijs van Soest, Min-Kai Wu and Paul R. Wesselink. Diagnosis of vertical root fractures with optical coherence tomography. *JOE* 2008;**34**(6):739-42.
7. R. O. Rominu, C. Sinescu, D.M. Pop, M. Hughes, A. Bradu, M. Rominu, and A. Gh. Podoleanu. En-face optical coherence tomography and fluorescence in evaluation of orthodontic interfaces. World Academy of Science, Engineering and Technology 32 2009.
8. B. W. Colston, Jr., U. S. Sathyam, L. B. DaSilva et al, Dental OCT, *Optic Express*, 1998;**3**(6):230-238. http://dx.doi.org/10.1364/OE.3.000230
9. Pedra Wilder-Smith, Kenneth Lee, Shuguang Guo et al. In vivo diagnosis of oral dysplasia and malignacy using coherence tomography: preliminary studies in 50 patients. *Lasers in Surgery and Medicine* 2009;**41**:353-357. http://dx.doi.org/10.1002/lsm.20773
10. Carmen Todea, Cosmin Balabuc, Cosmin Sinescu et al, En face optical coherence tomography investigation of apical microleakage after laser-assisted endodontic treatment, *Lasers Med Sci* 2009.