

MODERN APPROACHES OF ANALYSIS AND TREATMENT OF ENDODONTIC LESIONS USING THE ENDOSCOPE AND THE OPTICAL COHERENCE TOMOGRAPHY

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ABSTRACT

Aim of the study: The main reason of the present study is to analyze and record the evolution of two revolutionary methods in dental medicine with which endodontic treatments can be performed as well as the evaluation of their quality that appeared in the last twenty years. Materials and Methods: An electronic search was done on Research Gate, Science Direct and PubMed using terms about modern endodontic treatments between 1990 and 2019. Every article containing the terms of interest has been read carefully and selected according to its importance in this article. Terms used for search included: Endoscopy; Tooth Anatomy; Optical Coherence Tomography; Magnification in Dental Medicine; Diagnostics in Dental Medicine; Cariology; Restorative dentistry; Endodontics; Pedodontic; Prosthetics; Periodontology. Results: Studies have shown that technology is constantly growing in the field of dentistry, bringing new results every year, improved for the diagnosis, evaluation and treatment of dental injuries. Looking at the presented study, we can see the history and applicability of a new method of magnification, namely the use of the endoscope that tends to replace the endodontic microscope which, in the case of a curved canal root, it is often impossible to explore the details of the root canal. Also, current imaging methods commonly used in endodontics which are often two-dimensional images with high doses of radiation have an alternative non-invasive version to obtain three-dimensional imaging, namely, the optical coherence tomography (OCT). Conclusions: The endoscope can be used as an alternative to the endodontic microscope with the advantage of providing real three-dimensional images of the endodontic space even beyond the root canal curves. Optical Coherence Tomography is a very important tool that can be used to establish endodontic diagnoses and also to evaluate endodontic treatments.

Keywords: anatomy of the teeth; endoscope; optical coherence tomography; non-invasive endodontic treatment;

INTRODUCTION

1.1 General History of endoscope

The history of modern endoscopy dates back to the 1800s when trying to avoid the four obstacles that stood in the way of success. These

obstacles are the creation and widening of an entry into the internal cavity of the body, the safe entry of light, the transmission of a clear image and the magnification of the field of vision. In 1868, Adolph Kausmaus was the first person to use an endoscope to examine the inside of the stomach in vivo [1].

Over the years, this procedure has progressed through knowledge, and so we can say that the endoscope allows the inspection, manipulation and treatment of internal organs without the need for an incision sufficiently large to allow the practitioner to use his hand or fingers to enter the operator field. As a first priority in the use of endoscope, it has been demonstrated that a reliable method of body access such as natural or small incisions in existing cavities in areas with low risk of perforations or infections is required. Secondly, to investigate natural holes, it was necessary to have small and flexible instruments that would not damage the surrounding anatomical structures. The inside of the human body, of an internal organ is found in total darkness, therefore, it was necessary to obtain an external light that could make it possible to investigate but not to cause any burn or injuries due to the emanating heat. Due to its reduced flexibility, the rigid endoscope has been shown to be dangerous to vital organs causing perforations, therefore, Rudolf Schindler along with Georg Wolf designed in 1934, the semi-flexible instrument made up of a rigid and somehow flexible portion with a still large diameter of 12mm [2]. In 1967, endoscope modernization continued to produce a better illumination system that provided clearer details and vivid colours using a small diameter. At the same time, the flexible endoscope was introduced, followed by obtaining a sensor at the end of the endoscope that converted the optical image into a digital signal that could be transferred to an image processor where a standard video signal was displayed on a monitor. Thus, the

ergonomics of the practitioner improved by looking at a monitor with both eyes compared to a single eye in a lens. In the 21st century, vital organs can be analysed using endoscopes such as the nose, pharynx, larynx, esophagus, stomach, duodenum, colon, abdominal cavity and joints without endangering their health. The quality of the image transmitted through this instrument should be as good or better as the images obtained with the naked eye. The aim of endoscope technology has therefore become not only to obtain an exact diagnosis, but also to perform definitive therapeutic procedures [3].

1.2 General History of Optical Coherence Tomography

The history of optical coherence tomography (OCT) begins in 1986 with Fercher and Roth who reported on the practicability of interferometry with partially coherent light to measure the optical length of human eyes in vivo [4,5]. In the early 90s the OCT had its first applications in medicine [6-10]. The OCT can be classified into two types, the Fourier Domain optical coherence tomography and the time domain optical coherence tomography which was developed in 1991 by Huang D. to diagnose ophthalmic injuries [11]. The main drawback of the second type was that it could not produce three-dimensional images of objects [12] compared to the Fourier Domain optical coherence tomography which can also reduce the measurement time by a hundred times. Time domain can acquire approximately 400 A-type scans per second using six radial scanning with 30-degree intervals. There is a risk of

omitting pathologies that affects areas between scans. On the other hand, Fourier/Spectral domain technology performs approximately 20,000-40,000 scans per second, continuously on the scanned area increasing the accuracy, improving the resolution and reducing the risk of artifacts by skipping some tissue portions and omitting possible pathologies. Basically, the optical coherence tomography is based on a Michelson interferometer built with the following components: the light source, the scanning system and the detector.

These components meet almost all the essential functions of the equipment. The beam of light emitted by the source is decomposed into two beams with the help of a beam splitter. One of those two is directed to the measured sample and the other to the reference mirror, so that the light scattered by the sample and the one reflected by the reference mirror will be overlapped through the beam splitter and they will interfere [Fig 1]. The interfering beam is collected with the help of the detector [13].

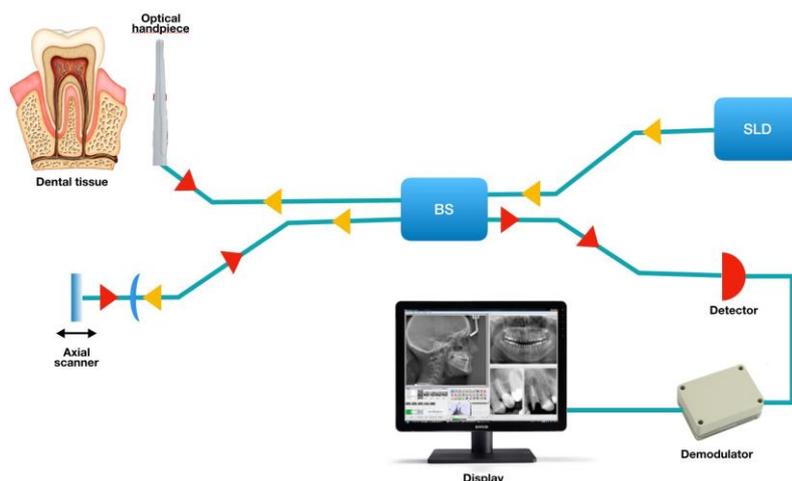


Figure 1. Schematic of the in vivo dental OCT System.

2. MATERIALS AND METHODS

An electronic search was done on Research Gate, Science Direct and PubMed database between January 1990 and February 2019. The publications have been selected according to the search terms: endodontic treatment and/or therapy, magnification in endodontics, microscope, endoscope in dentistry, optical coherence tomography.

All articles containing one or more of the above listed terms have been evaluated and selected if they met the requirements of this study.

The articles were selected following the evolution of the OCT and the endoscope over the years in dental medicine, as well as the results obtained. Thus, all of items that were considered

to have contributed to the development of these systems were noted.

3. RESULTS AND DISCUSSIONS

3.1 Introduction of endoscope in endodontics

At the end of the 20th century, a new method of investigation was proposed for investigating the oral cavity structures by using a modified medical endoscope. This endoscope uses a fiber optic, making the instrument easy and flexible, unlike the previous endoscope, which offer better work ergonomics but weaker quality images. Pioneering the use of endoscopes as a diagnostic aid in endodontic was done in 1971 [51], but increased magnification and improved illumination of these systems was achieved only in the 90s [52,53]. Compared with the surgical microscopes dedicated to endodontics, the increased flexibility of the endoscopes allows them to directly explore the teeth in lateral areas. The size of 25 mm according to the specific ISO standards is sufficient to inspect the root canals. The focal depth of 10 mm allows quick view of the apical region, especially in the right root canals.

The system can also be used for the revision of root-fill materials and also for detection of fractured instruments in the root canal under direct visual control. The advantage is the elimination of additional radiographic controls during treatment, thus lowering the radiation dose to which the patient is subjected. Irrigation of the root canal is performed conventionally, but the canal should be dried prior to endoscopic inspection with

paper cones to avoid distracting reflections [54]. Applications of micro endoscopy in medical technology and industry require small work sizes with diameters from 0.15 to 1 mm [55-59]. The endoscope is flexible due to the special coating of nitinol. The 0.9 mm diameter optical part is a piece of equipment that allows clinicians to magnify up to 20 times giving a clear picture with a broad perspective. For therapeutic procedures, the endoscope is inserted into a special handpiece that gives it the possibility of treatment and observation. The handpiece contains three channels: the central one where the endoscope is found and the other two channels are for suction and for instruments [59]. There is only one type of handpiece and three types of cannula [59]. Endodontic endoscopes have been used to visualize the anatomy of the root canals because the images obtained are macroscopic and similar to those of intraoral chambers [60].

3.2 Introduction of optical coherence tomography in dental medicine

In 1998, the optical coherence tomography was introduced in dentistry showing the first images of human dental tissue with a depth up to 3 mm in hard tissues and 1.5 mm in soft tissues [14]. In the same year, Feldchtein F., presented images of the three types of oral mucosa: masticatory, lining and specialized. The same authors displayed pictures of a composite resin dental restoration taken in vitro and also caries lesions located in the occlusal fissure and in the cervical area providing a great level of details comparing with a normal conventional x-ray image [15]. In the

beginning of the 20s Otis L. presented the differences between two OCT prototypes who were using different wavelength, 850 nm and 1310 nm with a relatively low numerical aperture, 0.03 respectively 0.20. Therefore, after only 2 years it was illustrated the improvement in imaging dental structures obtained with the new system [16]. In 2003, the same authors did a survey with twenty-one practitioners showing OCT images of extracted premolars with occlusal sealant or restored with composite restoration proving that the technology can be used by dentists easily [17]. For the next decade, a series of eight articles were published by a group of authors increasing the knowledge about the usage of OCT [18-25]. It was proven, in 2006, that the optical coherence tomography can monitor and quantify the artificial lesion progression [18] and also the remineralization and efficacy of intervention with fluoride and lasers on severe early artificial enamel caries [19,20]. After three years, they proved

that the OCT can also be used to measure remineralization on dentin and root surfaces and assess inhibition of demineralization by anti-caries agents [21-25]. The effectiveness of the technology was also analysed on the enamel structure of primary teeth considering that the tooth decay can affect both primary and permanent teeth [26]. In addition to analysing dental structures as well as evaluating and monitoring remineralization of enamel and dentin, the OCT had also found its applicability in the treatment of carious lesions using CO2 lasers [27-32].]. One of the largest branches of dental medicine, dental prosthesis, was approached and analyzed in 2008 by Sinescu C., with the help of the OCT, aiming at the non-invasive identification of small prosthetic material defects and micro leakages at prosthetic interfaces [33].

3.3 The use of optical coherence tomography in endodontics

Table 1. OCT in endodontics in the last 12 years of publications.

Author	Year	Title	Methods	Results
F. Kauffman [34]	2006	Characterization of the dental pulp using optical coherence tomography	Ex-vivo study on male wistar rats molars	Images clearly identifying dentin, pulp chamber and root
Shemesh H. [35]	2007	The Ability of Optical Coherence Tomography to Characterize the Root Canal Walls	Ex-vivo study on ten extracted single rooted mandibular incisors	Correlation between the histologic images and the OCT output
Shemesh H [36]	2008	Diagnosis of vertical root fractures with optical coherence tomography	Ex vivo study on twenty five premolars	Appearance of vertical root fractures
Meda	2008	Root canal filling	Ex-vivo study on	Existence of micro

L.Negrutiu [37]		evaluation using optical coherence tomography	thirty monoradicular teeth that with root canal fillings	leakage in the investigated root canal fillings
G. van Soest [38]	2008	Optical Coherence Tomography for Endodontic Imaging	Ex-vivo study in ten extracted single-rooted mandibular incisors	Images with anatomy of root canal walls uncleaned fins and vertical root fractures

Table 1: Continued

Author	Year	Title	Methods	Results
Ana K.S. Braz [39]	2009	In Vitro Tomographic Image of Human Pulp-Dentin Complex: Optical Coherence Tomography and Histology	In vitro study on five human maxillary premolars	Clear images of the pulp-dentin complex obtained with a non-invasive and non-destructive procedure
Meda L Negrutiu [40]	2010	Root canal filling evaluation using optical coherence tomography	Ex-vivo study on twenty-one extracted single root canal human teeth, instrumented and obturated with thermoplasticizable polymer of polyesters	Compared to the CB μ CT who didn't revealed any defects, the OCT investigation showed small micro leakage and defects inside if the endodontic material
Todea C. [41]	2010	En face optical coherence tomography investigation of apical micro leakage after laser-assisted endodontic treatment	Ex-vivo study on ninety single rooted human teeth with straight root canal and closed apices prepared with diode laser, Nd: YAG laser and with conventionally treatment.	OCT technology showed micro leakage in the apices areas but with no significant differences between the laser decontamination and preparation of the root canals and the conventional treatment.

Y. Natsume [42]	2011	Estimation of lesion progress in artificial root caries by swept source optical coherence tomography in comparison to transverse microradiography	Ex-vivo study on twenty-four bovine root dentin specimens comparing the images from before and after demineralization with OCT and TMR analysis	The OCT estimated the depth of lesion and the mineral loss with cavitated dentin lesions in vitro
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Table 1. Continued

Author	Year	Title	Methods	Results
Toshihiko Yoshioka [43]	2013	Detection of Root Surface Fractures with Swept-Source Optical Coherence Tomography (SS-OCT)	Ex-vivo analyze on twelve extracted mandibular teeth with a total of 25 roots without any caries, calculus or root treatment with micro-CT and SS-OCT technology.	SS-OCT showed the same but more effective results of the root fractures compared with the micro-CT
Yoshiko Iino [44]	2014	Detection of a Second Mesio Buccal Canal in Maxillary Molars by Swept-source Optical Coherence Tomography	Ex-vivo study on forty extracted human maxillary molars with a prepared access cavity mounted in autopolymerising resin and scanned with micro-CT, DOM and SS-OCT systems.	The OCT system showed significantly better results than DOM, being possible that the optical coherence tomography to exclude false positives found by the other system
J. Ding [45]	2014	Application of optical coherence tomography to identify pulp exposure during access cavity preparation using an Er:YAG laser	Ex-vivo study on twenty human mandibular incisors using an Er:YAG laser to penetrate the hard tissue over the pulp chamber and examined with micro-CT and OCT.	The OCT system can identify the pulp exposure during opening and access to the Er:YAG laser.

P. Majkut [46]	2015	Validation of optical coherence tomography against micro-computed tomography for evaluation of remaining coronal dentin thickness	In-vitro study on ten human molar teeth with deep occlusal dentin caries comparing the optical coherence tomography with micro-computed tomography.	OCT images showed better details of the anatomic shape of the pulp with higher backscatter intensities while the micro-CT presented well-distinguished contours.
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Table 1. Continued

Author	Year	Title	Methods	Results
Takuya Minamino [47]	2015	Non-destructive observation of teeth post core-space using optical coherence tomography: comparison with microcomputed tomography and live images	Ex-vivo study on three single and straight root canals comparing the differences between OCT and micro-CT technology on evaluating the resin core build-up treatment.	The use of optical coherence tomography showed superior and better images of gap formations while the images obtained with micro-CT were better for understanding the shape.

Nicola Scotti [48]	2016	Evaluation of composite adaptation to pulpal chamber floor using optical coherence tomography	Ex-vivo study on thirty intact upper molars with gutta-percha canal root filled covered with flowable composite, bulk layering of bulk fill flowable composite and oblique layering of nanohybrid composite analyzed using OCT.	OCT system showed less interfacial gaps when fluid resins were used and also the differences between the conventional flow and the bulk filling composite were presented.
Bruna Paloma de Oliveira [49]	2017	Detection of Apical Root Cracks Using Spectral Domain and Swept-source Optical Coherence Tomography	Ex-vivo study on twenty mandibular incisors prepared using reciproc system and scanned with micro-CR, SD-OCT and SS-OCT.	Detection capability was confirmed for both OCT system offering promising tools for diagnosing apical micro fractures.

Table 1. Continued

Author	Year	Title	Methods	Results
R. C. Lee [50]	2017	Activity assessment of root caries lesions with thermal and near-IR imaging methods	Ex-vivo study on artificial bovine and natural root caries lesion using PS-OCT, thermal and NIR cameras	The OCT system offered great details about the highly mineralized surface layer on both natural and simulated lesions, and the thermal imaging provided the most accurate diagnosis of root caries lesion cavity making them ideally suited for non-destructive root caries examination.

4. CONCLUSIONS

With the help of a semiflexible or flexible endoscope, the dentist can view real-time, three-dimensional images from inside the endodontic field with the ability to overcome certain difficulties encountered when using a microscope. Thus, the success rate of endodontic treatments is expected to increase.

OCT is an instrument that can be used to study different tissues in vivo and in vitro. With the help of the

optical coherence tomography it has been demonstrated the possibility of early diagnosis of dental caries in primary and permanent dentition, analysis of dental restorations, treatments and endodontic obturations, dental prosthetics quality analysis and diagnosis of periodontal diseases. It is an improvement of the usual radiographs, orthopantomography and alveolar radiography, being a non-invasive technique capable of providing three-dimensional real time images of the analyzed structures.

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