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Modern Evaluation of the Quality of the Techniques of Root Canal Dental Obturation

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ABSTRACT

1) *Background:* One of the key factors for a successful endodontic therapy is to adequately fill the root canals. The aim of this *in vitro* study was to compare the quality of three different techniques of root canal obturation: tapered single-cone, cold lateral condensation, warm vertical condensation and injection system, using non-invasive Optical Coherence Tomography (OCT). 2) *Materials and methods:* A total of 30 extracted single-rooted teeth, prepared with Reciproc System (VDW, silver Reciproc) were divided into three groups, based on the filling method: the first group obturated with "single-cone" (n=10) Reciproc guttapercha single-cone tapered according to the diameter, length and conicity of the preparation, the second group obturated with cold lateral condensation (n=10) and the third group, "combined-system" (E&Q META BIOMED) (n=10). OCT technology can generate high-resolution cross-sectional imaging, capable to evaluate the micro-leakages of dental restorations and endodontic fillings. 3) *Results:* OCT showed that none of the root canal filled teeth were gape-free; the highest percentage of filling material was observed in the combined system group (warm vertical and injection system). 4) *Conclusions:* OCT represents a valuable method for investigation with high depth resolution which can be used for evaluation of endodontic fillings.

Keywords: Dental medicine, biomedical imaging, Optical Coherence Tomography (OCT), root canal filling, non-invasive investigations.

1. INTRODUCTION

The dental obturation of the root canal is an essential stage of the treatment that is aimed to seal the root canal in order to prevent future bacterial contamination/recontamination of the canal space. Many dental obturation methods have been introduced over the years, each attempting to provide a better seal of the root canal. All have in common the assumption that the root canal is properly cleaned and shaped before the obturation stage [1-5]. It is assumed by all that if the root canal is not adequately prepared and if tissue remnants and debris are present along the walls, a proper sealing may be jeopardized, even with the best root canal filling method [6-8].

Optical Coherence Tomography (OCT) was first developed by Fujimoto's group at MIT in the early 1990s [9], and the method has since matured into an important clinical imaging modality [10-21]. The success of OCT in making such a rapid transition from research and development into the clinical setting [16,17] is not surprising given the numerous advantages that it offers to the clinicians. Thus, OCT is a non-invasive and non-destructive method for imaging the microstructural details of the tissue. It is comparable to ultrasound as both create a cross sectional image by measuring the echo time delay and intensity of the reflected and backscattered wavelength.

OCT is a non-invasive diagnostic tool to perform *ex vivo*, and it is showing great potential for *in vivo* structural imaging of features in the oral cavity. It can generate high-resolution cross-sectional and *en-face* images of the internal architecture in the investigated sample (1-2 mm in depth).

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2. MATERIALS AND METHODS

A total of 30 extracted single-rooted teeth were selected, with no root carries, restorations, or previous endodontic treatment. The teeth were stored in normal saline solution. The soft tissue remnants and calculus on the external root surface were removed mechanically.

All patients provided their informed consent, according to the regulations of the Ethics Committee of the “Victor Babes” University of Medicine and Pharmacy of Timisoara (Timisoara, Romania).

After preparing a standard access cavity in each tooth, a #10 k-file was introduced into the canals until the tip was just visible at the apical foramen. The working length was determined at 0.5 mm short of this measurement, after hand file using and establishing a glide path. The rotary files (Reciproc) were operated with a handpiece attached to the Reciproc Silver motor. The rotary files R25, R40, R50 were used according to the manufacturer’s protocol to clean and shape the root canal. Irrigation was performed during instrumentation with sodium hypochlorite (NaOCl) 5.25% and 17% Ethylenediaminetetraacetic acid (EDTA) solution. The canals were then rinsed with distilled water.

The samples were randomly divided into three experimental groups (n=10 samples/group):

Group 1: Single-cone (Reciproc tapered single-cone).

A single cone of gutta-percha tapered with a diameter and a conicity corresponding to the shaping instrument (R25, R40 or R50) was tried in the root canal after visual and thug-back control. The canal was dried with paper points. Adseal, MetaBiomed sealer was applied to the root canals, using paper points. Then, the single-cone was inserted to the working-length. The excess of gutta-percha was removed with a heated instrument.

Group 2: Cold lateral condensation.

Lateral condensation was done using standardized gutta-percha as the master cones, finger spreaders and medium-fine accessory cones (Dentsply Maillefer). The excess gutta-percha at the orifices was removed by a heated instrument and final compaction was done by a cold plugger.

Group 3: Combined-system (E&G MetaBiomed).

The apical third was filled by warm vertical condensation using heat carrier (DownPack) and hand pluggers chosen according to the root canals. The coronal two-thirds were filled with warm gutta-percha, injected by the backfill handpiece, following the manufacturer’s instructions. After canal obturation and sealing the access cavities by Filtek Z250 Composite (Germany, 3M), all the teeth were stored in normal saline until testing.

3. RESULTS

The quality of endodontic treatments and root canal fillings were investigated using the *en-face* Time Domain (TD)-OCT technology – Fig. 1. It was thus possible to identify areas of apical micro-leakage between the filling material of the root canal space, the gutta-percha and the root canal walls – Fig. 2.

The confocal image aids guidance and allows for focus adjustment in the OCT investigation. In order to obtain the images, section up to a depth of 2 mm were scanned. During the examination, it has been noticed that in some samples, defects were present in all sections to a full depth of 2 mm, while in others, defects were observed in a fewer layers. This observation allowed for a quantitative statistical analysis based on the number of sections in which defects were present.

OCT showed that none of the root canal filled teeth were gape-free. Voids were detected in all samples.

The highest percentage of filling material was observed in the combined system group (warm vertical and injection system), in comparison to the single-cone group and the cold lateral condensation group - Fig. 2.

Figure 1. Mounting a sample for an analysis with the TD OCT in-house developed system.

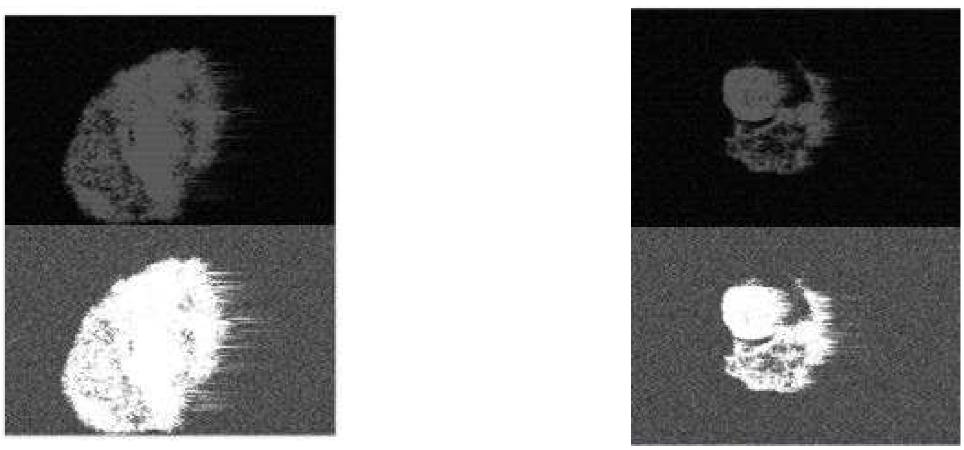

Figure 2. OCT images, using C-scan at 1300 nm sections, revealing that using the warm vertical condensation and injection system (left) resulted in the highest percentage of filling material, compared to cold lateral condensation (right).

4. DISCUSSION AND CONCLUSIONS

An adequate root canal filling should present higher volume of gutta-percha and a thin layer of sealer at the sealer / dentin interface. The presence of voids or gaps is not desirable for a satisfactory dental obturation due to the risk of fluid infiltration and to the consequent contamination of the root canal system.

Several methods have been used to evaluate the adaptation and quality of root canal fillings. Confocal laser microscopy can be used to visualize sealer adaption by adding a fluorescent dye in the sealer [22,23]. This method is recommended when it is necessary interfacial, and the presence of gaps at the sealer/dentin interface is verified. Stereomicroscopy can be also used to evaluate root canal fillings [22,24]. These latter two methods require sectioning the samples before the analysis.

Leakage tests are another method to analyse the adaptability of filling materials [22,25]. Micro-CT has been proposed and used to evaluate the quality of dental obturation techniques. The percentage of the volume of voids and gaps in the root canal can thus be calculated. The analysis includes the demarcation of voids and gaps in the 2D slices and then the reconstruction in a volumetric image.

3D images can also be obtained with cone beam computed tomography (CBCT), a method that is considered nondestructive, like micro-CT. CBCT has been used in endodontic research to evaluate several variables [25,26]. This equipment has the advantage to be faster for scanning in comparison with micro-CT, and consequently the levels of radiation exposure are lower [27]. This characteristic of CBCT allows for its use for clinical researches and *in vivo* analysis. Nonetheless, micro-CT has a higher resolution due the lower voxel size. CBCT is therefore indicated for *in vivo* analysis, while micro-CT is recommended for laboratory researches.

In dentistry, the scientific literature shows that OCT has been successfully used for acquiring images of: dental biofilm, attrited teeth, enamel erosion, dentin structures, vertical root fractures, and incipient carious lesions. It was also used for the evaluation of severity in advanced carious lesions and re-mineralization of root caries, dentin re-mineralization, lesion progress in root caries, for quantification of re-mineralization, as well as for determining the efficiency of different agents in the inhibition of demineralization. Additionally, several research groups have demonstrated that OCT is capable to evaluate the oral mucosa, the micro-leakages and internal defects of composite restorations, dental sealants and endodontic fillings, the root internal structure, the dental implant-abutment interface, and dental adhesives.

OCT is able to identify early signs of inflammation, unlikely to be detected by clinical examination. OCT imaging offers the exciting potential to detect peri-implantitis before significant osseous destruction occurs. OCT has also been employed for periodontal diagnosis, for evaluating the integrity of dental prosthesis, their quality, their marginal fitting and their adhesion to the tooth structure, for monitoring the periodontal ligament changes induced by orthodontic forces, and orthodontic interfaces.

Indeed, there are numerous studies that proved the existence of micro-leakage in the root canal obturation, from the die method penetration technique to gas argon penetration [28], micro CT (14) and even scanning electronic microscopy (SEM). A strong correlation was found between the micro–CT and OCT in the study validation of OCT against micro-CT for evaluation of remaining coronal dentin thickness [29]. However, none of these evaluation methods performed a comparison between the root canal obturation technique itself, like the one between cold lateral condensation, monocone and the warm injection technique, using the OCT system.

In this study the quality of endodontic treatments and root canal fillings were investigated with an *en-face* TD-OCT technology. It was possible to identify areas of apical micro-leakage between the filling material of the root canal space, the gutta-percha cones, and the root canal walls – Fig. 1. In order to obtain the images, sections up to a depth of 2 mm were scanned, thus quantifying the level at which defects appeared within the filling material or between the filling material and the gutta-percha material. During the examination, it some samples, defects were present in all sections to a full depth of 2 mm, while in others defects were observed in fewer layers.

In conclusion, OCT is a non-invasive and valuable method for investigation with high depth resolution, which can be used for evaluation of endodontic fillings.

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