IMAGING OF DEFECTS AT THE INTERFACE OF FIBER POSTS RESTORED ENDODONTICALLY TREATED TEETH

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INTRODUCTION

The restoration of severely destroyed teeth often requires intracanal posts.¹ A wide variety of prefabricated posts (stainless steel, zirconium, carbon, glass or quartz fibers) are available in dentistry, in different geometries and sizes.² The long-term performance of restorations in endodontically treated teeth with intracoronal posts depends on the retention of the post. The post must be cemented in the prepared root canal so that it cannot be dislodged by external forces.³ Failures of endodontic posts, however, predominantly result from either loss of retention or from root fracture. Post retention can be improved by the adhesive luting technique, comprising
dentin adhesives and resin-based luting cements.\textsuperscript{3–5} In addition, resin-bonded posts were demonstrated to reinforce the restored roots and showed less microleakage than conventionally cemented posts.\textsuperscript{1}

For the prevention of root fractures, the use of fiber posts has been recommended, because they are commonly supposed to have a similar modulus of elasticity as dentin. Based on theoretical considerations and on finite element analyses, Duret et al.\textsuperscript{6,7} postulated that posts should match the restored tissue, i.e. dentin, as closely as possible, especially regarding modulus of elasticity. As a result, loads applied to the restoration are assumed to be uniformly distributed to the supporting dentin and stress concentrations at the restorative interface are presumably avoided.\textsuperscript{8}

Isidor et al.\textsuperscript{9} observed significantly fewer fractures in roots restored with carbon fiber compared to titanium or cast gold posts. In addition, failure incidence was found to be more dominant in carbon compared to cast gold posts: although roots restored by carbon posts fractured at lower loads, the site of fracture in most cases was located within the core or post, thus allowing repair, which was not possible in fractured roots restored by gold posts where fracture was located within the root. Teeth restored using quartz fiber posts featured a higher resistance to fracture than was located within the root canal. Teeth restored using quartz fiber posts, adhesive luting cement and root canal wall and adhesive and operative procedures. The distribution of resin cement into the post space during the luting procedure and the anatomical and histological characteristics of the root dentine seemed to influence bond strength between resin luting agent and root canal regions. An adequate polymerization of luting agent is necessary to provide its mechanical properties, which clinically ensure post retention. Many current resin luting agents polymerize through a dual-curing process that requires light exposure to initiate the reaction. It has been reported that the mechanical properties of dual-cure type resin agents appear improved after photo-activation compared with chemical-activation alone. Dual-cure resin cements are different in their handling characteristics, compositions and properties (such as polymerization ability, flexural strength, hardness).\textsuperscript{10}

There is not much information in the literature about the sealing ability of fiber-post bonding. Although microleakage has been evaluated using various techniques, the fluid-filtration system is considered most adequate because it provides full quantitative volumetric data on sealing ability. In addition, thanks to this non-destructive methodology, each specimen can, immediately after sealing ability assessment, be subjected to a push-out bond strength test.\textsuperscript{11}

Several studies have demonstrated the potential of optical coherence tomography (OCT) to image both hard and soft oral tissues at high resolution. The OCT images provide microstructural details that cannot be obtained with any other imaging modalities.\textsuperscript{12} Therefore, OCT was proposed as a potential tool for in-vivo endodontic imaging.\textsuperscript{14,15} Using an en face\textsuperscript{16} version of OCT, we have recently demonstrated real time thorough evaluation of quality of root canal fillings.\textsuperscript{17–19}

The aim of this study was to analyze the quality of marginal adaptation and gap width between FRC posts, adhesive luting cement and root canal wall and to assess the quality of the interface after each fiber post luting using en face OCT (efOCT) method.

MATERIALS AND METHODS

Twenty four extracted single-root canal human teeth were horizontally sectioned at the cemento-enamel junction with a diamond disk. Each root was at least 12 millimeters in length. We instrumented all roots up to a no. 40 master apical file, 1 mm from the anatomical apex. The root canals were irrigated with 1% sodium hypochlorite, followed by 17% ethylenediaminetetraacetic acid (EDTA), which was left in place for three minutes in order to
remove the smear layer. Then, the teeth were flushed with saline solution. After the instrumentation was completed, standardized post spaces in all root canals were prepared to a depth of 8 mm, using the manufacturers’ corresponding post drill system (Fig.1). After post space preparation, each canal was rinsed with 17% EDTA and distilled water (in that order) and dried with paper points. The root canal walls were etched with phosphoric acid gel, rinsed with water and dried with paper points. In order to cement the posts into the prepared teeth, a primer/adhesive system was applied and a dual-cured resin based cement system was used. The cement and the bonding agent were mixed and handled precisely according to the manufacturers’ instructions. The cement was applied into the root canal using a lentulo spiral and the post was cemented to a length of 8 mm (Fig.2). After 15 minutes, the specimens were placed in a high-humidity environment at 37ºC for 48 hours before the investigation.

The scanning procedure was performed vestibular, oral, mesial and distal for each sample. All the samples were bonded with the same adhesive cement. A dual channel en-face OCT/CM system was used as described in one of our previous reports. The system uses a high NA interface optics allowing 1 mm image size. The OCT channel is driven by a super-luminescent diodes (SLD) emitting at 1300 nm and having spectral bandwidths of 65 nm, which determines an OCT longitudinal resolution of around 17.3 µm in tissue. The confocal channel is driven by an SLD at 970 nm.

RESULTS

The σOCT scanning revealed good interfaces, but also material defects within the thickness of the adhesive cement between the fiber posts and the root canal wall (fig.4-6).

Gaps between the root canal walls and luting cement on one hand and root luting cement and FRC post on the other hand are observed.

To assess the microleakage, it is necessary to understand the 3-D aspect of the root canal. Software visualization allows 3-D reconstruction of the interested area. The 3-D software can be used for frontal, sagittal, and axial analysis of the samples (fig.7).
Figure 4. C-scan OCT image (4 mm x 4 mm lateral size): good interface of composite adhesive luting cement and root canal wall at slice 10 from 94

Figure 5. C-scan OCT images (9.5 mm x 9.5 mm) at different depths. Sample nr.23. Material defects (MD) in the luting cement between the root canal walls (RCW) and the FRC post (P); The C-scan in b) is 0.13 mm deeper than the C-scan in a), while the C-scan in c) is deeper by 0.6 mm than the C-scan in b)

Figure 6. Sample nr.23. Material defects (MD) in the luting cement between the root canal walls (RCW) and the FRC post (P); (a) C-scan OCT image at a depth similar to that in fig. 5b), 4 mm x 4 mm lateral size; (b) B-scan OCT image, 4 mm lateral size, vertical size is along depth, 1.25 mm, measured in air, displaying a large material defect

Figure 7. 3-D reconstruction of the marginal microleakage area using a stack of 89 C-scan OCT images. Top volume is produced from images in the confocal channel. Bottom volume is produced from C-scan images delivered by the eOCT channel.

DISCUSSION

Bond strength to root-canal dentin is generally lower than to coronal dentin. Generally, no correlation has been found between bond strength and microleakage. The main factors that affect the bond strength into the root canal, such as the intensity of the interaction between the adhesive and dentin, the shrinkage stress due to the polymerization and the degree of polymerization, the potential presence of residual endodontic sealer or gutta-percha, and the occurrence of droplets, seem to be crucial for sealing at the interface as well. The formation of interface gaps within the root canal must mainly be ascribed to the quality of interaction between adhesive and dentin, and the unfavorable cavity configuration.

Various pretreatment procedures, such as silanization, hydrofluoric acid etching, sandblasting, and tribochemical silica coating, are currently being investigated for increasing the bond strength of the post to the luting cement.

Some authors noticed that the effects of silanization appeared to be clinically negligible, but the type of fiber post had a significant effect on bond strengths. Almost none of the groups showed adhesive failure between posts and luting materials. Accordingly, silanization had no significant effect on bond strengths in the present study.

Design of the fiber post is also an important factor for retention in the root canal. Parallel FRC posts are
reportedly to have better retention than tapered posts.\textsuperscript{7} A finite element analysis study reported that stresses were, in general, higher with tapered dowels than with parallel-sided dowels. Stresses were reduced by bonding and with an increasing modulus of elasticity, increasing diameter, and increasing length of the dowel.\textsuperscript{20}

CONCLUSIONS

The qOCT has numerous advantages which justify its use in the oral cavity in comparison with conventional dental imaging. It reveals material defects in the adhesive cement and also at the interfaces between the fiber posts/luting cement and adhesive cement/root canal wall. The results obtained in this study point out the existence of marginal adaptation failures and gaps between FRC posts, adhesive luting cement and root canal wall fillings. Such gaps could lead to line fractures in the mentioned interfaces, with failure of the restoration.

None of the investigated samples revealed homogeneous and tight seal at the post–cement–dentine interface. The bonding strategy and the unfavorable cavity configuration within the root canal might be mainly responsible for the high correlation between the bond strength and the sealing ability of the adhesive cement. The cement–dentine interface is the weakest part of the root–cement–post unit, which is well in line with the clinical findings.

The advantages of the used investigation method consist in its noninvasiveness and resolution in imaging extremely detailed structural morphology.

REFERENCES