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Effect of different lengths of post-space preparation on microcrack formation in root dentin: a micro-computed tomography assessment

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Purpose: The aim was to determine the effect of different lengths of post-space preparation on the incidence of root crack formation using micro-computed tomography (micro-CT).

Methods: Forty-two single and straight-rooted human mandibular premolar teeth were used. Teeth were randomly divided into two groups (n = 21). All teeth were scanned using micro-CT before and after the canal shaping, followed by filling with gutta-percha and a resin-based root canal sealer. Different lengths of post-space (1/2 [Group 1] and 2/3 [Group 2] of the canal length) were prepared for the teeth in Group 1 and Group 2. Teeth were again scanned with micro-CT.

Results: After the post-space preparation, no new microcrack formation was observed. As a result of the propagation of microcracks detected in the first scan, completed fractures were detected in 3 teeth in Group 1 and 2 teeth in Group 2.

Conclusion: It can be concluded that the different lengths of post-space preparation did not affect the incidence of microcrack formation in root dentin.

Keywords: Dentinal microcrack, micro-computerized tomography, post space preparation.

Introduction

Successful root canal treatment is based on correct diagnosis and treatment planning, knowledge of anatomy and morphology, and the traditional concepts of shaping, cleaning, and obturation. Endodontically-treated teeth significantly lose a large amount of tooth structure due to access cavity preparation (1). In such cases, restorative approaches have been suggested, such as intracanal post-application (2) and the use of endocrowns (3). Intracanal post-application is recommended to increase the retention of the final restoration (4). Among post-systems, fiber posts have advantageous physical properties, such as a similar modulus of elasticity with dentin and good bonding to dentin with the use of adhesive resins, besides being esthetically acceptable (5). As a result of these properties, a balanced stress distribution is achieved throughout the root structure (6).

The quantity of root dentin remaining after access cav-

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ity preparation and the preparation of post space plays an important role in the resistance of the tooth to fracture (7). However, preparing a deep canal space for a large diameter post can diminish the resistance of the tooth to fracture (8), preferring to insert the post too deeply can affect the apical seal (9,10). Some studies recommend the use of long fiber posts because they distribute stress better than shorter ones and provide more adhesive bonding areas, thereby reducing the risk of root fracture (11,12). In contrast, a study showed that the fracture strength of endodontically-treated teeth did not increase with an increase in the length of the placed post (13). However, another in vitro study showed that the use of resin-reinforced cement could compensate for the reduction in post-length (14).

Various methods, such as scanning electron microscopy (15), micro-CT (16,17), and/or root-sectioning methods (18), have been proposed to evaluate the effect of intracanal procedures, including root canal preparation and obturation on the formation of dentin microcracks. In recent years, micro-CT has become a widely used imaging modality in endodontic research (19,20). Using micro-CT, it is possible to increase the accuracy of in vitro experiments, as well as obtaining a three-dimensional view of the tooth before and after intracanal procedures without the need for sectioning (21,22).

The aim of this study was to evaluate the effect of different lengths of post-space preparation on microcrack formation in root dentin using micro-CT. The null hypothesis was that the formation of dentinal microcracks would not be affected by the length of post-preparation.

Materials and Methods

Ethical approval was obtained from the Ethics Committee of Erciyes University of Medical Sciences in Kayseri, Turkey (2017/557). Based on the data from a previous study (21), the results of power calculations indicated that the sample size for each group should be a minimum of 15. This value has been determined by projecting the power as 0.80, the effect size as 0.742, and the significant level as 0.05. Consequently, 21 teeth in each group were selected for this study. Forty-two extracted human mandibular premolar teeth with straight and single canals were selected and kept in 0.9% physiological saline solution until used. The teeth were examined under a dental operating microscope (OPMI Pico; Carl Zeiss, Germany) at ×16 magnification to exclude the presence of external defects or microcracks. Periapical radiography was taken from the mesial and distal angles to confirm that the teeth had single roots and single canal. Teeth with caries, resorption, or calcification, those which were endodontically-treated, or had fractures or microcracks were excluded from the study. The calculus and soft-tissue residue on the root surfaces of the selected teeth were removed. The teeth were then randomly divided into two groups (n = 21).

- G1: Teeth with a post-space prepared at 1/2 the canal length
- G2: Teeth with a post-space prepared at 2/3 the canal length.

First micro-CT Scan

All teeth were scanned by a 14-µm voxel size, 80-kV X-ray tube voltages, and 125-µA anode current using a micro-CT (Skyscan 1272, Bruker, Kontich, Belgium) after dividing into groups. The raw images obtained from scanning were saved in TIF format and were then reconstructed with NRecon v.1.7.4.2 software (SkyScan, Aartselaar, Belgium). As a result of the reconstruction, 45,592 axial section images of 14 µm/pixel size and 1632 × 1632 pixel resolution were obtained. Images obtained from the first scan were analyzed using CTAn (SkyScan, Aartselaar, Belgium) software. Teeth with "completed fracture" or vertical root fracture (VRF) were excluded from the study. Before the second scan, teeth matching the above criteria were included in the study in their place.

Root Canal Preparation

Access cavities were prepared for teeth in each group using a high-speed diamond bur (Brasseler USA, Savannah, GA) under water cooling. A #10 K-file was inserted into the root canal until its tip was visible at the major apical foramen, and the working length was determined by subtracting 1 mm from this length under a dental operating microscope (Carl Zeiss, Oberkochen, Germany). A silicon impression material (Zetaplus; Zhermack SpA, Badia Polesine, İtaly) was used to coat the surface of the roots to mimic the periodontal ligament space, and teeth were then embedded in acrylic resin. For the preparation of the root canals, Reciproc R25 and R40 files (VDW, Munich, Germany), were used in "Reciproc" mode of the X-Smart Plus (Dentsply Sirona, Switzerland) endodontic motor according to the manufacturer's recommendations. During each file change, the canals were irrigated with 2 ml of 2.5% sodium hypochlorite (NaOCl) solution. During the canal preparation, a total of 10 mL of 2.5% NaOCl were used for each tooth. After the root canal preparation, the final irrigation was completed using 5 mL of 0.9% saline solution, 5 ml of 17% ethylenediaminetetraacetic acid, and 5 mL of distilled water. A 29-G side-vented NaviTip irrigation needle (Ultradent, South Jordan, UT) was used during all irrigation protocols.

Second Micro-CT Scan

Teeth were stored in 0.9% saline solution until the scanning procedure commenced. Teeth in Groups 1 and 2 were scanned by micro-CT a 2nd time using the parameters from the first scan. Raw images were then reconstructed as in the first scan.

Root Canals Obturation and Post-Space Preparation

Root canals were obturated using a warm vertical compaction technique using AH Plus root canal sealer (Dentsply, DeTrey Konstanz, Germany). The coronal 3 mm of gutta-percha was removed from the canal with a heated plugger, and orifices were sealed with temporary filling material (Cavit: 3M ESPE, St Paul, MN). Teeth were stored for 1 week at 37°C and 100% humidity to allow the sealer to set. Gutta-percha was removed using a heated instrument, and the post-space was prepared using BISCO post-system drills (BISCO Dental Products, Schaumburg, IL, USA) of size #0.5 (apical diameter 0.8 mm and coronal diameter 1.25 mm) and size#1 (apical diameter 0.9 mm and coronal diameter 1.5 mm) to 1/2 of the canal length of the teeth in Group 1 and to 2/3 of the canal length of the teeth in Group 2. During each post-drill change, the root canals were irrigated with 2 ml of distilled water.

Third Micro-CT Scan

After the post-space preparation, all teeth were scanned for the 3rd time with a micro-CT device based on the parameters of the first scan. Raw images were then reconstructed as in the first scan. Teeth with "incomplete fracture" or VRF were recorded.

All cross-sectional images obtained during the micro-CT scans were screened by 2 previously calibrated observers who were blinded to the groups, aiming to identify the presence of dentinal microcracks. To validate the screening process, image analyses were repeated twice at 2-week intervals; in the event of any divergence, images were examined together until an agreement was reached.

Results

A total of 42 teeth (21 teeth in each of both Group 1 and Group 2) were initially scanned using micro-CT. The number of scanned sections in all teeth was 45,592. While the number of scanned sections in Group 1 was 22,768, the number of scanned sections in Group 2 was 22,824. After the first scan, the number of sections with incomplete microcracks in all teeth was 6,840 (15% of all teeth). While the number of sections with incomplete microcracks in Group 1 was 2,960 (13% of teeth in Group 1), the number of sections with incomplete microcracks in Group 2 was 3,880 (17% of teeth in Group 2). According to the results of the micro-CT scan after root canal preparation, no new microcracks were observed in either group (Fig. 1). According to the micro-CT scan after post-space preparation, no new microcracks were observed in either group. However, as a result of the propagation of the existing dentinal microcracks, completed fractures were detected in three teeth in Group 1 and in two teeth in Group 2 (Fig. 1).

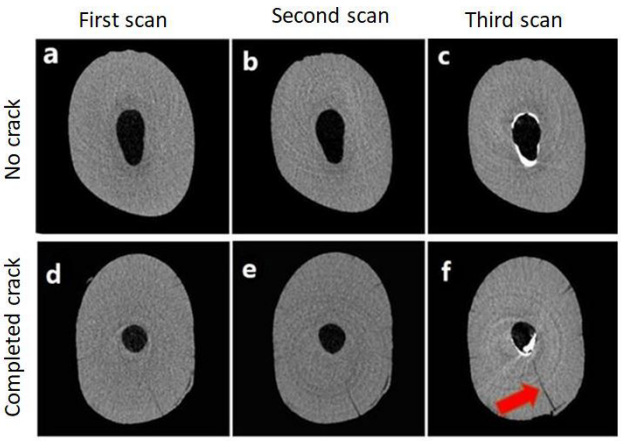

Fig. 1. Two specimens showing no-crack and completed microcrack. (a-c) show different scans of a no-crack sample. (d-e) show different scans of a sample with pre-exist microcrack. Red arrow shows crack propagation during post-space preparation (completed fracture)

Discussion

Endodontic procedures such as root canal shaping, obturation, retreatment, and post-preparation can produce dentinal microcracks. Post-preparation can cause excessive tissue loss, making teeth susceptible to VRF. Although the risk of VRF is higher in teeth placed by intracanal post, there are few studies that have evaluated the formation of dentinal microcracks after post-space preparation (23,24).

Micro-CT is a non-destructive, reproducible method that allows accurate two- and three-dimensional evaluation of the root canal system. By comparing specimens before and after the endodontic procedure, it is precisely determined whether pre-existing microcracks have progressed or new microcracks have formed (25). In many studies which have examined microcracks after root canal preparation and root canal obturation techniques, the presence of microcracks was investigated by sectioning from the roots. On the other hand, recent studies using micro-CT have shown that both root canal preparation and root canal obturation methods do not cause the formation of new microcracks (26-29).

As a result of the first micro-CT scan, no endodontic

procedures were performed, and a total of 45,592 cross-section images of 42 teeth were examined. It was determined that 15% of these sections examined had dentinal microcracks. In many micro-CT studies, microcracks were detected at different rates in the teeth examined before endodontic procedures (21,25,30). The cause of existing dentinal microcracks before endodontic procedures may be due to excessive force during tooth extraction (31) or may be based on patient and dental factors such as age, functional stress, early occlusal contacts, and parafunctional habits (32).

As far as we know, there have been no studies which have evaluated the effect of different lengths of post-space preparation on the formation of microcracks in root dentin using micro-CT. In addition, only one study has evaluated the effect of hand K files, Peeso reamer, and Para-Post XT Drills during the post-space preparation of the same length on microcrack formation using micro-CT. This study showed that dentinal microcracks were already present before the experimental procedure and increased significantly during root canal shaping and post-space preparation (32). In the present study, root canal preparation did not cause new microcracks. However, completed microcracks were observed in 2 teeth in G2 (9%) and in 3 teeth in G1(14%), as revealed by micro-CT scanning following post-space preparation at different lengths. These completed microcracks may be the result of the propagation of pre-existing microcracks. Post-space preparation has caused neither an incomplete new microcrack nor a completed new microcrack. The results in the present study indicate that post-space preparation caused the propagation of dentinal microcracks and is consistent with previous studies (23,32). Incomplete dentinal microcracks that existed before the endodontic procedures could be considered a triggering factor for completed dentinal microcrack formation, along with the reduction of dentin thickness during post-space preparation. Considering the clinical situation, the abovementioned patient-and dental-related factors may also trigger the turning of pre-existing incomplete microcracks into complete microcracks.

A deeper post-space preparation and the use of longer posts could result in the excessive removal of healthy dentin and reduced resistance to root fracture (33). Macedo et al. (34) evaluated the effect of the length of cementation on the pull-out bond strength of fiber posts and determined that the increased length of cementation caused improvement in the retention of posts. A recent study evaluating the bond strength of glass fiber posts cemented at different lengths using a pull-out test also showed that there is no statistical difference between the bond strength of posts cemented at 2/3 of the root length and posts cemented at 1/2 length of the root length (35). Given that the different lengths of post-space preparation in the current study did not make a difference in terms of the incidence of microcracks, in clinical applications, fiber posts of 2/3 length of the root can be used safely in the absence of anatomical difficulties.

Conclusions

Within the limitations of this study, no new microcrack formation was observed after different lengths of post-space preparation. Pre-existing incomplete microcracks could be propagated into completed microcracks or VRFs after post-space preparation. Further studies are needed to investigate the effects of different variables, such as post-drill design and diameter during post-space preparation.

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Informed consent: Written informed consent was obtained from patients who participated in this study.

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