Removal of Filling Materials from Oval-shaped Canals Using Laser Irradiation: A Micro–computed Tomographic Study

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Abstract

Introduction: The aim of this study was to assess the efficacy of lasers in removing filling remnants from oval-shaped canals after retreatment procedures with rotary instruments using micro–computed tomographic imaging. **Methods:** The root canals of 42 mandibular canines were prepared and obturated using the warm vertical compaction technique. Retreatment was performed with rotary instruments, and the specimens were distributed in 3 groups (n = 14) according to the laser device used in a later stage of retreatment procedure: Er:YAG, Er:YAG laser–based photon-induced photoacoustic streaming, and Nd:YAG. The specimens were scanned in a micro–computed tomographic device after root canal filling and each stage of retreatment at a resolution of 13.68 μm. The percentage differences of the remaining filling material before and after laser application within and between groups were statistically compared using the paired sample t test and 1-way analysis of variance test, respectively. Significance level was set at 5%. **Results:** Overall, filling residues were located mainly in the apical third and into canal irregularities after the retreatment procedures. After using rotary instruments, the mean percentage volume of the filling remnants ranged from 13%–16%, with no statistical significant difference between groups ($P > .05$). Within groups, additional laser application had a significant reduction in the amount of the remaining filling materials ($P < .05$). A comparison between groups showed that Er:YAG laser application after the use of rotary instruments had a significantly higher removal of filling remnants (~13%) than Er:YAG laser–based photon-induced photoacoustic streaming (~4%) and Nd:YAG (~3%) ($P < .05$). **Conclusions:** None of the retreatment procedures completely removed the filling materials. The additional use of lasers improved the removal of filling material after the retreatment procedure with rotary instruments. *(J Endod 2015;41:219–224)*

Key Words

Er:YAG laser, gutta-percha removal, micro–computed tomography, Nd:YAG laser, photon-induced photoacoustic streaming, retreatment

Root canal procedures involve the use of instruments and substances to clean, shape, and disinfect the root canal system as well as materials to fill the root canal space. Although recent advances in endodontic instruments and devices have made proper root canal treatment more predictable, failure can occur (1). In cases in which endodontic therapy has failed, the nonsurgical approach has been the preferred treatment. The main goal of nonsurgical canal retreatment is to re-establish healthy periapical tissues by the removal of the root canal filling materials, further cleaning and shaping, and refilling (2). Therefore, the removal of as much filling material as possible from an inadequately prepared and/or filled root canal system is necessary to uncover remaining necrotic tissues or bacteria that might be responsible for periapical inflammation and, thus, post-treatment disease (3, 4).

Traditionally, root canal retreatment has been accomplished using solvent and hand files (5). An attempt to use rotary nickel-titanium (NiTi) instruments specifically designed for retreatment, such as the R-Endo system (Micro-Mega, Besançon, France), has led to the development of a more efficient way to remove the bulk of the filling materials in comparison with conventional techniques (6, 7). Unfortunately, several reports showed substantial amounts of filling remnants in the canal after retreatment using rotary instruments (4, 6–10). Despite the fact that it has not been proved that the complete removal of filling materials can improve the outcome of the retreatment procedure (3, 11), filling remnants can theoretically impair disinfection by avoiding irrigants to contact the persisting microorganisms. During this process, the anatomy of the root canal system must always be taken into account because the cross-sectional root canal shape has been reported to significantly influence the retreatment procedure (4). Although in straight canals with a round cross-section the operator may simply use rotary files of greater dimensions in order to remove filling residues (12), the retreatment of oval-shaped canals requires additional procedures (4, 7, 9, 13–15) because further enlargement may create complications such as root perforation or canal transportation (16).

Additional attempts to improve the removal of filling remnants have been made with ultrasonic systems, heat-carrying devices, solvents, and lasers (17). The application of lasers in retreatment procedures relies mainly on the thermal effect of irradiation, which presents evidence to improve the removal of filling remnants (18–21). Recently, photon-induced photoacoustic streaming (PIPS), a new laser-activated irrigation system device, has been introduced. This system uses a very low-power source

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(subablative) to rapidly pulse laser light energy, which is absorbed by the molecules within the irrigant. This transfer of energy results in a series of rapid and powerful shock waves capable of forcefully propelling the irrigant throughout the root canal system (22, 23).

Currently, despite some types of lasers being tested as an adjunct in nonsurgical retreatment (18–21), no study has investigated the use of PIPS in a later stage of endodontic retreatment. Thus, the aim of this study was to assess the efficacy of lasers in removing filling remnants from oval-shaped canals after retreatment with rotary instruments using micro–computed tomographic (micro-CT) imaging. The null hypothesis tested was that there is no difference in the percentage of filling remnants with the additional use of laser after a first retreatment stage with rotary instruments.

Materials and Methods

Sample Selection

After ethics committee approval (protocol #116/2013), 110 straight single-rooted extracted mandibular canines were initially selected on the basis of radiographs (Belmont Phot-X II; Takara Belmont Corp, Osaka, Japan) taken in both buccolingual and mesiodistal directions to detect any possible root canal obstruction. All teeth presenting apical curvature, previous endodontic treatment, resorptive defects, or more than 1 root canal were excluded. The specimens were disinfected in 0.1% thymol solution and stored in distilled water at 4°C.

To attain an overall outline of the internal anatomy, each tooth was scanned in a micro-CT device (SkyScan 1172; Bruker-microCT, Kontich, Belgium) at an isotropic resolution of 13.68 μm, 100 kV, 100 μA, 180° rotation around the vertical axis, rotation step of 0.4°, and camera exposure time of 1900 milliseconds. X-rays were filtered with a 500-μm-thick aluminum filter and a 38-μm-thick copper filter. Frame averaging of 2 and random movements were also applied to the acquisition phase for increasing signal-to-noise ratio and reducing ring artifacts. The acquired projection images were reconstructed into cross-section slices (NRecon v.1.6.9, Bruker-microCT), and 3-dimensional models of the canals were obtained. Additionally, morphologic parameters of the canals (root length, volume, surface area, and structure model index) were calculated using CTAn v.1.14.4 software (Bruker-microCT). Then, 42 mandibular canines presenting the ratio of the long to the short diameter of the canal >2 at 5 mm from the apex and >3 at 8 mm from the apex were selected. These teeth were matched to create 14 threesomes based on the morphologic aspects of the root canals. One tooth from each threesome was randomly assigned to 1 of the 3 experimental groups (n = 14). After checking the normality assumption (Shapiro-Wilk test), the degree of homogeneity (baseline) of the 3 groups with respect to the morphologic parameters of the root canals was confirmed by 1-way analysis of variance test (P > .05).

Root Canal Preparation

Root canals were accessed, and the coronal third was flared with a #3 LA Axxess Stainless Steel bur (SybronEndo, Orange, CA) followed by irrigation with 5 mL 2.5% sodium hypochlorite (NaOCl). Patency was confirmed by inserting a size 10 K-file (Dentsply Maillefer, Baillagues, Switzerland) through the apical foramen before and after completion of root canal preparation. For all groups, a glide path was created by scouting a stainless steel size 15 K-file (Dentsply Maillefer) up to the WL, which was established by deducting 1 mm from the canal length.

The root canals were then serially enlarged by a single experienced operator with Revo-S NiTi rotary instruments (Micro-Mega) driven by a torque-controlled motor (W&H, Bürmoos, Austria) using a gentle in-and-out motion in a crown-down manner. SC1, SC2, and SU instruments were used up to the WL, resulting in an apical third shaped to a size 25, 0.06 taper. Then, the sequence was completed using apical preparation instruments (AS 30, 35, and 40) up to the WL. Apical enlargement was finished manually with a size 45 K-File (Mani Co, Tokyo, Japan). Between each preparation step, irrigation was performed using disposable syringes with a 30-G NaviTip needle (Ultradent, South Jordan, UT) inserted 1 mm short of the WL in a total of 20 mL 2.5% NaOCl per canal. A final rinse with 5 mL 17% EDTA (pH = 7.7), delivered at a 1-mL/min rate for 5 minutes, followed by a 5-minute 5-mL rinse with bidistilled water was performed. Then, canals were dried with absorbent paper points (Dentsply Maillefer).

Root Canal Filling

Root canals were obturated using the warm vertical compaction technique (BeeFill 2in1; VDW, Munich, Germany). After coating the canal walls with a thin layer of sealer (AH Plus; Dentsply DeTrey GmbH, Konstaz, Germany), a size 45, 0.02 taper gutta-percha master cone (Aceone-Endo; Aceonedent Co, Geonggi-Do, Korea) coated with sealer was fit with tug back to the WL. The sequential removal of thermoplasticized gutta-percha and vertical condensation of the remaining filling materials were completed when an ISO size 60 hot plugger (BeeFill Downpack, VDW) was 3–4 mm from the WL. The canals were then backfilled using the BeeFill Backfill unit (VDW) according to the manufacturer's instructions. Radiographs were taken in both buccolingual and mesiodistal directions to confirm the adequacy of root canal filling. If voids were observed in the obturation mass, the specimen was replaced by another one with similar canal morphology. Then, the specimens were stored at 37°C and 100% relative humidity for 1 week to allow the complete setting of the sealer.

Root Canal Retreatment

The retreatment procedure was performed with R-Endo NiTi rotary instruments driven by a torque-controlled motor (W&H) set to 340 rpm with circumferential filing action. The R-Endo Re instrument (15 mm; size 25, 0.12 taper) was used up to 3 mm beyond the canal orifice followed by the R1 instrument (15 mm; size 25, 0.08 taper) to the beginning of the middle third. Then, R2 (19 mm; size 25, 0.06 taper) and R3 (23 mm; size 25, 0.04 taper) instruments were used to the apical third. Considering that the teeth were not decoronated with the purpose of making a sufficient reservoir for the laser activation of the irrigants, R-Endo instruments were not able to reach the WL. Therefore, retreatment was further accomplished manually using a size 45 K-file (Dentsply Maillefer) to the WL. Each canal was irrigated with 5% NaOCl solution between files in a total of 20 mL per canal. The instruments were replaced after 4 canals, and retreatment was considered completed when the WL was reached, no material was observed between the flutes of the instruments, and the irrigating solution appeared clear of debris after the final rinse. Then, apex was sealed with 2 layers of nail varnish, and a flip of a coin was used to define which experimental group would be treated with each of the following additional applications of laser irradiation:

Group 1 (n = 14): Irradiation with an Er:YAG laser (2,940 nm, Fidelis AT; Fotona, Ljubljana, Slovenia) at 1 W, 20 Hz, and 50 mJ per pulse in the very short pulse mode (VSP) delivered with a 14-mm-long optic fiber plain tip (Ø = 300 μm). The laser was activated after the tip of the optic fiber was placed 3 mm from the WL. Then, the tip was withdrawn gently from the apical to the coronal region with helical movement and reintroduced to the apex.

Group 2 (n = 14): Irradiation with an Er:YAG laser (2940 nm, Fotona) at 1 W, 20 Hz, and 50 mJ per pulse in the VSP mode delivered with a 14-mm-long tapered PIPS fiber tip (Ø = 300 μm). The tip

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