Elimination of Intracanal Tissue and Debris through a Novel Laser-activated System Assessed Using High-resolution Micro–computed Tomography: A Pilot Study

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Abstract

Introduction: Laser-activated irrigation to remove organic debris from canal isthmuses was investigated using x-ray microfocus computed tomographic imaging. **Methods:** A total of 14 extracted human mandibular molars were used. The mesial canals were prepared using a standardized instrumentation protocol. Two groups (n = 7) underwent final irrigation using either standard needle irrigation (SNI) or photon-induced photoacoustic streaming (PIPS). After enlarging canals to 30/.06, canal volumes were reconstructed from micro–computed tomographic scans before and after irrigation to assess removal of organic tissue and inorganic debris by quantitative analysis of the superimposed volumes. Comparisons of the volumes were made using 2-way analysis of variance and Tukey method, with statistical differences considered significant at the alpha = 0.05 level. **Results:** Debris removal and an increase in root canal system volume for the laser-activated PIPS group was more significant ($P < .001$) than for the SNI group ($P = .04$). Irrigation using PIPS increased the canal volume and eliminated debris from the canal system 2.6 times greater than SNI. **Conclusions:** Eliminating debris from complex canal spaces found in mandibular molars was achieved at a significantly greater level using laser-activated PIPS irrigation compared with SNI. *(J Endod 2014;40:584–587)*

Key Words

Er:YAG laser, photon-induced photoacoustic streaming, root canal disinfection

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Essential to the success of endodontic treatment for teeth with apical pathosis is the elimination of microorganisms and their byproducts from the root canal system (1, 2). It would appear that a limiting factor in canal disinfection is the inability to adequately have irrigant enter canal isthmuses because they are blocked by hard tissue created during mechanical preparation (3) or infected pulp tissues and their associated microbes. Additionally, the blockage of canal isthmuses prevents fluid interchange regardless of the volume of irrigant (4–6). Examination of the intricacies associated with molars, the most commonly treated teeth even among general dentists (7), has shown that the isthmus remains untouched during canal preparation (8). Examination of the apical 5 mm of molars found the incidence of canal isthmuses and complex systems to range from 17.25% to 80% (4, 5, 9, 10), which if left untreated could account for post-treatment disease (11). Enlarging canals to include isthmus preparation would result in gross enlargement and likely root perforation while not significantly increasing the amount of contact of the instrument to dentin in the canal (12).

The elimination of microbes has been shown to be enhanced when using lasers in canal disinfection (13). Recently, canal disinfection protocols such as photodynamic therapy have been investigated to decrease the intracanal bacterial load (14). Targeted delivery of photosensitizer into the root canal system complexities still proves challenging, and elimination of bacteria is not guaranteed. Another laser-activated approach, photon-induced photoacoustic streaming (PIPS) involving agitation of standard intracanal irrigants, has been shown to create explosive vapor bubbles with secondary cavitation effects, enhancing fluid interchange and the removal of debris (15–17). Laser activation using a modified tip design has shown the removal of the smear layer in the presence of EDTA (18, 19).

A novel 9-mm-long, 600-μm quartz tip for use in an Er:YAG laser has been developed that transfers energy into the irrigant causing removal of organic debris with only a minor increase in tooth temperature. PIPS is a nonthermal subablative phenomenon that has also been shown to eliminate the smear layer in the presence of EDTA (19) and provide more negative bacterial samples than ultrasonic activation (20). The tip is tapered and stripped of its polyamide sheath 3 mm from its end. PIPS has the potential to remove tissue from intricate canal anatomy and, with the use of an appropriate irrigant, provide better canal disinfection (19). The aim of this study was to assess the change in root canal system volume by the removal of tissue from the radicular pulp space using PIPS laser activation assessed using micro–computed tomographic (micro-CT) scanning.

Materials and Methods

For the purpose of this study, 16 recently extracted vital human mandibular molars had only their mesial roots prepared. Tooth length was standardized by grinding the occlusal plane flat and embedding each tooth in a matrix that allowed precise positioning on the micro-CT stage. Scanning of all specimens before access cavity preparation was performed using micro-CT imaging (Varian Medical Systems, Palo Alto, CA) at 75 kV and 100 μA through 180° of rotation around the vertical axis and a single rotation step of 0.9° during a 15-minute scan with a source to object distance of 300 mm and

a cross-sectional pixel size of approximately 30 μm. Each slice was a 16-bit addressable 1,024 × 1,024 area that was used to create a 1-K 3-dimensional image volume-rendered representation to screen for the presence of an isthmus (VG Studio Max 2.2; Volume Graphics GmbH, Heidelberg, Germany).

Access cavity preparation was performed. The working length was established by visualizing an ISO #10 file at the canal terminus and subtracting 0.5 mm, which provided the canal preparation length. Instrumentation was completed to size 30/.06 (ProFile Vortex; Dentsply Tulsa Dental Specialties, Tulsa, OK) in a crown-down fashion. The apical size determination was dictated by the ability to irrigate to within 1 mm of the working length using a 30-G side-vented Luer-Lok needle (ProRinse, Dentsply Tulsa Dental Specialties). Samples were irrigated using 10 mL 6% sodium hypochlorite (The Clorox Co, Oakland, CA) during canal preparation, and canal patency was maintained. The pulp chamber was flooded with sodium hypochlorite and replenished with 1 mL irrigant after each instrument. The samples underwent a definitive scan with a slice thickness of 16.84 μm, designated the primary scan, from which the root canal system's initial volume was calculated. Teeth were randomly divided into the following experimental groups:

Group 1 (*N* = 7): Standard Needle Irrigation

The standard needle irrigation (SNI) protocol after canal preparation involved irrigation with a 30-G side-vented Luer-Lok needle delivering 4 mL 17% EDTA (Roth Drug Co, Chicago, IL) over a period of 60 seconds at a distance 1 mm short of the working length. This was followed by SNI of 10 mL 6% sodium hypochlorite delivered over 30 seconds.

Group 2 (*N* = 7): PIPS Laser-activated Irrigation

The PIPS protocol was followed exactly according to the manufacturer's instructions by a clinician proficient with the PIPS protocol. A 2,940-nm wavelength Er:YAG laser was used (Fidelis; Fotona, Ljubljana, Slovenia) at 15 Hz and 20 mJ using a 9-mm-long, 600-μm diameter endodontic fiber with the polyamide tip stripped back 3 mm. The tip was placed into the access cavity only and activated with each of the following irrigating solutions as they were applied into the access cavity with a 28-G irrigating needle:

1. Three 30-second cycles of continuous flow sodium hypochlorite
2. A 30-second cycle of water
3. A 30-second cycle of EDTA
4. Three 30-second cycles of water

The total volume of sodium hypochlorite and EDTA was the same as for the SNI group.

Controls (*N* = 2)

Two samples served as controls and underwent canal preparation to size 30/.06 (ProFile Vortex, Dentsply Tulsa Dental Specialties), irrigating with 6% sodium hypochlorite but without any postpreparation irrigation or PIPS.

A second micro-CT scan was performed on both groups and controls using the same parameters as the first scan. The pre- and post-backscatter projections were geometrically aligned with pin registration, and the 3-dimensional data sets were superimposed. The total volume from each scan was derived from voxels with black color interpreted as soft tissue, liquid, or air. Opaque (bright) voxels were interpreted as debris within the confines of the radiopaque canal walls. The removal of opaque voxels from each sample following irrigation protocols created a second canal volume. The data derived from the difference between the pre- and postirrigation regimens was recorded and analyzed.

Measuring the same teeth both before and after different irrigation regimens allowed the use of repeated measures statistical tests, thereby increasing statistical power by controlling for the variability in canal volume between teeth. The measurements in pre- and post-SNI and PIPS groups passed the Shapiro-Wilk test for normality (P = .44) and had equal variances (P = .91), so repeated measures 2-way analysis of variance was used to detect the interactive effects and Tukey HSD (α = 0.05). The power calculation for the sample size in the present study was 0.998. SigmaPlot 12.3 (Systat Software Inc, Chicago, IL) was used to conduct statistical analyses.

Results

No significant difference in the initial root canal system volumes between each group existed. There were significant differences between the SNI and PIPS irrigation groups and the time of measurement (pre- or post-irrigation) factors (P = .02). Although both treatments resulted in a significant increase in root canal system size, the interaction in the increase in debris removal was more significant for PIPS (P < .001) than for SNI (P = .04). The mean increase in the canal volume for PIPS (1.51 mm^3) was × 2.6 greater than for SNI (0.58 mm^3). Control samples represented no effective change in the root canal system volumes between scans.

Discussion

This *in vitro* study attempted to examine the effectiveness for intracanal debris removal using SNI and PIPS laser-activated irrigation assessed using micro-CT imaging from the mesial roots of freshly extracted vital mandibular molars. All samples exhibited complex root canal systems that included the presence of cul-de-sacs and isthmuses, which act as an impediment to allowing interchange of irrigants or intracanal medicaments when occupied by organic tissue and microbes or blocked by inorganic debris from instrumentation techniques. Given the anatomic complexities and the inability to remove hard and soft tissue debris, it is logical that the success rate for mandibular molar endodontics has been shown to be lower compared with other teeth (21). A previous study of complex root canal systems found isthmuses and regions secondary to the main canals to account for almost half the canal system, with the investigators unable to eliminate debris from the isthmus area using SNI (22). This finding is in agreement with a previous investigation that showed hard tissue accumulation in the canal system isthmus after canal preparation (3). However, no irrigation was used in the study. In the current investigation, there was a tendency for debris to be retained in the isthmus area because instrumentation debris was packed laterally into the isthmus. We found that this packed organic and inorganic debris was removed 2.6 times greater volumetrically using the PIPS irrigation protocol (Fig. 1*A–I*) as compared with SNI (Fig. 2*A–C*).

Some authors have suggested the need for large canal preparations (ie, greater than #60) to enable a 28-G needle to reach the canal terminus and reduce the microbial load significantly (23). Inherent in large apical size preparations is the potential for canal transportation while canal ramifications remain untouched by any instrument (24). Only energized irrigation sources have been shown to permit fluid interchange throughout the root canal system and the disruption of tissue and the significant removal of debris (25). This study used 30-G needles to ensure canal penetration to within 1 mm of the working length during SNI.