Impacts of Conservative Endodontic Cavity on Root Canal Instrumentation Efficacy and Resistance to Fracture Assessed in Incisors, Premolars, and Molars

Rajesh Krishan, DDS, Frank Paqué, DMD,† Arezou Ossareh, BASc,* Anil Kishen, MDS, PhD,* Thuan Dao, DMD, MSc, PhD,‡ and Shimon Friedman, DMD**

Abstract

Introduction: Conservative endodontic cavity (CEC) may improve fracture resistance of teeth but compromise the instrumentation of canals. This study assessed the impacts of CEC on both variables in 3 tooth types. **Methods:** Extracted human intact maxillary incisors, mandibular premolars, and molars (n = 20/type) were imaged with micro–computed tomographic imaging (20-μm resolution) and assigned to CEC or traditional endodontic cavity (TEC) groups (n = 10/group/type). Minimal CECs were plotted on scanned images. Canals were prepared with WaveOne instruments (Dentsply Maillefer, Ballaigues, Switzerland) using 1.25% sodium hypochlorite and post-treatment micro–computed tomographic images obtained. The proportion of the untouched canal wall (UCW) and the dentin volume removed (DVR) for each tooth type was analyzed with the independent-samples t test. The 60 instrumented and 30 intact teeth (negative control, n = 10/type) were loaded to fracture in the Instron Universal Testing machine (Instron, Canton, MA) (1 mm/min), and the data were analyzed with 1-way analysis of variance and the Tukey test. **Results:** The mean proportion of UCW was significantly higher ($P < .04$) only in the distal canals of molars with CEC (57.2% $\pm$ 21.7%) compared with TEC (36.7% $\pm$ 17.2%). The mean DVR was significantly smaller ($P < .003$) for CEC than for TEC in incisors (16.09 $\pm$ 4.66 vs 23.24 $\pm$ 3.38 mm^3), premolars (8.24 $\pm$ 1.64 vs 14.59 $\pm$ 4.85 mm^3), and molars (33.37 $\pm$ 67.71 mm^3). The mean load at fracture for CEC was significantly higher ($P < .05$) than for TEC in premolars (586.8 $\pm$ 116.9 vs 328.4 $\pm$ 56.7 N) and molars (1586.9 $\pm$ 196.8 vs 641.7 $\pm$ 62.0 N). In both tooth types, CEC did not differ significantly from the negative controls. **Conclusions:** Although CEC was associated with the risk of compromised canal instrumentation only in the molar distal canals, it conserved coronal dentin in the 3 tooth types and conveyed a benefit of increased fracture resistance in mandibular molars and premolars. *(J Endod 2014;40:1160–1166)*

Key Words

Dentin volume removed, endodontic cavity, fracture resistance, instrumentation efficacy

Traditional endodontic cavity (TEC) designs for different tooth types have remained unchanged for decades with only minor modifications. Highlighting "convenience form" and "extension for prevention" (1), TEC promotes the controlled removal of tooth structure beyond gaining access to canal orifices to facilitate cleaning, shaping, and filling of root canals and to prevent procedural complications (1, 2). Consequent removal of tooth structure, coronal to the pulp chamber, along the chamber walls, and around canal orifices, may undermine the resistance of the tooth to fracture under functional loads (3–5). Indeed, fractures and possible subsequent extraction of root-filled teeth (6–9) have undermined the confidence of dentists and patients in the long-term benefits of endodontic treatment (5, 10).

Recently, Clark and Khademi (10, 11) modified the endodontic cavity design to minimize tooth structure removal. In departure from the completely unroofed, coronally divergent, straight-line access to canal curvatures, the conservative endodontic cavity (CEC) preserves some of the chamber roof and pericervical dentin (10). Clinically, the smallest CEC possible for each tooth can be outlined on cone-beam computed tomographic (CBCT) images (12) by plotting the trajectory toward each canal. Although the preserved tooth structure may offer a benefit of improved fracture resistance under functional loads (5), the confined CEC outline restricts cleaning, shaping, and filling of the root canals (10, 11), increasing the risks of inefficient canal instrumentation and the occurrence of procedural errors (2). Specific investigation into CEC is warranted to assess the associated risks and benefits for different tooth types.

Mechanical efficacy of canal instrumentation is routinely assessed with nondestructive micro–computed tomographic (micro-CT) imaging (13–18). Analysis of pre- and postoperative micro-CT images enables measurements of changes in root canal morphology, including volume of the dentin removed and canal wall surface areas untouched by instruments (13–18). Fracture resistance of teeth is routinely assessed by simulated functional loading in the Instron Universal Testing machine (Instron, Canton, MA) until fracture occurs (19, 20). Loading point, force, and direction can be controlled and the load at fracture recorded (19, 20).

From the *Disciplines of Endodontics, University of Toronto, Toronto, Ontario, Canada; †Department of Endodontology, University of Zurich, Zurich, Zurich, Switzerland; and ‡Disciplines of Prosthodontics, University of Toronto, Toronto, Ontario, Canada.

Address requests for reprints to Dr Shimon Friedman, Faculty of Dentistry, University of Toronto, 124 Edward Street, Toronto, Ontario M5G 1G6, Canada. E-mail address: s.friedman@utoronto.ca

0099-2399/$ - see front matter

http://dx.doi.org/10.1016/j.joen.2013.12.012

The objectives of this study were to assess the potential risks and benefits associated with CEC in different tooth types. The specific aims were to characterize canal instrumentation performed through CEC and TEC regarding the (1) proportion of the untouched canal wall area (UCW), (2) volume of dentin removed (VDR), and (3) load at fracture under dynamic loading. We hypothesized that when comparing CEC with TEC, UCW would be significantly higher, VDR significantly less, and the load at fracture significantly higher. We also hypothesized that (4) the load at fracture would be significantly lower for both CEC and TEC than in the negative control.

Materials and Methods

After ethics approval (reference #27381), 90 previously extracted human noncarious, mature, intact, maxillary central incisors, mandibular second premolars, and mandibular first molars were selected to represent the 3 main tooth types (n = 30 teeth/type). Teeth were stored in a 0.1% thymol solution at 4°C until used. They were radiographically exposed (Digora Soredex, Helsinki, Finland) from 2 perpendicular views; their mesial-distal and buccal-lingual dimensions, length, and degree of canal curvature were used to match teeth within each type when allocated into groups.

Sample Size and Groups

In the absence of directly applicable fracture resistance data, studies on root canal instrumentation efficacy were used as reference (14–18); these studies typically assessed 6–30 canals/group and reported differences in the proportion of UCW ranging from 4%–100%. The sample size was set at 10 teeth/type (10 and 30 canals/group for incisors/premolars and molars, respectively) to analyze minimal differences in the proportion of UCW of 12% (incisors/premolars) and 23% (molars) with 80% power and 5% significance. For each tooth type, 20 teeth were equally assigned to groups CEC (experimental) and TEC (control), and 10 teeth were assigned to negative control for fracture testing only.

Instrumentation Efficacy and Volume of Dentin Removed

Teeth in the CEC group were mounted in a custom-made device (17) and imaged with micro-CT (μCT 40; Scanco Medical, Brüttisellen, Switzerland) at an isotropic resolution of 20 μm (pretreatment scan). Scans were used to plan CEC outlines by projecting the access trajectory to each canal orifice that required the least tooth structure removal. CECs were drilled with diamond burs (F392-016; Axis Dental, Coppell, TX) at high speed. Incisors were accessed 1 mm palatal to the incisal edge, and cavities extended apically along the long axis. Premolars were accessed 1 mm buccal to the central fossa, and cavities extended apically, maintaining part of the chamber roof and lingual shelf. Molars were accessed at the mesial quarter of the central fossa, and cavities extended apically and distally while maintaining part of the chamber roof (Fig. 1*A*). Canals were located while minimizing mesial-distal, buccal-lingual, and circumferential pericervical dentin removal. Teeth in the TEC group were prescanned as described earlier but had traditional endodontic cavities prepared (1, 2) (Fig. 1*A*). The enamel in all teeth was beveled with a tapered diamond bur.

Canals were negotiated with size 10 K-type files (Flexofile; Dentsply Maillefer, Ballaigues, Switzerland) to the major apical foramen as observed under the microscope at 4× magnification. The working length was established 0.5 mm short of the portal of exit. A glide path was established with a size 15 K-type file and canals instrumented to length with WaveOne reciprocating instruments (Dentsply Maillefer). The primary instruments were used in the premolars and mesial canals of molars; large instruments were used in the incisors and distal canals of molars. Canals were intermittently irrigated with 5 mL 1.25% sodium hypochlorite using ProRinse side-vented 30-G needles (Dentsply Tulsa Dental Specialties, Tulsa, OK). After cleaning and shaping, teeth were imaged again with micro-CT imaging at 20 μm to capture the instrumented canal shape (post-treatment scan).

Pre- and post-treatment scans were precisely repositioned through a software-controlled iterative superimposition algorithm (17). Canal and crown boundaries were demarcated at the buccal-lingual level of the cementoenamel junction in incisors and premolars and at the chamber floor level in molars. The proportion of UCW and VDR in the crown and canals were determined with custom-made software (IPL; Scanco Medical, Brüttisellen, Switzerland). Based on the voxel size, root canal surface was termed "untouched" when less than 20 μm of dentin was removed.

Load at Fracture

The 60 teeth in the CEC and TEC groups and the 30 teeth (n = 10/type) kept intact without endodontic cavities drilled (negative control) were mounted on brass rings with the roots embedded in self-curing resin (SR Ivolen; Ivoclar Vivadent, Schaan, Lichtenstein) up to 2 mm apical to the cementoenamel junction. In all incisors, a groove was drilled with a #4 round bur into enamel coronal to the cingulum.

The 90 tooth specimens were placed in a custom-made water bath and mounted in the Instron Universal Testing Machine. Premolars and molars were loaded at the central fossa at 30° from the tooth long axis, whereas incisors were loaded at the drilled palatal groove at 135°. A continuous compressive force was applied with a spherical crosshead at 1 mm/min until failure occurred, which was defined as a 25% drop in the applied force. The load at fracture was recorded in newtons (N).

Analysis

The mean percentage of the UCW was calculated for the CEC and TEC groups for the total canal length and for the coronal, middle, and apical canal thirds. Similarly, the mean DVR was calculated for the CEC and TEC group for the entire tooth and for the crown and 3 canal levels. Data sets were calculated independently for the incisors, premolars, and molars' mesial and distal canals. Data for CEC and TEC groups were then compared with an independent samples t test.

Mean load to fracture values were calculated for each tooth type in the CEC, TEC, and negative control groups. Data were compared among and between groups with 1-way analysis of variance and a post hoc Tukey test. Tests were 2 tailed and interpreted at a 5% significance level.

Results

Instrumentation Efficacy

No WaveOne instrument fractures occurred. Typical examples of superimposed pre- and post-treatment micro-CT images are shown in Figures 1*B–E* (molar with CEC) and 2*A* and *B* (incisors with CEC and TEC). The mean proportion of the total UCW (Table 1) was lowest in the mesial roots of molars and highest in premolars, ranging from 36.7% ± 17.2% (distal canals of molars with TEC) to 76.1% ± 17.3% (premolars with TEC). It was statistically significantly higher (P < .04) in the distal canals of molars with CEC than with TEC. Small differences were observed between the CEC and TEC groups in the mesial canals of molars and premolars; in incisors, the difference was more substantial but not statistically significant. Comparing the groups at 3 canal levels, the proportion of UCW differed significantly only in the apical third of molar distal canals; it was higher (P < .05) for CEC than for TEC.